RED MAPLE COMPOSITION IN AN OLD GROWTH FOREST 50 YEARS FOLLOWING DISTURBANCE

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Abstract—Red maple (*Acer rubrum*) has become an increasingly important component in forests of the Eastern United States. In the absence of disturbance, this species proliferates in the understory and grows into the canopy. Growth and expansion of red maple was assessed in an old-growth forest in northern Georgia. Forty plots were established in the forest in 1960 following an ice storm, covering three forest communities (i.e., oak-pine (*Quercus* spp.-*Pinus* spp.), chestnut oak (*Q. montana*), and mixed forest). These plots were remeasured in 2015. Seedling frequency increased in the oak-pine and chestnut communities, red maple saplings comprised significant portions of saplings in the understory, and basal area increased throughout the forest. In an effort to assess seedling numbers in the forest, Geographically Weighted Regression was employed to allow for an assessment of variable changes throughout the forest. The best-fitting model had an adjusted R^2 value of 0.77 and included basal area and slope, indicating the importance of these variables on red maple seedling germination. This supports the 'super generalist' label of red maple, and its continued growth into the midstory could allow red maple to become a canopy dominant species following subsequent natural disturbances. Forest managers should be prepared to take necessary steps to control red maple in similar forests in the Southeastern United States.

INTRODUCTION

Red maple (*Acer rubrum*) has become an increasingly significant component of forests in the Southern United States previously dominated by oak species (*Quercus* spp.) (Abrams 1998, Fei and Steiner 2007, McDonald and others 2002). This species has increased in 69 percent of forests in the Eastern United States (Fei and Yang 2011). An increase in red maple impacts understory vegetation, has implications for nutrient and hydrologic factors in these forests (Alexander and Arthur 2010), and indicates a compositional shift in areas where their prevalence increases and fire is excluded from the landscape. It has earned the label of 'super generalist' because it can grow as an early- or late-successional species, survive dry and low-light understory environments, and proliferate into canopy gaps following disturbance (Abrams 1998, Rantis and Johnson 2002). Red maple is also able to maintain its under- and midstory dominance in areas where fire has been excluded from the landscape or harvesting occurs (Fei and Steiner 2009).

The increase in red maple has occurred since observations of species composition were made in early colonization of the United States (Lorimer 1984). In unmanaged forests, particularly old-growth forests, small-scale disturbances are the primary agents of change. Such events generate canopy gaps that promote red maple seedling germination in the understory, often for many years following disturbance (Rankin and Pickett 1989, Warren and others 2004). Red maple seedlings are able to persist in the understory, grow into the midstory at the expense of less shade tolerant species, and release following disturbance. Therefore, it is important to assess changes in red maple seedling compositions following disturbance. The objective of this study is to quantify changes in the red maple composition of an urban, old-growth forest and develop a model to determine seedling numbers within a portion of the forest 50 years following a damaging ice storm.

METHODS

The Marshall Forest Preserve, located within the city limits of Rome, GA, comprises approximately 300 acres of forest. In 1960, 40 permanent 0.1-acre plots were established within the forest, including three forest communities, oak-pine, chestnut oak, and mixed forest (Lipps 1966, Lipps and DeSelm 1969, fig. 1). A portion of these plots were remeasured in 1989 and 2015 (Butler and others 2018, Fail 1991). Also in 2015, all plots were located and clearly marked. They were

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Citation for proceedings: Bragg, Don C.; Koerth, Nancy E.; Holley, A. Gordon, eds. 2020. Proceedings of the 20th Biennial Southern Silvicultural Research Conference. e–Gen. Tech. Rep. SRS–253. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 338 p.

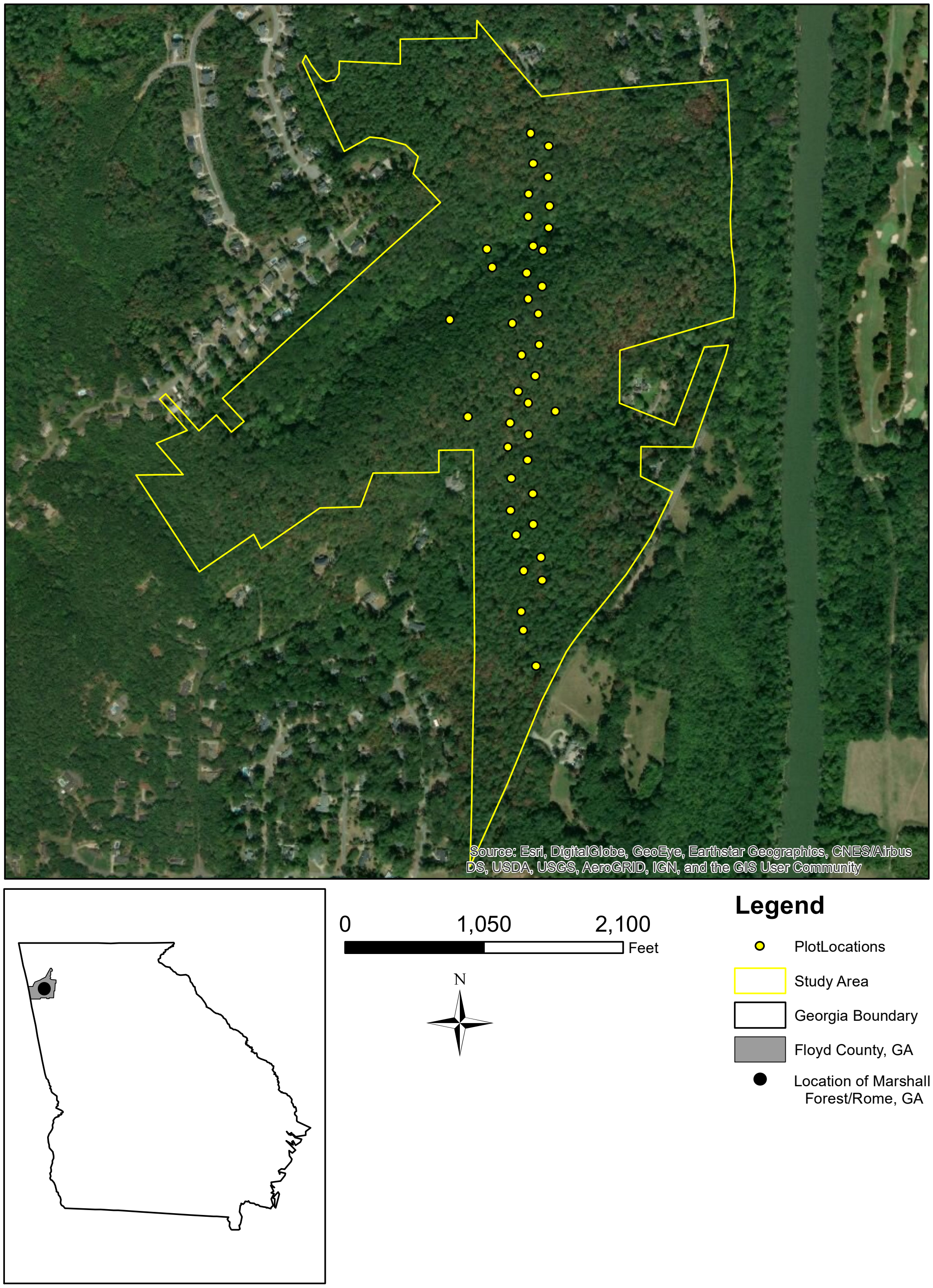

Figure 1—Study area in Marshall Forest, located in Rome, GA.

remeasured following the original methodology of Lipps (1966). All species on plots were recorded, including seedling counts on each plot. The seedlings were totaled for red maple and expanded to a per acre basis. Geographically Weighted Regression (GWR) was used to estimate seedling numbers throughout the sampled area. The GWR is a regression technique employed when the variables are non-stationary through space (Fotheringham and others 1996). The analysis was performed using ArcMap 10.3.

RESULTS AND DISCUSSION

The initial plots were established following an ice storm that damaged portions of the forest. In the initial study (Lipps and DeSelm 1969), red maple was present in each community and drastically increased in basal area after the ice storm (table 1). In the current assessment,

Table 1—Comparison of seedling and sapling frequency of occurrence (percent of plots with red maple) and basal area between 1961 and 2015

	Seedlings		Saplings		Sapling density		Tree BA	
Community	1961	2015	1961	2015	1961	2015	1961	2015
	----------------*percent of plots*----------------				*number per acre*			
Pine-oak	30	93.3	33.3	66.7	32	37	0	3.3
Chestnut	60	100.0	80.0	100.0	360	42	1	7.2
Mixed forest	100	100.0	100.0	60.0	220	42	1	4.6

Tree BA=average basal area.

approximately 800 of 1,900 trees measured were red maple. There were more than 1,000 seedlings per acre, on average, for the 40 plots measured in this study and 38 of 40 plots had red maple seedlings present. Generally, the sapling density decreased, but this was likely a consequence of the dramatic increase in the size of the red maple trees growing into the midstory, as indicated by the increase in the basal area of red maples (table 1). This occurred as a result of a lack of recruitment of oak species and was consistent with findings in similar forested areas (McDonald and others 2002). In the understory, sapling-sized trees were predominantly hickory (*Carya* spp.) or red maple and seedlings were dominated by *Pinus* spp. or red maple (table 2). These results indicated that red maple had become widely distributed in Marshall Forest, similar to other results from throughout the region (Fei and Yang 2011) and seemed to fit the 'red maple dominance hypothesis' posited by Lorimer (1984). Marshall Forest is in an urban environment and prescribed fire would be difficult to manage and has been excluded from the forest on a large scale since the 1920s (Petrucelli and others 2014).

Table 2—Seedling and sapling percentages by species in Marshall Forest, 2015

Species	Seedlings	Saplings
	percent	
Acer rubrum	26	36
Cornus florida	0	2
Carya spp.	6	38
Nyssa sylvatica	0	6
Pinus spp.	36	0
Quercus spp.	11	9
Other	21	9

Predicting Seedlings with GWR

Adjusted R-squared values for GWR was 0.77; the GWR model also had spatially random residuals, indicating the model was properly specified (Fotheringham and others 1996, Lu and others 2014). The variables in the best fitting model were basal area and slope. The interpolation of intercept values showed the greatest values along the southern portion of the study area, which was in flatter terrain (fig. 2a). The influence of basal area on red maple seedlings varied throughout the study area (fig. 2b) with greater basal area being related to a decrease in seedling numbers. This trend was different than that observed at the northern end of the study area where greater basal areas had greater numbers of seedlings. It is likely that the greater coverage of herbaceous species and small shrubs (e.g., blueberry (*Vaccinium* spp.)) at the southern end of the forest further inhibited light availability in this area (Warren and others 2004). The influence of slope was important as greater slope was related to greater seedling numbers (fig. 2c).

The GWR predicted values were similar in space to observed values (figs. 3a and b) with the greatest differences occurring in the northern third of the study area where slopes were greatest. The local R-squared values were greatest in the northern and southern quarters of the study area where the terrain was generally more even. The central portion of the study area indicated a transition in coefficient impacts on seedlings numbers. It could be that there was not a good relationship among those variables and seedling numbers in varying terrain. It would be useful in future studies to consider an indicator of diversity, such as Shannon's Diversity Index, to assess the influence of local competition. Interpolating the local coefficients with sparse data points can give the illusion of a trend across the landscape (Cho and others 2009), but this is likely not the case in this study area given its small areal coverage. Increasing the number of plots and their distribution throughout the forest would further improve the model utility.

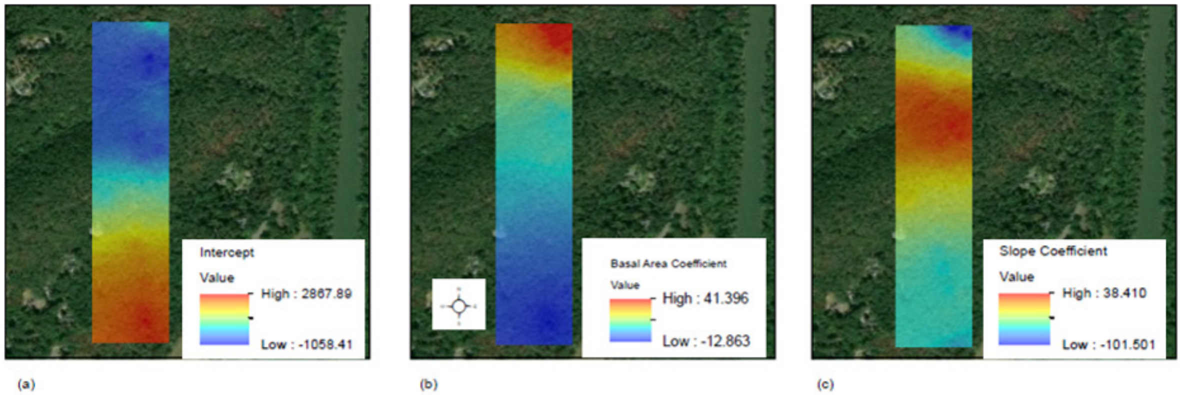

Figure 2—Results of Geographically Weighted Regression showing local values for intercept (a), basal area (b), and slope (c).

Figure 3—Interpolation of observed (a) red maple seedlings and predicted values resulting from Geographically Weighted Regression model (b).

CONCLUSIONS

Marshall Forest will likely continue to transition towards a greater composition of hickory species and red maple. With no sapling-sized pine in the study area, there will be no further recruitment into the canopy. This is similarly true for oak species, although there are oak saplings in the understory and the process will take longer to transition. The GWR model would benefit from more extensive sampling, which would also provide data regarding red maple abundance throughout the forest, particularly within some of the higher elevations where there is a greater area of pine species. Managing the forest for oak-pine cover would be difficult given the urban location with homes bordering the forest and widespread tree removal to generate canopy gaps would impact the natural ecological process. The Marshall Forest remains a natural laboratory to study forest succession and the impacts of disturbance on forests of the Southern United States.

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