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Assessing Tropical Storm Helene Damage to UNCA's Chestnut Ridge Forest

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Abstract

Natural disasters are increasing in frequency and intensity due to climate change, and they are significantly impacting global ecosystems. To minimize disturbance impacts, we need to develop damage mitigation practices. Previous regional research has primarily focused on restoration following large-scale disturbances, leaving smaller-scale systems less understood. Our research assessed the ecological effects of Tropical Storm Helene on Chestnut Ridge, a 27-hectare mixed hardwood-pine forest adjacent to the University of North Carolina Asheville campus, to develop a restoration plan for this and other impacted small-scale landowners. I surveyed twenty 0.04 ha plots recording standing and downed trees (dbh > 5cm) and woody saplings (>1 m tall and < 5 cm dbh). I sampled seedlings (< 1m tall) in 0.002 ha nested plots. I compared pre- and post-storm canopy composition and assessed the regeneration layer (seedlings and saplings). Pre-storm data forest composition at the site was 60% Montane Oak-Hickory, 20% Rich Cove Forest, and 20% White Pine. Post-storm composition shifted to 65% Montane Oak-Hickory Forest, 20% Rich Cove Forest, and 15% White Pine, with some areas treeless post-storm. Regeneration primarily consisted of the shade-tolerant, fire-sensitive mesophytes, tulip poplar

(*Liriodendron tulipifera* L.) and red maple (*Acer rubrum* L.), indicating that without active management, this forest will shift from more fire-tolerant, pyrophytic species, such as oaks (*Quercus* spp.) and hickory (*Carya* spp.) to the more mesophytic species, tulip poplar and red maple. Past management had deviated from the ecologically expected composition: 60% Montane Oak-Hickory Forest, 25% Rich Cove Forest, and 15% Pine-Oak Heath or Mixed Oak/Rhododendron. Management efforts to shift composition toward this ecologically expected composition could include releasing desirable pyrophytic species through silviculture, supplementing these through direct planting, and managing invasive exotic species, which have drastically expanded in storm-damaged areas.

Introduction

Natural disturbances play a critical role in shaping forest composition, structure, and succession. Among these disturbances, wind events such as storms and downbursts are especially influential. While most wind-related damage in this region tends to be small-scale, limited to single-tree falls or small canopy gaps, climate change is contributing to an increase in the frequency and intensity of severe weather events, amplifying their ecological impact (Greenberg & McNab, 1998; Goode et al., 2022).

In September 2024, Tropical Storm Helene struck Western North Carolina with intense winds and heavy rainfall, causing widespread flooding, landslides, and infrastructure damage. The ecological consequences were severe, with Buncombe County estimated to have lost up to 40% of its trees (Jones, 2024). One significantly impacted site was Chestnut Ridge, a 27-hectare mixed hardwood forest located on the University of North Carolina at Asheville (UNCA) campus. The storm uprooted numerous trees, reshaped the canopy, and disrupted natural regeneration processes, creating an urgent need for a detailed and site-specific recovery plan. A storm damage intensity map (Fig. 1) illustrates the spatial variability of disturbance across the site and highlights areas of concentrated canopy loss.

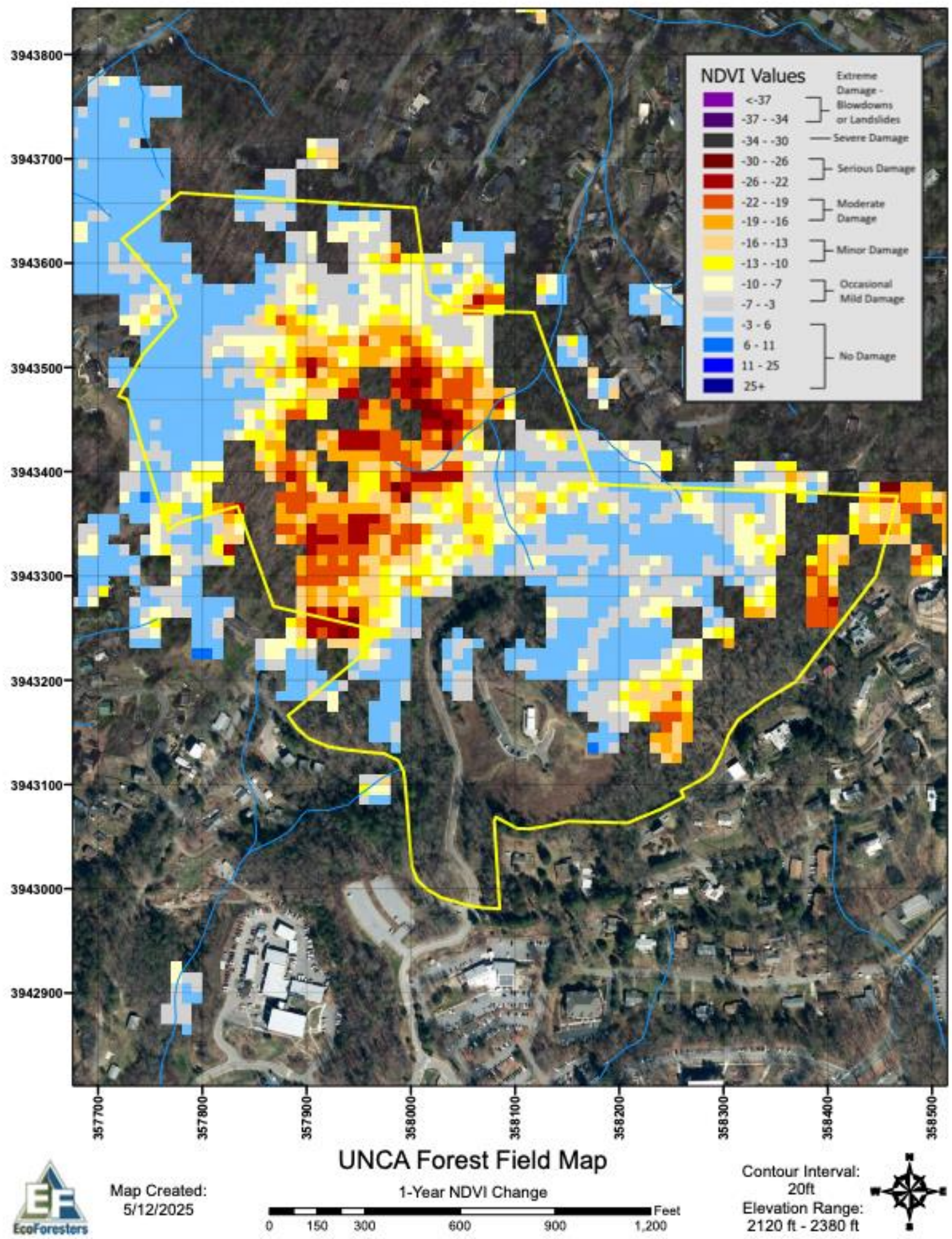


Figure 1. Storm disturbance intensity map of Chestnut Ridge based on one-year NDVI changes. Areas with greater NDVI decline represent higher levels of canopy damage following Tropical Storm Helene.

Previous research offers relevant background for understanding forest response to wind disturbances in this region. Greenberg and McNab (1998), studying canopy gaps formed by downbursts during Hurricane Opal, reported significant reductions in tree density (19–39%) and basal area (30–53%). Their work also highlighted species-specific vulnerability, with red oaks (*Quercus rubra* L.) being disproportionately uprooted, while species such as red maple (*Acer rubrum* L.) and black tupelo (*Nyssa sylvatica* Marshall) showed greater resistance. A follow-up study by Greenberg (2021) found that although tree growth was enhanced in disturbed areas, oak regeneration was minimal. Instead, more mesic species like red maple and yellow-poplar (*Liriodendron tulipifera* L.) became dominant, suggesting a successional shift toward more moisture-tolerant species, a process referred to as mesophication (Alexander et al., 2021). Goode et al. (2022) expanded on these findings, showing that intermediate disturbances tend to increase mortality among larger canopy trees, while smaller, shade-tolerant species have higher survival rates. Their work also demonstrated how spatial patterns of canopy openings influence regeneration outcomes, as differences in gap size and distribution both shape light availability and competition, often favoring fast-growing species in larger gaps and shade-tolerant species in smaller gaps.

Building on this foundation, my research aimed to assess the ecological impacts of Tropical Storm Helene on Chestnut Ridge and to develop a practical, restoration-focused management plan. The primary objectives of this study were to (1) quantify storm-related damage in terms of species affected and the number of downed or damaged trees, (2) characterize the composition and structure of the residual canopy, (3) assess the regeneration layer, including seedling and sapling abundance and composition, and (4) propose a recovery strategy based on these findings.

To inform restoration planning, I will first describe the ecological forest type predicted for this area based on the past physiography. I will then reconstruct the pre-storm forest composition using standing and downed tree data, compare it with current post-storm conditions, and evaluate the structure and species composition of the regeneration layer. By projecting the likely future forest trajectory, I aim to identify whether it aligns with ecological expectations. If it does not, I will recommend management actions that help guide the forest back toward a more ecologically expected composition.

Methods

Field Sampling

Using GIS-generated maps of Chestnut Ridge Forest, provided by my community partner, EcoForesters, sampling sites were systematically selected based on the 100-meter Universal Transverse Mercator (UTM) lines overlaid on the maps. Plot centers were established at the intersection of N-S and E-W UTM lines, ensuring a consistent 100-meter spacing between each plot center. A total of 20 plots were sampled. Each plot measured 0.04 ha (20 m x 20 m) and was used to assess forest composition by recording saplings (< 5 cm dbh) and standing and downed trees (with roots originating in the plot) with a diameter at breast height (DBH) greater than 5 cm. Nested within each larger plot was a 0.002 ha (approximately 4.5 m x 4.5 m) subplot located at the center, used to sample tree seedlings shorter than 1 m. This nested sampling design follows the methodology outlined by Goode et al. (2022). Fieldwork was conducted using maps, meter tapes for plot layouts, rebar and caps to mark plot centers, and flagging tape to define plot boundaries. For each tree and seedling, genus and species were recorded, along with diameter at breast height (DBH; measured at 1.37 m above ground using a Biltmore stick [Conway Cleveland Corp., Grand Rapids, MI]) and canopy position (classified as overtopped, intermediate, co-dominant, or dominant).

Invasive Species Management

To measure invasion coverage, each site was visually surveyed and assigned a percent cover estimate based on the intensity of invasion (0-100%). The primary invasive species present were also recorded. In addition, a systematic survey of the site was conducted by walking trails and recording dominant invasive species and invasion intensity at 50 m intervals using a 1-5 rating scale (1 = low presence, 5 = high density). EcoForesters then compiled these data to generate an invasive species intensity map.

Data Processing and Analysis

Basal area (BA, m^2) was calculated for each individual tree and summed by species within each plot. These values were standardized to basal area per ha (m^2/ha). Species-level basal area data were then used to determine dominant canopy composition and assign each plot to a forest type (Montane Oak–Hickory, Rich Cove Forest, or White Pine) based on relative basal area contributions. Basal area was then grouped into 10-cm diameter classes (e.g., 0–10 cm, 10–20 cm) for each forest type. Pre-storm composition included both standing and recently downed trees, while post-storm composition included only standing trees. These data were used to compare diameter class distributions and assess structural changes following the storm. Seedling and sapling data were summarized by species and abundance within each plot and aggregated by forest type to characterize the regeneration layer. These data were used to evaluate potential future forest composition. EcoForesters then assisted in producing a GIS map of the Chestnut Ridge stand types based on our new plot classifications. These summarized data and resulting figures were used to assess the composition and structure of the regenerating forest stand after the storm.

Results

Change in Forest Type Distribution

Based on the GIS analysis done by EcoForesters, the ecologically expected composition of Chestnut Ridge consisted of approximately 60% Montane Oak–Hickory Forest, 25% Rich Cove Forest, and 15% Pine–Oak Heath or Mixed Oak/Rhododendron (Fig. 2). Pre- Tropical Storm Helene, data showed that the forest composition was 60% Montane Oak-Hickory, 20% Rich Cove Forest, and 20% White Pine. Post-storm data showed that the distribution shifted slightly to 65% Montane Oak–Hickory Forest, 20% Rich Cove Forest, and 15% White Pine Forest (Fig. 3), with several plots now lacking a closed canopy due to severe windthrow and tree mortality.

Montane Oak-Hickory Forest

Pre- and post-storm diameter class distributions for Montane Oak–Hickory plots show that basal area was reduced by Tropical Storm Helene in size classes ≥30 cm DBH, particularly within the 30–50 cm and >50 cm classes (Fig. 4). Losses were most notable among large canopy individuals of *Quercus velutina* Lam., *Quercus montana* Willd., and *Pinus strobus* L. In contrast, smaller diameter classes (<30 cm DBH) showed relatively little change in basal area following the storm. Regeneration was dominated by Ac*er rubrum*, *Liriodendron tulipifera*, and *Carya* spp., with *Prunus serotina*, contributing substantially to both the seedling and sapling layers (Table 1).

Rich Cove Forest

Rich Cove Forest plots showed substantial reductions in basal area across multiple diameter classes following TS Helene (Fig. 5). Several species that were present in the pre-storm forest were absent in the post-storm within specific size classes. *Carya* species were absent in the post-storm dataset, particularly from the 10–20 cm, 40–50 cm, and >50 cm diameter classes. Similarly, *Quercus velutina* disappeared entirely from the 40–50 cm class. In contrast, smaller diameter class species such as *Acer rubrum* and *Liriodendron tulipifera* increased. In the Rich Cove forest type, regeneration was dominated by *Acer rubrum, Liriodendron tulipifera,* and *Carya* spp., with a notable presence of the invasive species Ailanthus altissima (Table 2).

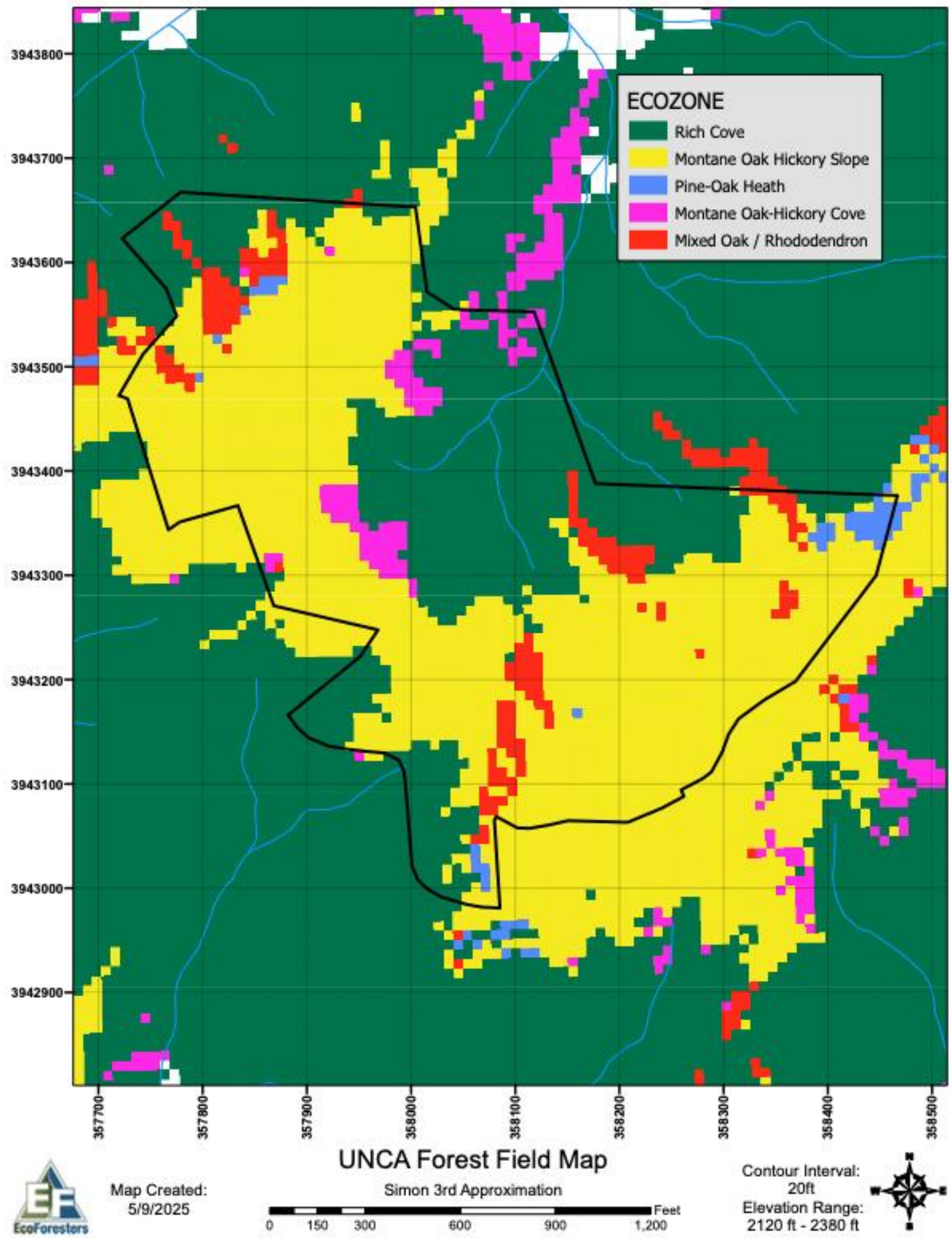


Figure 2. Ecologically predicted (historical reference) forest types for Chestnut Ridge based on GIS analysis by EcoForesters.

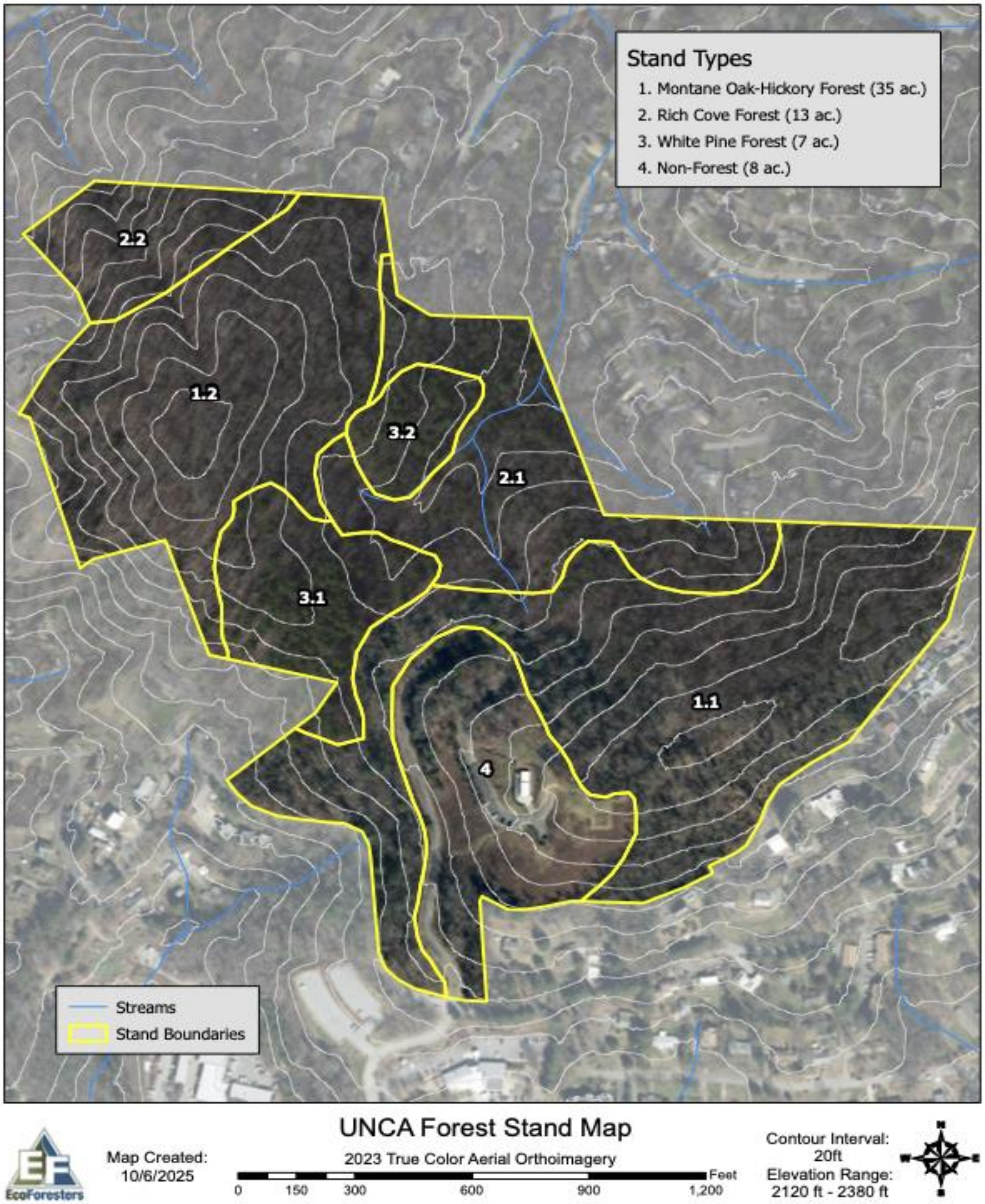


Figure 3. Post-storm forest type distribution at Chestnut Ridge. Stand types include (1) Montane Oak-Hickory, (2) Rich Cove, (3) White Pine, and (4) non-forest.

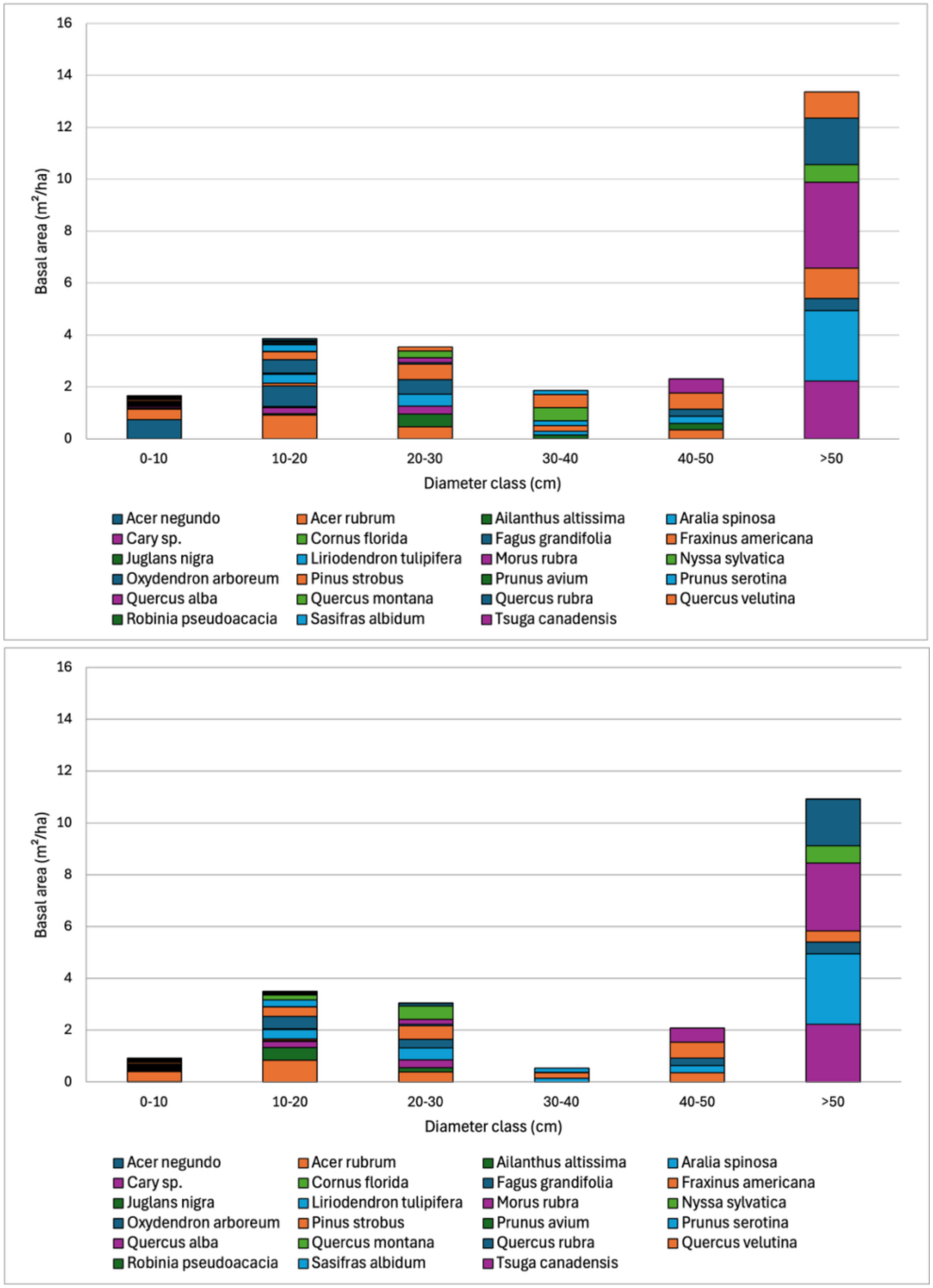


Figure 4. Pre-storm (top) and post-storm (bottom) diameter class distributions for Montane Oak–Hickory Forest plots at Chestnut Ridge. Basal area (m^2/ha) is shown across 10 cm diameter classes.

Table 1. Mean (± SE) seedling and sapling densities (stems/ha) by species in the Montane Oak–Hickory forest type.

Montane Oak-Hickory	**Species**	**Density** (stems/ha)
Saplings	*Acer rubrum*	492.3 ± 127.5
	Carya sp.	280.8 ± 82.8
	Liriodendron tulipifera	146.2 ± 104.1
	Prunus serotina	105.8 ± 35.4
	Ailanthus altissima	71.2 ± 32.6
	Nyssa sylvatica	65.4 ± 38.2
	Sassafras albidum	65.4 ± 33.8
	Oxydendrum arboreum	48.1 ± 14.0
	Quercus valentina	38.5 ± 18.3
	Quercus rubra	34.6 ± 15.1
	Fraxinus americana	32.7 ± 21.8
	Prunus avium	19.2 ± 8.6
	Morus sp.	17.3 ± 15.3
	Prunus pendula	15.4 ± 15.4
	Pinus strobus	9.6 ± 6.0
	Quercus montana	7.7 ± 5.9
	Fagus grandifolia	5.8 ± 4.2
	Magnolia acuminata	5.8 ± 5.8
	Ostrya virginiana	3.8 ± 2.6
	Cornus florida	3.8 ± 2.6
	Tsuga canadensis	1.9 ± 1.9
	Ilex opaca	1.9 ± 1.9
	Juglans nigra	1.9 ± 1.9
	Juniperus viriginana	1.9 ± 1.9
Seedlings	*Acer rubrum*	3945.2 ± 1530.7
	Liriodendron tulipifera	2867.9 ± 891.8
	Prunus serotina	1215.6 ± 800.7
	Carya sp.	856.4 ± 273.2
	Quercus rubra	650.3 ± 296.3
	Quercus alba	59.4 ± 39.9
	Oxydendrum arboreum	630.8 ± 271.9
	Quercus velutina	209.8 ± 180.0
	Nyssa sylvatica	215.0 ± 136.9
	Sassafras albidum	161.1 ± 134.9
	Pinus strobus	18.0 ± 12.3
	Ilex opaca	104.9 ± 90.0
	Ailanthus altisima	52.4 ± 45.0
	Juglans nigra	52.4 ± 45.0
	Magnolia acumanata	7.0 ± 4.7
	Ostrya virginiana	7.0 ± 4.7
	Quercus stellata	7.0 ± 4.7

White Pine Forest

White Pine Forest plots experienced extensive canopy loss, particularly among later diameter classes (>30 cm DBH), with *Pinus strobus* and *Quercus rubra* showing the greatest reduction in basal area (Fig. 6). Following TS Helene, *Nyssa sylvatica* and *Quercus montana* were absent from the 10-30 cm diameter classes in and smaller diameter classes were dominated by hardwood species rather than pine in post-storm data. In the White Pine Forest, regeneration was primarily composed of *Acer rubrum*, *Oxydendrum arboreum*, and *Nyssa sylvatica*, while *Carya* spp. contributed substantially to seedling densities (Table 3). Across all forest types, larger canopy trees (>30 cm DBH) experienced the greatest reduction in basal area, while smaller size classes showed greater survival and regeneration.

Invasive Species Distribution

Invasive species were observed across much of the study area, with the greatest number occurring in the White Pine Forest plots (Fig. 7). The most frequently encountered species were *Celastrus orbiculatus*, *Ailanthus altissima*, *Rosa multiflora*, *Hedera helix*, and *Microstegium vimineum*. Invasive intensity was greatest along trails and in areas with extensive canopy distribution and treefall. White Pine stands and severely impacted plots exhibited the highest invasive severity, while less disturbed Montane Oak-Hickory areas generally showed lower invasive cover.

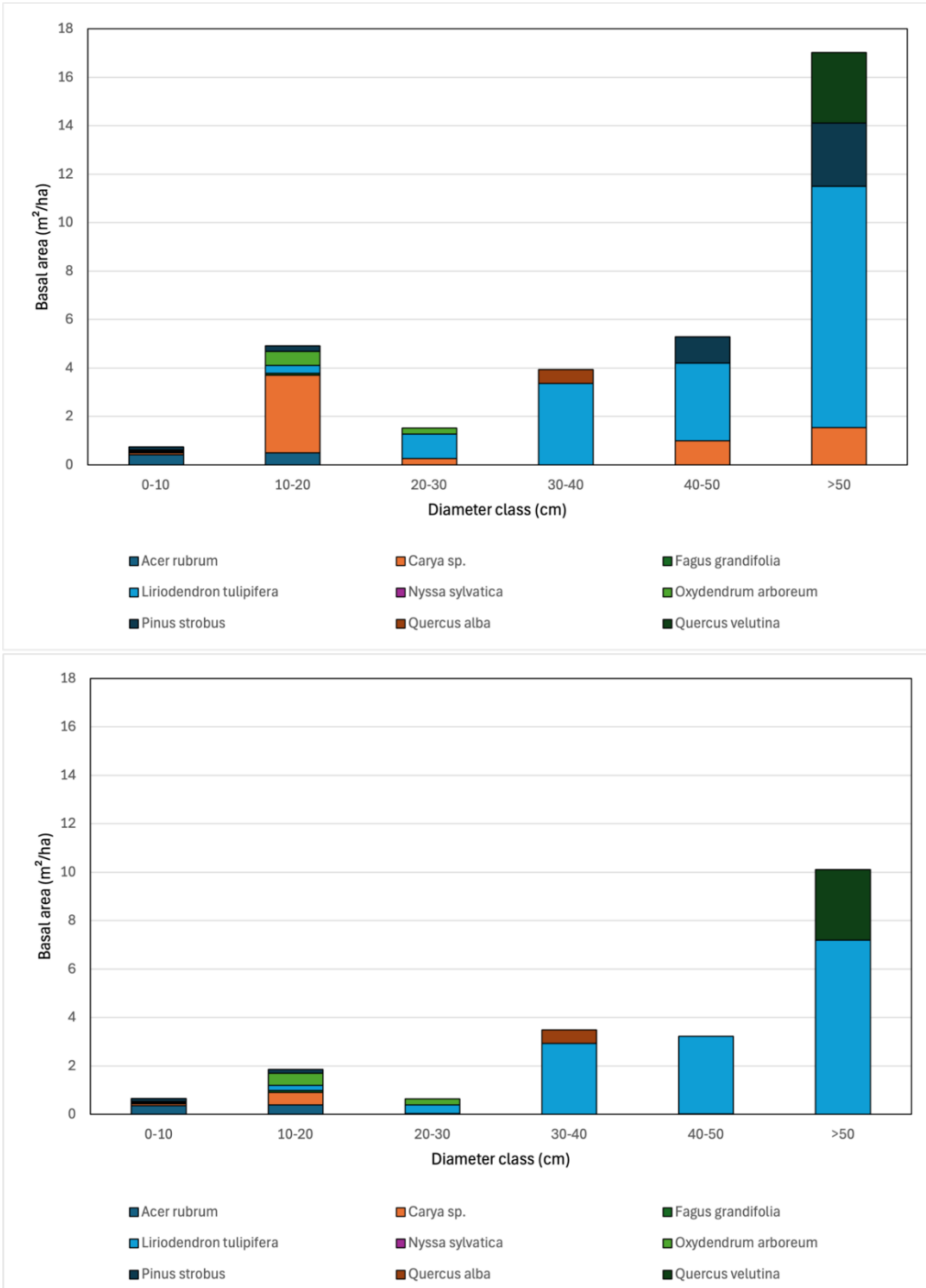
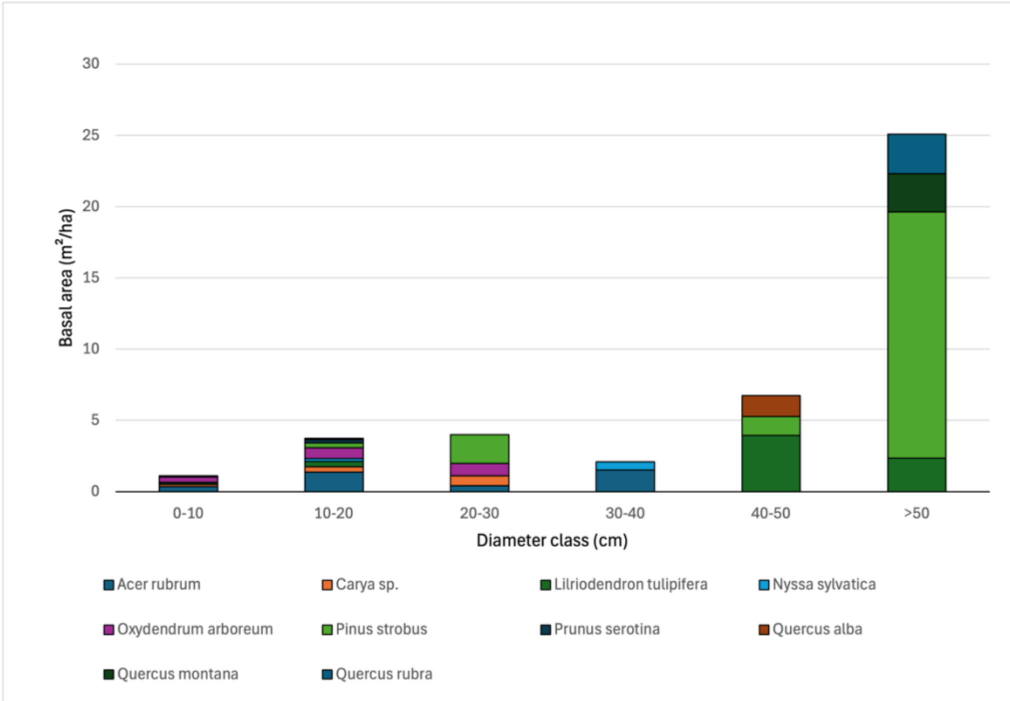


Figure 5. Pre-storm (top) and post-storm (bottom) basal area by diameter class for Rich Cove Forest plots. Basal area (m^2/ha) is shown across 10 cm diameter classes.

Table 2. Mean (± SE) seedling and sapling densities (stems/ha) by species in the Rich Cove forest type

Rich Cove	**Species**	**Density** (stem/ha)
Saplings	*Acer rubrum*	868.8 ± 195.4
	Lirodendron tulipifera	275.0 ± 266.7
	Carya sp.	225.0 ± 117.3
	Ailanthus altissima	187.5 ± 187.5
	Quercus alba	125.0 ± 125.0
	Prunus serrulata	106.3 ± 83.2
	Fraxinus americana	56.3 ± 21.3
	Amelanchier arborea	37.5 ± 37.5
	Prunus avium	37.5 ± 37.5
	Prunus serotina	37.5 ± 37.5
	Nyssa sylvatica	25.0 ± 17.7
	Quercus rubra	25.0 ± 17.7
	Fagus grandifolia	18.8 ± 18.8
	Pinus strobus	12.5 ± 7.2
	Robinia pseudoacacia	12.5 ± 12.5
	Castanea dentata	6.3 ± 6.3
	Quercus valentina	6.3 ± 6.3
	Oxydendron abrorium	6.3 ± 6.3
	Pyrus calleryana	6.3 ± 6.3
	Morus rubra	6.3 ± 6.3
Seedlings	*Liriodendron tulipifera*	27875.0 ± 14578.9
	Acer rubrum	4750.0 ± 976.3
	Carya sp.	1500.0 ± 750.0
	Ailanthus altissima	1250.0 ± 819.7
	Quercus velutina	875.0 ± 757.8
	Prunus serotina	625.0 ± 409.8
	Quercus alba	375.0 ± 324.8
	Quercus rubra	250.0 ± 125.0
	Fraxinus americana	250.0 ± 125.0
	Nyssa sylvatica	125.0 ± 108.3
	Quercus montana	125.0 ± 108.3



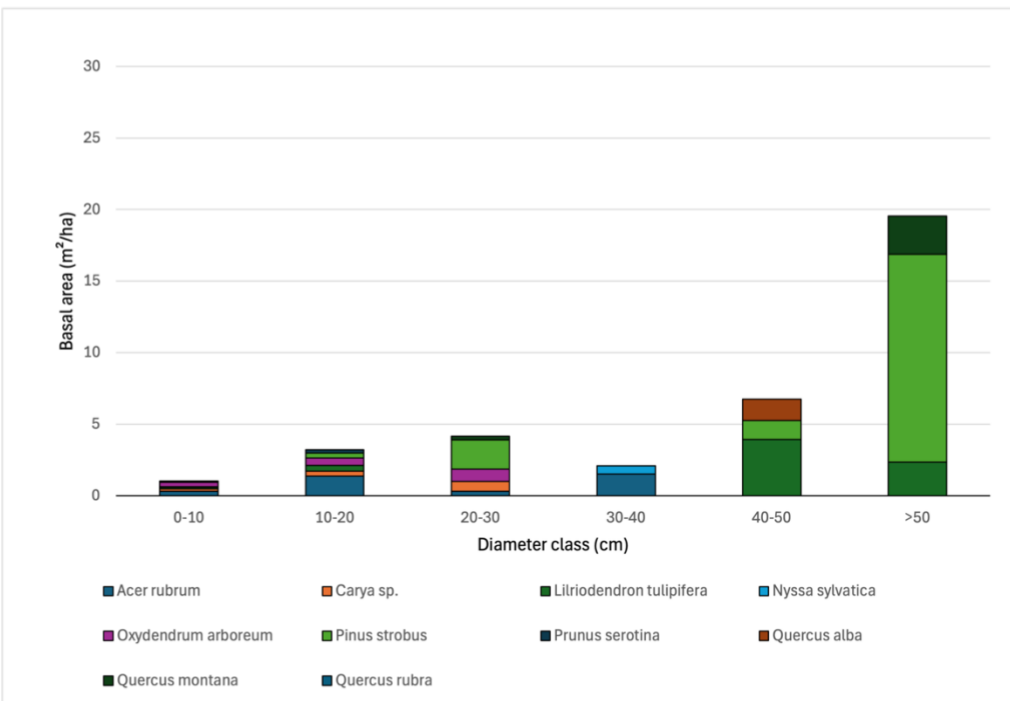


Figure 6. Pre-storm (top) and post-storm (bottom) basal area distribution for White Pine Forest plots. Basal area (m^2/ha) is shown across 10 cm diameter classes.

Table 3. Mean (± SE) seedling and sapling densities (stems/ha) by species in the White Pine forest type.

White Pine	**Species**	**Density** (stem/ha)
Saplings	*Acer rubrum*	783.3 ± 318.3
	Oxydendrum arboreum	200.0 ± 142.2
	Nyssa sylvatica	125.0 ± 80.4
	Pinus strobus	100.0 ± 87.8
	Carya sp.	91.7 ± 54.6
	Morus rubra	33.3 ± 33.3
	Fagus grandifolia	25.0 ± 14.4
	Prunus serotina	25.0 ± 14.4
	Fraxinus americana	25.0 ± 25.0
	Liriodendron tulipifera	16.7 ± 8.3
	Quercus rubra	16.7 ± 16.7
	Prunus avium	8.3 ± 8.3
Seedlings	*Acer rubrum*	3419.7 ± 733.3
	Carya sp.	1333.3 ± 666.7
	Quercus rubra	1166.7 ± 928.0
	Nyssa sylvatica	833.3 ± 441.0
	Oxydendrum arboreum	666.7 ± 441.0
	Prunus serotina	500.0 ± 500.0
	Quercus montana	500.0 ± 500.0
	Pinus strobus	333.3 ± 166.7
	Liriodendron tulipifera	333.3 ± 333.3
	Quercus alba	166.7 ± 166.7
	Fraxinus americana	166.7 ± 166.7

Discussion

The impacts of Tropical Storm Helene left Chestnut Ridge with substantial canopy loss, particularly among large-diameter trees, with the greatest structural changes occurring in White Pine and Montane Oak–Hickory stands. Notable losses occurred in *Quercus* spp., *Carya* spp., and *Pinus strobus* L., alongside increases in *Acer rubrum* L. and *Liriodendron tulipifera* L. in the regeneration layer (Table 1). These disturbances created canopy gaps that are driving rapid shifts in forest composition and altering regeneration pathways. Overall, the storm resulted in a structural and compositional shift away from oak–pine dominance toward a more mesophytic, hardwood-dominated system.

Although current forest types broadly resemble ecologically historical patterns, both pre- and post-storm conditions differ from the ecologically predicted composition, largely due to past land use and the persistence of White Pine stands. Historical reconstructions based on GIS analysis of physiography suggest that Chestnut Ridge was once more

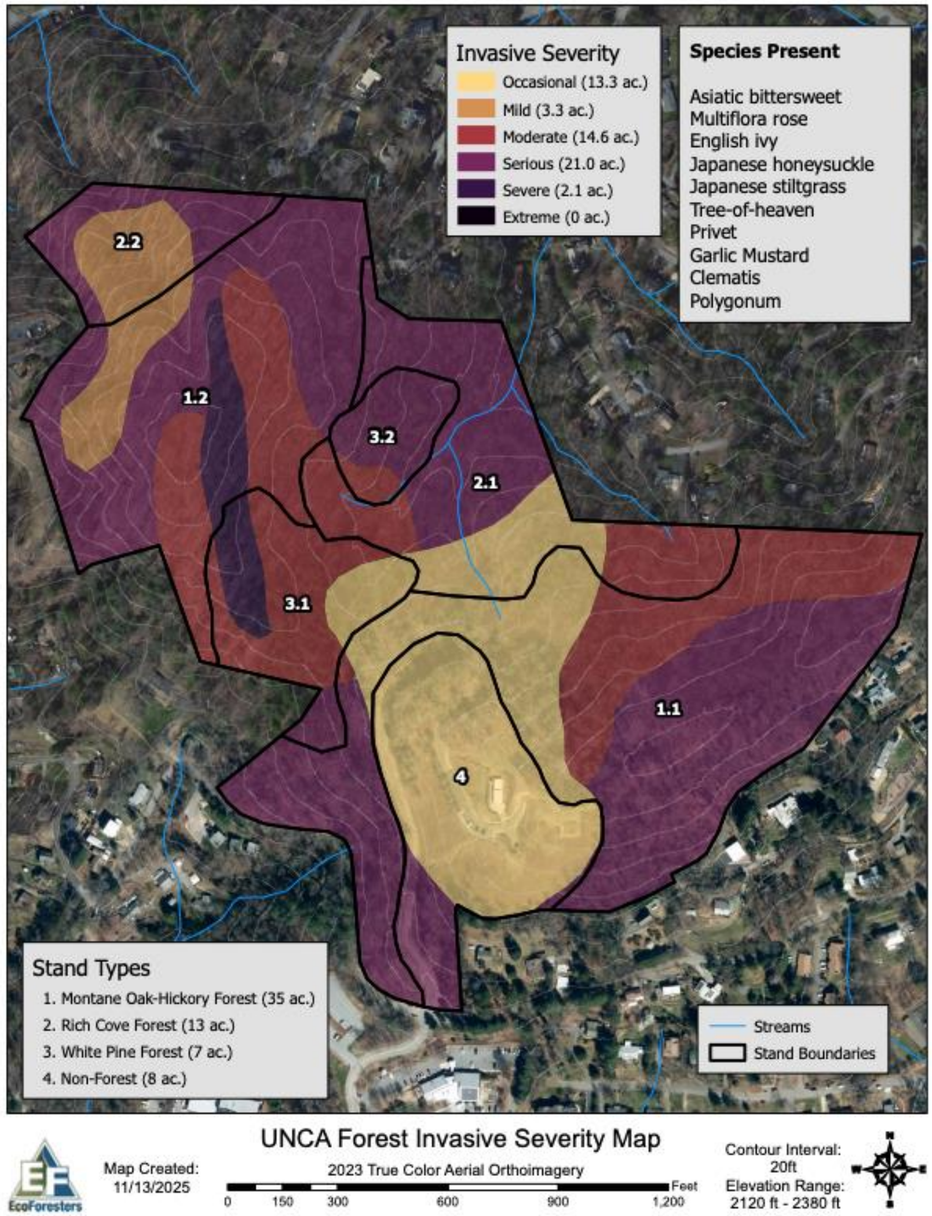


Figure 7. Distribution and severity of invasive species across forest types at Chestnut Ridge. Color indicates invasive severity.

strongly dominated by fire-tolerant *Quercus* and *Carya* species. In contrast, the current forest, both before and after the storm, shows a greater presence of *Acer rubrum* and *Liriodendron tulipifera*. This indicates that the forest may have already been undergoing a gradual shift toward more mesophytic conditions before the disturbance. The effects of Tropical Storm Helene appear to have accelerated this trajectory by removing large canopy oaks and creating conditions that favor fast-growing, gap-dependent species. As a result, the forest is likely continuing along a path of mesophication, in which shade-tolerant and moisture-associated species increasingly dominate over historically fire-adapted oak–hickory systems.

Regeneration

Across all forest types, Tropical Storm Helene disproportionately impacted large-diameter canopy trees, particularly *Quercus*, *Carya*, and *Pinus strobus*, resulting in significant reductions in basal area within larger size classes. This pattern is consistent with previous studies of wind disturbance in Appalachian forests, where larger canopy trees are more vulnerable to uprooting and breakage (Greenberg 1998; Goode et al. 2022). The removal of these dominant canopy species created extensive canopy gaps, fundamentally altering forest structure and light availability.

Regeneration patterns across the study area indicate a strong shift toward species that are well adapted to disturbed, high-light environments. *Liriodendron tulipifera*, a shade-intolerant, fast-growing species, showed substantial recruitment in gaps, while *Acer rubrum*, a widely adaptable and moderately shade-tolerant species, occurred at high densities across both seedling and sapling layers. These trends suggest that post-disturbance recovery is being driven by species capable of rapidly growing into canopy openings rather than by the regeneration of lost canopy oaks and hickories. Similar post-disturbance dynamics have been documented in montane oak forests, where wind events disproportionately removed large-diameter oaks and caused shifts the regeneration toward fast-growing, early successional species (Greenberg 2021; Goode et al. 2022). Within Chestnut Ridge, this pattern was evident across Montane Oak–Hickory, Rich Cove, and White Pine stands, all of which showed increased representation of *Acer rubrum* and *Liriodendron tulipifera* in smaller diameter classes.

Additionally, windthrow not only removes canopy trees but also reshapes the forest floor through the creation of pit-and-mound microtopography. Previous work in the southern Appalachians has shown that wind disturbances generate heterogeneous microsites with varying light, moisture, and soil conditions, which play a key role in determining vegetation establishment (Clinton & Baker 2000). Similar patterns of post-disturbance regeneration have been documented following hurricane events in the southern Appalachian forest, where increased light availability and structural heterogeneity promote rapid successional species (Elliott et al. 2002). This assortment of environmental conditions further influences regeneration pathways, contributing to shifts in species composition.

Mesophication

Multiple lines of evidence indicate that Chestnut Ridge is undergoing mesophication, with historically fire-adapted oak–hickory forests increasingly replaced by shade-tolerant, moisture-associated species. Large-diameter *Quercus* spp., *Carya* spp, and *Pinus strobus* experienced disproportionately high storm-related mortality, while *A. rubrum* and *L. tulipifera* dominate the regeneration layer (Table 1). Mesophication theory predicts this pattern under suppressed fire regimes and gap-forming disturbances, as feedbacks among light, soil moisture, and litter decomposition progressively disadvantage fire-adapted species (Alexander et al., 2021). Without intervention, the forest is likely to continue along a trajectory favoring mesophytic species, further reducing the probability of oak–hickory regeneration.

Invasion

Non-native invasive species were most concentrated in areas of high disturbance, particularly within White Pine stands and along trail corridors. These areas experienced the greatest canopy loss and soil disturbance, creating favorable conditions for invasives to establish. Increased light availability, reduced competition, and exposed soil surfaces likely facilitated the spread of invasive species across these sites. The most abundant invasive species observed were *Ailanthus altissima, Microstegium vimineum*, and *Celastrus orbiculatus* (Fig. 7). These species are known for their ability to rapidly colonize disturbed environments and outcompete native vegetation. The relatively high invasion levels observed in this urban forest may reflect greater propagule pressure from nearby developed areas and more frequent disturbance compared to less urbanized landscapes, such as areas along the Blue Ridge Parkway.

Management

Active management will be necessary to alter the current trajectory of forest succession at Chestnut Ridge. One of the most immediate priorities is invasive species control, particularly in highly disturbed areas where invasives are most abundant. Effective management will likely require multiple treatments over several years, with estimated costs ranging from approximately $75,000 to $90,000 over a 5–10 year period, depending on treatment intensity and coverage (Table 4).

Table 4. Estimated cost for invasive species management at Chestnut Ridge across three treatment rounds. Costs are presented by infestation area (acres), with corresponding minimum and maximum subtotal estimates for each treatment phase. Total projected costs range from approximately $75,000 to $90,000 over a 5–10-year management period.

Treatment	Infestation Level	Occasional	Mild	Moderate	Serious	Severe	Total
First Round	Acres Infested	13.3	3.3	14.6	21	2.1	54.3
	Max Subtotal Cost	$3,990	$1,600	$10,950	$21,000	$10,500	$48,090
	Min Subtotal Cost	$3,325	$1,320	$9,125	$18,375	$6,300	$38,445
Second Round	Acres Infested	3.3	14.6	21	2.1	0	54.3
	Max Subtotal Cost	$990	$7,300	$15,750	$2,100	$0	$26,628
	Min Subtotal Cost	$825	$5,840	$13,125	$1,838	$0	$21,628
Third Round	Acres Infested	14.6	21	2.1	0	0	54.3
	Max Subtotal Cost	$4,380	$10,500	$1,575	$0	$0	$16,455
	Min Subtotal Cost	$3,650	$8,400	$1,313	$0	$0	$13,363
Grand Total	Max Grand Total	$9,360	$19,450	$28,275	$23,100	$10,500	$90,685
	Min Grand Total	$7,800	$15,560	$23,563	$20,213	$6,300	$73,435

In addition to invasive removal, silvicultural practices such as crop-tree release could be used to promote the growth of desirable species. By selectively reducing competition around chosen oak and hickory individuals, these species may have a greater chance of reaching the canopy. Targeted planting of desired species, including oaks, hickories, and potentially American chestnut hybrids, may also be necessary to supplement natural regeneration. These efforts would help reintroduce species that are currently underrepresented in the regeneration layer. Without these interventions, natural regeneration alone is unlikely to restore the forest to its ecologically predicted composition, and the system will likely continue along a trajectory of mesophication and increased dominance by invasive species.

Conclusion

This study looked at the ecological impacts of Tropical Storm Helene on UNCA's Chestnut Ridge Forest and evaluated its path to recovery. Although the current forest types broadly resembled those ecologically predicted for this landscape, their composition and structure differ from these expected conditions.

Storm-related damage was not evenly distributed across forest types. The most severe impacts occurred in the White Pine and Montane Oak–Hickory stands, where large-diameter canopy trees experienced extensive windthrow and mortality. These losses substantially altered stand structure and created large canopy openings, accelerating successional change. In contrast, Rich Cove forests experienced comparatively less structural damage, though compositional shifts were still noticeable. The post-storm analysis indicates that Chestnut Ridge is not currently on a trajectory toward recovering its ecologically predicted forest types. The regeneration layer is dominated by shade-tolerant and fast-growing mesophytic species, particularly *Acer rubrum* and *Liriodendron tulipifera*, while regeneration of historically dominant *Quercus* and *Carya* species remains outnumbered. This finding suggests that the natural forest regeneration cycle alone is not enough to reestablish the predicted forest communities.

As a result, active management will be necessary to restore and maintain ecologically accurate forest types at Chestnut Ridge. Management practices should focus on reducing invasive species, particularly in heavily disturbed areas, and promoting desired native species through practices such as crop-tree release and targeted planting of desired and ecologically dominant species. Without such active forest management, continued mesophication and invasion of nonnative species are likely to shift the forest further away from its predicted condition. Overall, this study emphasizes the role of active management in guiding post-disturbance forest recovery under increasingly frequent and intense storm events. The findings provide a practical foundation for restoration planning at Chestnut Ridge and offer insights applicable to small-scale forest owners and land managers facing similar disturbance-driven challenges.

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