How structural complexity of vegetation facilitates invasion: Integrating LiDAR and FIA invasive species plot data in the Appalachian Mountains of the USA

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Introduction

Structural complexity of vegetation at regional scale is useful for ecological applications such as aboveground biomass estimation (Jung and Pijanowski, 2012), carbon mapping (Asner et al. 2011), understanding invasion mechanisms (Jung et al. 2013; Asner et al. 2008), and detecting anthropogenic disturbances (Jung et al. 2013; Ioki et al. 2014).

Light detection and ranging (LIDAR) technology is advantage of ascertain vegetation characteristics in a three dimensional scale to gauge canopy gap areas, canopy height, and stratum of vegetation (Jung and Crawford, 2012; Jung et al. 2013).

We investigated how the structural complexity of forests and the variation in forest canopy tree composition relates to where forest plant invasions occur at the regional scale.

Research questions

(1) How LiDAR data measures associate with invasive species?
(2) How LiDAR data measures associate with native species?

Methods

(i) Gathering LiDAR data measures for the study area

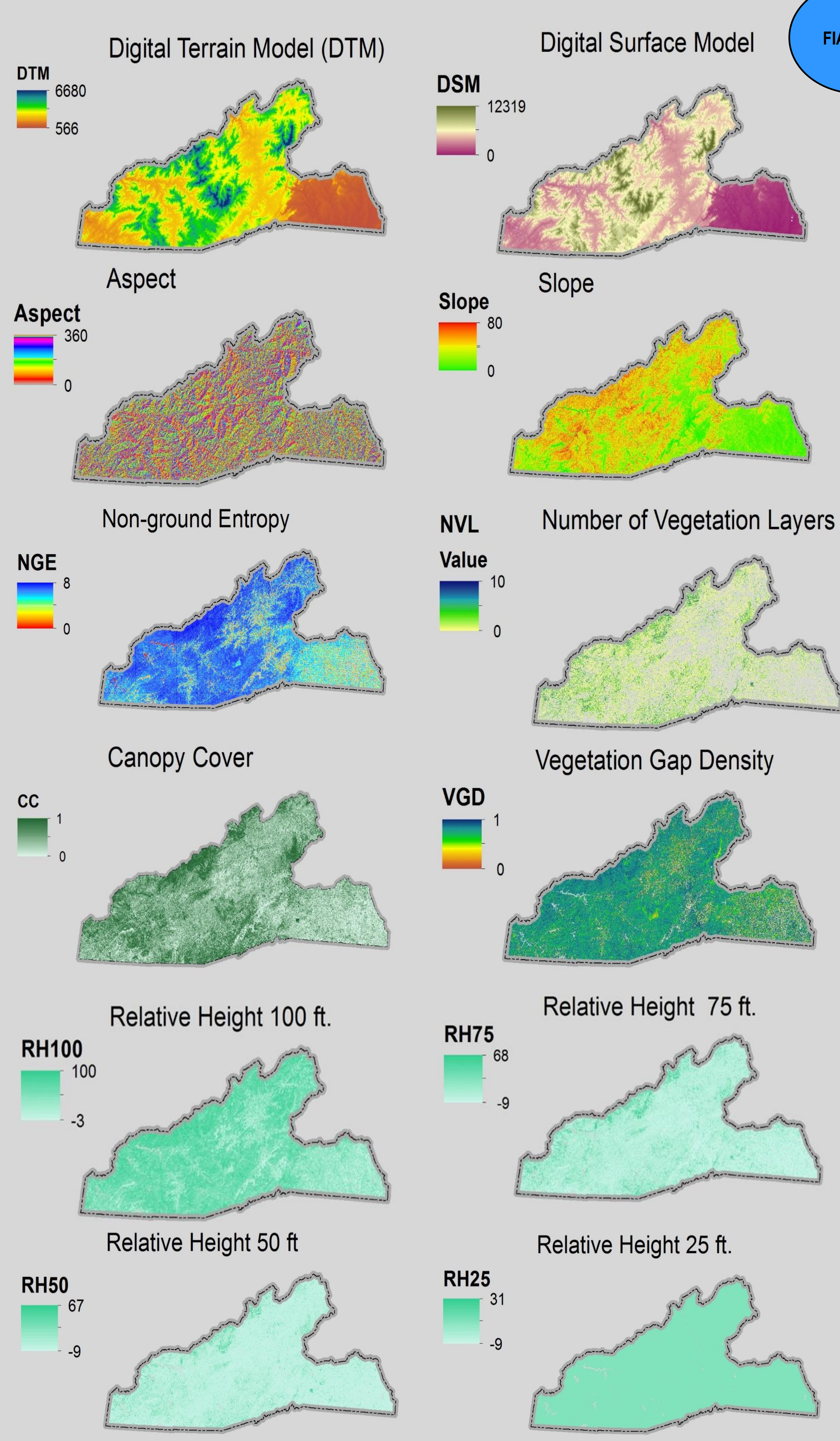


Fig. 1. LiDAR data matrices derived from point cloud data acquired in 2005

(ii) Gathering data on invasion plots in the FIA program

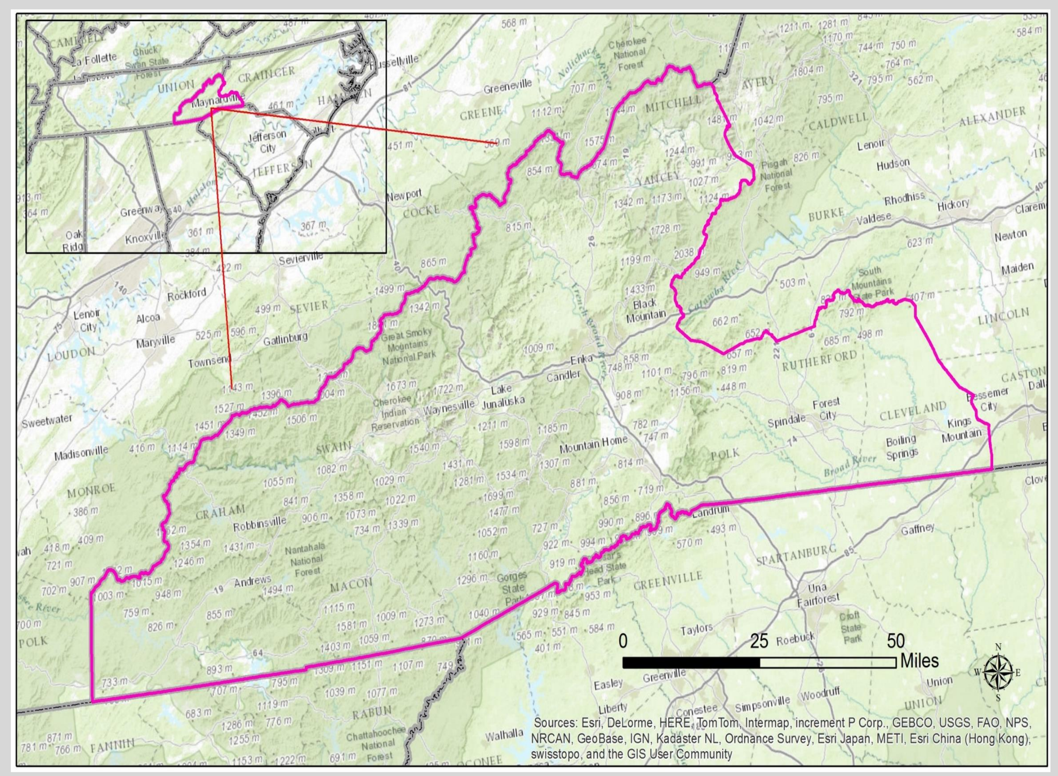


Fig. 2. The map of the study area

- Forest Inventory Analysis (FIA) plot data from 2003 -2010
- 575 FIA plots/ 160 invaded plots
- Invaded plots were separated as closed canopy and clear-cut/ canopy gap

(iii) Modeled measurements of invasive/native species as a function of LiDAR measures

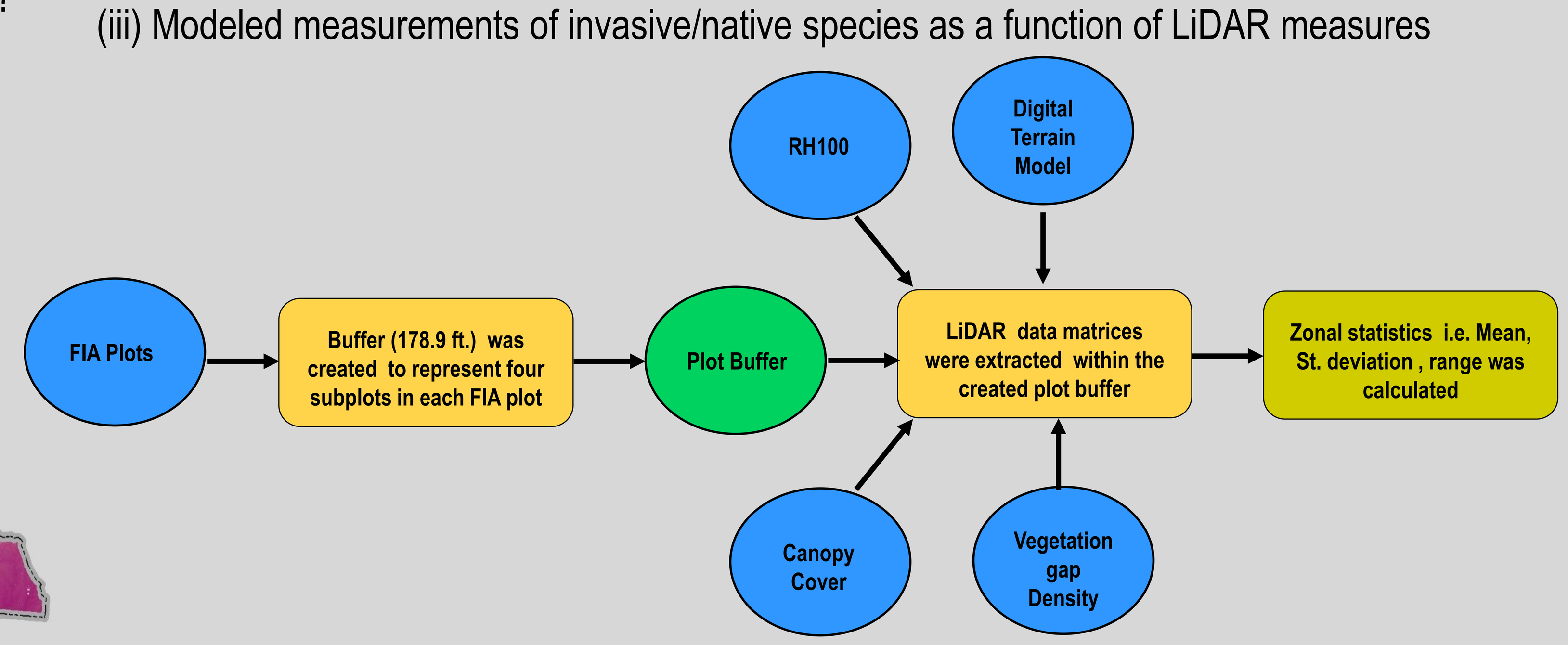


Fig. 3. The flow chart showing the LiDAR data extraction from the FIA plots

Results and Discussion

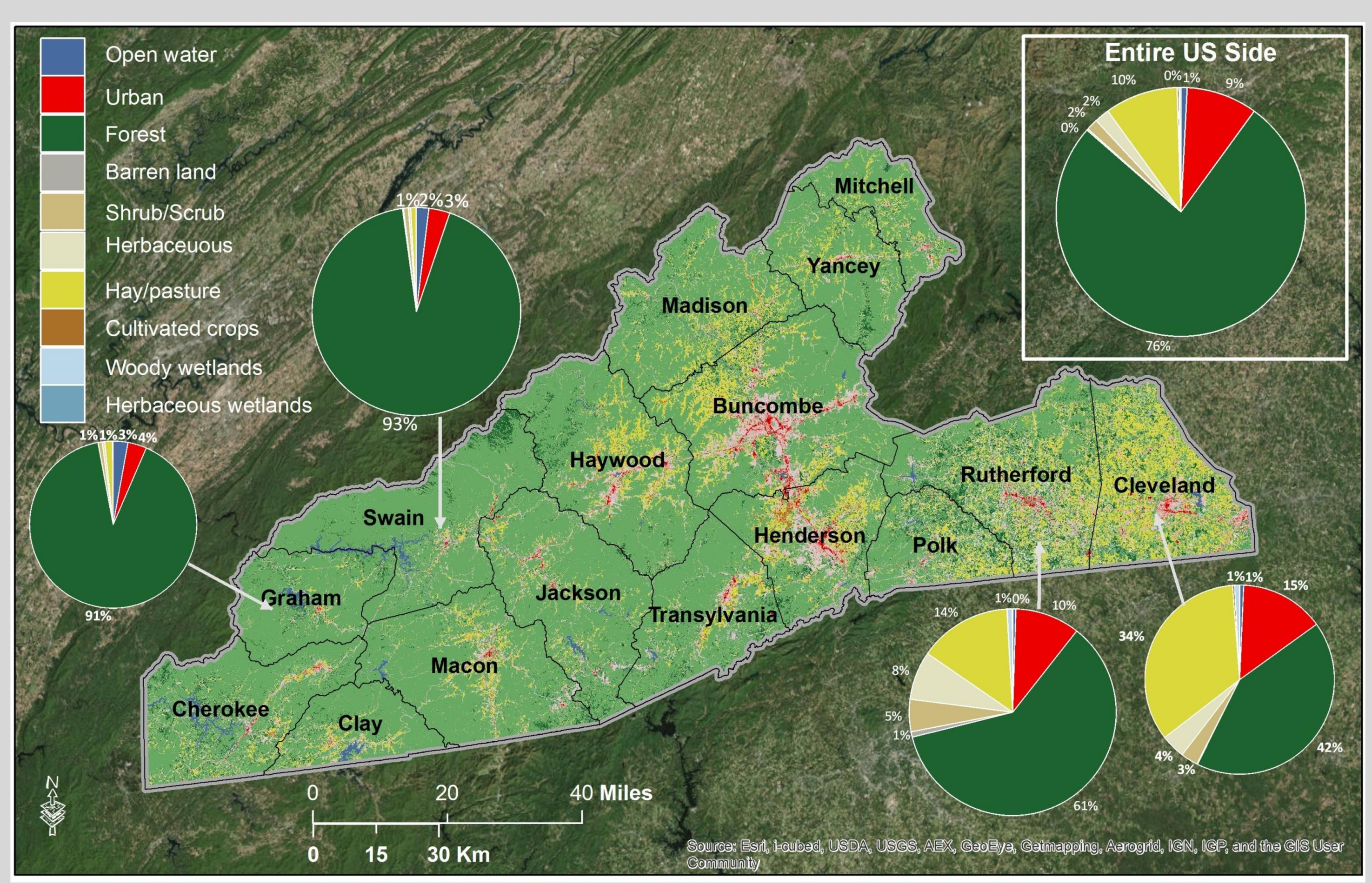
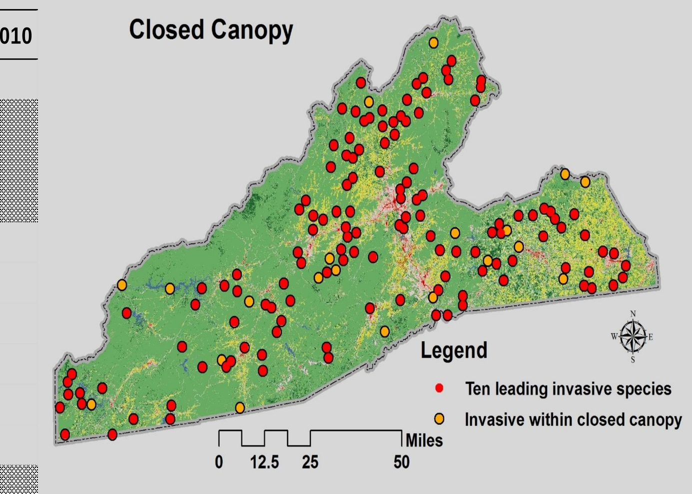


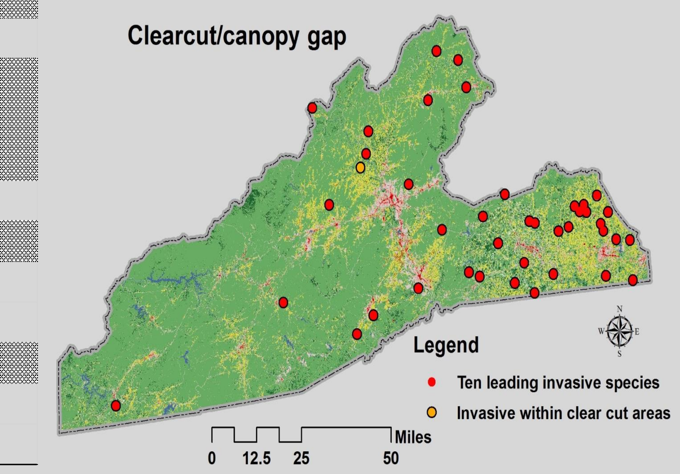
Fig. 4. Land-use/cover types in the Appalachian Mountains

- Forest is the major land cover type in this area and it covers 76% of the study area.
- Graham and Swain Counties have high forest cover (Fig. 4).
- Cleveland county has the least forest cover and the highest hay/pasture lands

Table 1. Comparison of invasive species at closed canopy and clear cut/canopy gap areas

Plant Species	Dispersal	% Freq.	2003	2004	2005	2006	2007	2009	2010
Closed Canopy (124 plots)									
Rosa spp.	birds/small mammals	51	■	■	■	■	■	■	■
Lonicera japonica	birds/small mammals	49	■	■	■	■	■	■	■
Ligustrum sinense	birds/small mammals	25	■	■	■	■	■	■	■
Microstegium vimineum	wind	17	■	■	■	■	■	■	
Ligustrum japonicum	birds	9	■	■	■	■	■		
Ailanthus altissima	wind	6	■	■		■	■		
Lespedeza cuneata	birds/small mammals	5	■	■			■	■	
Vinca minor	vegetative	6	■	■			■	■	
Celastrus orbiculatus	birds/water	5	■			■	■	■	
Festuca arundinacea	birds/small mammals	5					■	■	■
Clear cut/ Canopy gap (36 plots)									
Lonicera japonica	birds/small mammals	67	■	■			■	■	■
Rosa spp.	birds/small mammals	58	■	■		■	■	■	■
Ligustrum sinense	birds/small mammals	36	■	■		■	■		■
Microstegium vimineum	wind	22	■	■		■	■		
Lespedeza cuneata	birds/small mammals	14				■	■		■
Festuca arundinacea	birds/small mammals	14					■	■	
Ailanthus altissima	wind	11		■		■	■		
Ligustrum japonicum	birds	8	■				■		■
Lonicera spp.	birds	8	■				■		
Pueraria lobata	runner/seed	8					■		





- Frequency of occurrence of dominant invasive species are higher in clear-cut area than closed canopy area (Table 1).
- The most commonly occurring invasive species of the 22 recorded invasive species were *Rosa* spp., *Lonicera japonica* and *Ligustrum sinense.*
- Majority of species in both closed canopy and clear cut areas are dispersed by birds/ small mammals.

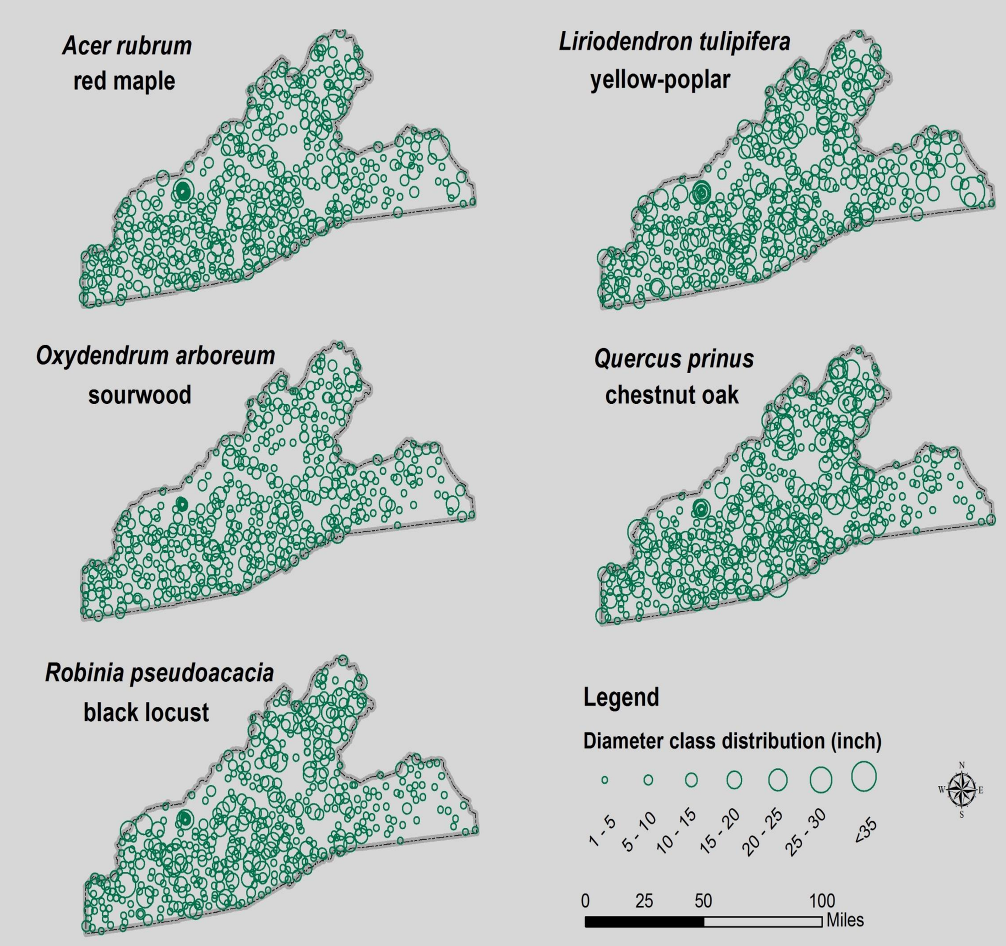


Fig. 5. DBH class distribution of five dominant native tree species in the study area

Table 2. The ten leading native tree species in the study area

Plant Species	Common name	Freq. of occurrence	% Freq.
Acer rubrum	red maple	435	76
Liriodendron tulipifera	yellow-poplar	330	57
Oxydendrum arboreum	sourwood	325	57
Quercus prinus	chestnut oak	254	44
Robinia pseudoacacia	black locust	252	44
Quercus rubra	northern red oak	247	43
Quercus alba	white oak	231	40
Betula lenta	sweet birch	216	38
Nyssa sylvatica	blackgum	197	34
Quercus coccinea	scarlet oak	194	34

- The FIA data showed that *Acer rubrum* (red maple; present in 76% of all plots), *Liriodendron tulipifera* (yellow-poplar; 57% of plots), and *Oxydendrum arboretum* (sourwood; 57% of plots) were the dominant tree species (from a total 80 native species) (Table 2, Fig. 5).
- In summary, the LiDAR data are useful to understand some mechanistic role of ecosystem invasion.

Table 3. GLM for invasive/native species richness and LiDAR matrices for closed canopy forests

Species	Fixed effects	Coefficient	SE	*t* Value	Pr(>|t|)
Invasive	Intercept	2.1694	0.1089	19.925	0.000 ***
	DTM	-0.2456	0.1095	-2.242	0.027 *
	RH75	-0.2009	0.1094	-1.836	0.069•
	Aspect	-0.2832	0.1094	-2.588	0.011 *
glm(formula = Invasive ~ DTM + RH75 + Aspect) AIC: 406 Adj. r2=0.08					
Native	Intercept	7.7984	0.2143	36.397	0.000 ***
	CC	-1.3147	0.3901	-3.37	0.001**
	NG	2.5476	0.2797	9.11	0.000 ***
	NOL	1.2104	0.328	3.69	0.000 ***
	Aspect	0.9109	0.2153	4.231	0.000 ***
glm(formula = Native ~ CC + NG + NOL + Aspect) AIC: 574 Adj. r^2= 0.51					

- There is a negative relationship of invasive species richness with aspect (p<0.05) , while it is a positive relationship for native species (p<0.001) (Table 3).

Acknowledgements

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