

LONG-TERM EFFECTS OF FOREST HERBICIDES ON PLANT DIVERSITY IN PINE PLANTATIONS IN THE SOUTHEAST

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ABSTRACT

Conservation of biological diversity is an important issue on public and private forests worldwide. As concern for diversity maintenance escalates, more pressure will be placed on the forestry community to understand the effects of silvicultural treatments on biodiversity and its sustainable management. Biodiversity conservation in intensively managed forested regions will depend (at least partially) on species growing in tree plantations, their margins, SMZs, and rights-of-way. Within the Southeast, pine plantation acreage is projected to double by 2040, mainly replacing natural pine forests. Replacement and establishment occur through intensive harvesting, using herbicides and mechanical treatments, burning, planting closely-spaced genetically-improved seedlings, and often fertilizing. The singular or additive effects of all these treatments are often assumed to limit plant species richness and diversity, yet little has been documented to support or refute that assumption. To learn more about diversity changes following herbicide treatments for site preparation and release, I have led two teams in conducting both a region-wide research project at 13 locations in 7 states, and a study series in Central Georgia on 7 locations in 3 provinces. The following generalizations come from the tidings of these studies as well as from others' related research.

- The Southeast is biologically rich with over **3,000 species** of plants.
- The richness and diversity of plants associated with pine plantations vary considerably across the region and its **numerous physiographic** provinces.
- A common flora does exist of species that range across the region.
- Non-native invasive plants are increasingly impacting this floristic diversity.
- Southeastern forests are naturally very resilient because they have developed through a long history of frequent burning, clearing, and harvesting.
- Most of the flora is composed of perennials that are capable of residing as underground parts, while both perennials and annuals persist in a rich soil seed bank.
- Plant species richness and diversity rebound rapidly after forestry herbicide treatments, with short and long-term compositional shifts according to the selectivity and efficacy of the herbicide(s) used.
- Total species richness and diversity are only temporarily reduced after treatment.
- In the long term (10+ years) only perennial woody and semi-woody plants appear to be influenced, not total species richness.
- The density of the pine and/or hardwood canopy eventually dictates the composition, abundance, and spatial pattern of understory plants and their development.

INTRODUCTION

The conservation of biological diversity is an increasingly important issue on public and private forests worldwide. As concerns for diversity maintenance elevate, more pressure will be placed on forest industry and public forestry to develop a greater understanding of the effects of silvicultural treatments on biodiversity and its sustainable management. In the Southeast, pine plantations are increasingly being reestablished on prior plantations or through replacement of existing natural forest communities. Replacement occurs through: harvesting of most trees; treatments using herbicides and mechanical means to suppress regrowing vegetation; planting closely-spaced genetically-improved seedlings; and often followed by fertilization to stimulate vegetative growth. The singular or additive effects of all these treatments have been assumed to limit plant species richness and diversity.

Pine plantation acreage in the Southeast is projected to almost double by 2040, mostly through conversion of natural pine stands. At present, herbicide and fertilizer treatments are each applied in the region to over one million acres annually, mostly to aid pine plantation establishment. Because of this rapid move toward plantations, it is imperative that we gain a scientific understanding and document the influences of plantation management on diversity.

The dramatic changes in stand structure that occur by converting a natural forest to a plantation lead many to assume that corresponding changes in composition and abundance of plant species and wildlife uses will also occur. However, in the few research studies in Mississippi that have compared intensive mechanical and herbicide site prep to adjacent pine hardwood forests, very little differences were found in total number of species. Thus, many species are conserved, although questions on composition and structural changes still remain.

RESILIENCY OF SOUTHEASTERN FORESTS

Southeastern forest communities are naturally very resilient and represent fairly new assemblages, because most have undergone frequent burning for 10,000+ years, natural reforestation after clearing and replacement with row crops and pastures over a 200 year period, and several timber harvests of increasing intensity. The more recent harvests were often followed by intensive mechanical land clearing and tree planting. Because of this history, these communities are considered fire sub-climax and are composed of very robust species. Most of the flora is comprised of perennial plants, which can subsist as underground plant parts, or in the soil seed bank following burning or blow-down disturbance. This natural resiliency also limits the efficacy of competition suppression treatments. The spatial and temporal patterns of operational forestry herbicide treatments also encourage plant reinvasions from surrounding lands, margins, and rights-of-way.

SOUTHEASTERN FORESTS ARE RICH AND DIVERSE

The richness and diversity of plants associated with pine plantations vary considerably across the southeastern forest region and its numerous physiographic provinces. Distinct forest communities inhabit each physiographic province and vary within each province according to topographic and landform variation. However, a common flora does exist of species that range

throughout the region, especially in the provinces where pine plantations are predominantly grown. Special plant species, often rare or endangered, do occur in each sub-region and state, especially in unique habitats (e.g., bogs, marshes, bays, estuarine margins, etc.). There is a pressing need to understand the micro- and macro-effects of plantation establishment on biodiversity in all the situations where they occur.

PLANTATION MANAGEMENT IMPACTS ON RICHNESS AND DIVERSITY

The influence of plantation establishment on floristic diversity has only been studied in a few situations and in general not well reported. To learn more about diversity changes following herbicide treatments for site preparation and release, I have led two teams in conducting both a region-wide research project at 13 locations in 7 states and a study series in Central Georgia on 7 locations- The following generalizations come from these studies as well as from the research of others. Because herbicide treatments are often used in conjunction with other silvicultural treatments they are also briefly discussed.

Forest communities regrow after all intensities of herbicide treatments, either operational or lengthy-intensive experimental treatments. Perennial plants can reside temporarily underground as rootstocks, thickened lateral roots, **rhizomes**, bulbs, and corms, while both perennial and annual plants can persist in a rich soil seed bank. The vigor of sprouting and root sprouting of woody plants is influenced by the season of herbicide application as well as the season of cutting and burning. Spring burns and cuttings result in the least vigor, and each herbicide has an optimum timing window for maximum efficacy. Wind, surface waters, and activities of birds and mammals are continuously moving and depositing seeds into the soil seed bank. Seed germination can occur immediately after release, over the first growing season, or over a 10-to-50-year period. The soil seed bank extends to a depth of 6 or more inches with the majority of seeds at about 1 to 3 inches. Many notable seed bank species in the Southeast are ragweed, blackberries, **pokeweed**, fireweed, horseweed, **beautyberry**, and many asters. Seed rain is persistent from wind, water, and animals moving from adjacent lands and margins.

Mechanical treatments have the most direct influence on the underground plant parts.

These treatments can displace many plants when windrowing or destroy them through exposure by disking. However, even the most intensive, rootrake-pile treatments leave many underground parts in place, and often only mix the surface soil seed bank.

In the mild climate of the Southeast, **vegetative regrowth occurs immediately after** secession of **disturbance or herbicide toxicity**. Most forest herbicides by design are either short-lived at toxic levels in the soil (from one to six months) or have no residual soil activity. Once inside plants, herbicides can continue to assert control activities over an extended period, often over several years at sub-lethal levels, causing growth suppression or partial damage. These damaged plants can recover and regrow, and often become a sizable component of associated woody plants in pine plantations. Plants not harmed by treatment may also regrow faster if available resources (moisture, nutrients, and light) increase after the treatment. Plants that are damaged will recover or decline depending upon competitive position and advantage, and stressors such as drought.

Herbicide selectivity alters the long-term composition of perennial plants. The composition of the plant community associated with pine plantations will be altered by the specific selectivity of the herbicide(s) used and the efficacy of treatment. For example, **Arsenal™** generally enhances legume and blackberry presence while **Tordon™** and **Garlon™** reduce legumes and blackberry. **Accord™** controls huckleberries while **Velpar™** releases these commonly occurring shrubs. These changes in composition can greatly influence wildlife habitat value.

Plant succession continues within pine plantations. In general, after any type of disturbance, forbs dominate first-year revegetation and usually start to decline after the first or second year, with perennial grasses becoming their replacements in the ground-layer. Vines and blackberry species continue to increase in abundance, with blackberry peaking from ages 10 to 15 years. The growth of hardwoods and pines eventually suppresses shrub abundance during the same time frame.

There were no differences in overstory or under-story plant species richness and diversity 10 to 11 years after treatments with the commonly used site preparation and release herbicides in Central Georgia. The proportion of pines to hardwoods was increased, and selected woody species were less abundant or absent where herbicides were initially effective in control.

Pine canopy development eventually regulates successional trends in plantations. The development in density of the pine and/or hardwood canopy eventually dictates the density, composition, and spatial pattern of understory plants and their development. Very dense pine canopies can in certain micro-sites essentially eliminate understory plants, but **this** is not the **norm**. The spatial patterns of component richness, layer development, and overall abundance are dictated by topographic, micro-site, and stand variability. Our research with different forestry herbicides has found that at the time of plantation canopy closure, wide variations in **pine-hardwood** proportions did not influence the **understory** composition as would be assumed. However, woody plant diversity has been shown by others to be different after a wider range of site preparation treatments, from chainsaw felling to rootraking-piling-herbicides-fertilization.

Fertilization speeds recovery after disturbance but little is known about composition. Fertilization increases the amount and speed of woody and herbaceous vegetation regrowth not reduced or eliminated by herbicides. The few reported studies with fertilization show large increases in abundance, but little documented information on species changes.

Burning shifts the composition of the plant community due to the top killing of woody plants and the stimulation of other herbaceous plants to germinate and to grow faster, due to available post-burn mineralized nutrients. Top killed woody plants also can create structure to accommodate woody vine development. The absence of followup prescribed burning in developing stands permits maximum development of residual and invading vines and woody plants. Season of burning influences the size of woody plants killed and the resprouting vigor. Burning also increases the species number and abundance of legumes.

DIVERSITY DECREASED BY INVASIONS OF NON-NATIVE PLANTS

Non-native and native invasive plants are decreasing floristic diversity increasingly in the region and especially in pine plantations. Initially, invasive non-native plants add to richness by their entry, but then restrict richness and diversity due to their exclusive invasive habits. Herbicide applications with establishment of pine plantations are in many instances our most effective means of combating exotic invasive plants. Exotic plant spread is probably the greatest foreseeable threat to native plant diversity in the Southeast besides human development.

FOREST PLANT DIVERSITY MANAGEMENT IN THE FUTURE

Pine plantations will play an increasing role in biodiversity conservation within the landscape matrix of natural and conservation forests, rights-of-way, and urban-suburban community forests. Yet little is known about the conserving capabilities of pine plantations as they interplay with other land uses, as well as the benefits of coexisting plants to the long-term health and sustainability of forestlands. It is known that plants associated with pine plantations influence nutrient increment and conservation, wildlife diversity and productivity, wildfire intensity, and the pine productivity of a stand. More long-term, detailed research is needed on species changes following herbicide, mechanical, burning, and fertilization treatments for pine plantation management.

Developments in plant diversity management are essential in order to protect species richness for future generations with their unknown needs, to sustain and improve soil health and productivity, and to contribute to the maintenance of life-critical processes that bind the landscape with its surface and ground waters.

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