Ecological Significance of Phyllosphere Leaf Traits on Throughfall Hydrology, Biogeochemistry, and Leaf Litter Quality Among *Quercus* species in the Southeastern United States

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Introduction

- *Quercus* are a dominant genus in many forests across the United States that may contribute large amounts of water and nutrients through mechanism such as throughfall and leaf litter inputs.
- Throughfall is the precipitation falling through the canopy to the forest floor. As water passes over vegetative surfaces, nutrients are washed and leached from plant tissues to the forest understory.
- A large concentration of plant nutrients are also found within leaf litter and are released during decomposition.

Figure 2: Early spring leaf decomposition and vegetative growth

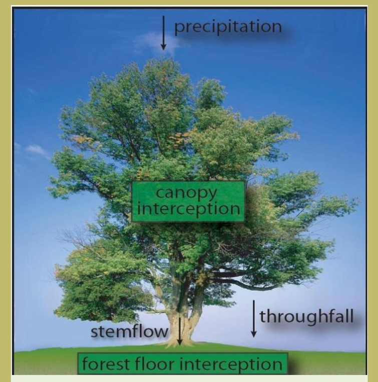

Figure 1: Mechanisms of water flowing over a tree

- The large canopies and annual inputs of litter in *Quercus* could be a vital source of water and nutrients to ecosystem processes.
- Recent forest management practices, largely due to fire suppression, has resulted in loss of *Quercus.*
- The lack of fire has enhanced forest mesophication processes that increase the moisture in forest microclimates due to the lack of reoccurring fire. This allows for understory shade tolerant species (*Carya* and *Acer* species) to quickly outcompete slower growing *Quercus* seedlings.
- Management activities have attempted to increase *Quercus* throughout the United States. These programs, however, lack fundamental information on *Quercus* functional traits that impact forest hydrology and nutrient dynamics.

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Objectives

- The recent decline of *Quercus* has the potential to alter forest health by influencing hydrology and nutrient cycling dynamics in several forest ecosystems in North America.

This study examines: [1] the contribution of water and canopy-derived nutrients from *Quercus* species and [2] the temporal distribution of leaf fall

1: Quantify canopy-derived nutrients
The influence of *Quercus* leaves and crown is monitored by:

[1] measuring throughfall hydrology and chemistry as a result of leaching and scavenging of atmospheric dry deposition, and [2] determining nutrient variation through interspecific leaf litter.

2: Temporal distribution of leaf fall
The timing and duration of leaf fall for *Quercus* species is quantified to determine the variation of leaf fall within species that subsequently alters hydrologic and biogeochemical fluxes.

Site Description

- Field collection occurred at an experimental research site located at Sessums Natural Area (SNA) in Starkville, Mississippi (33.42 N, 88.76 W) within a 15 ha mixed upland hardwood forest (Fig.3).

Figure 3: Field collection occurs at the Sessums Natural Area (SNA) in Starkville, Mississippi (33.42 N, 88.76 W) throughout a two year period. The canopy is largely comprised of *Q. shumardii* (shumard oak), *Q. pagoda* (cherrybark oak), *Q. stellata* (post oak), *Q. alba* (white oak), *C. ovata* (shagbark hickory), and *C. glabra* (pignut hickory).

- *Quercus* species have an average DBH of 64.9cm and an average crown area of 126.7m^2. *Carya* species have an average DBH of 39.8cm and an average canopy width of 60.5m^2.

Precipitation Collection

- Precipitation quantity, magnitude, and duration was measured with a tipping bucket rain gauge ~1km away from the SNA area.
- A high density polyethylene bottle (HDPE) and funnel apparatus were used to collect precipitation chemistry

Throughfall Collection

- Throughfall HDPE bottles and funnel apparatuses (Fig. 4) were located under three canopies of each *Q. shumardii, Q. Pagoda, Q. stellata, C. alba, C. ovata,* and *C. glabra* species at the SNA site. These apparatuses were collected and quantified for throughfall depth and chemistry after every rain event that exceed 5mm.

Figure 4: Throughfall depth and chemistry are collected using a HDPE bottle and funnel apparatus

- Water samples from each tree were combined, (total of 6 tree samples and one precipitation sample), tested for pH, and filtered to remove particles greater than 0.45µm. Samples were stored at 4 ℃.

Leaf Litter Collection

- Leaf litter traps (Fig. 5) were randomly located (10 total) and collected weekly to determine leaf are index (LAI) and leaf nutrient content for all species at this site.
- After leaf fall, leaf litter was collected using 6 .5m^2 quadrat plots, separated by species and analyzed for leaf litter quantity and quality for each species.

Figure 5: Leaf litter trap used to measure LAI in the field

Laboratory Analysis

Precipitation/Throughfall

Major ions have been analyzed using a Dionex-Ion Chromatograph (DX-500). Total kjeldahl nitrogen (TKN) have been analyzed using a Bran-Luebbe Auto Analyzer. Total organic carbon (TOC) has been quantified by using a HACH Low Range TOC Test kit and run on a HACH DR 5000 UV-Vis Spectrophotometer. This laboratory follows the QA/QC protocols outlined by the EPA.

Leaf Litter

Leaf litter was separated by species (Fig. 6) and dried in a oven. Samples were prepared for nutrient content by grinding the leaflets into <2mm particles and analyzed for C and N on a Costech Elemental Combustion Analyzer.

Results: Throughfall

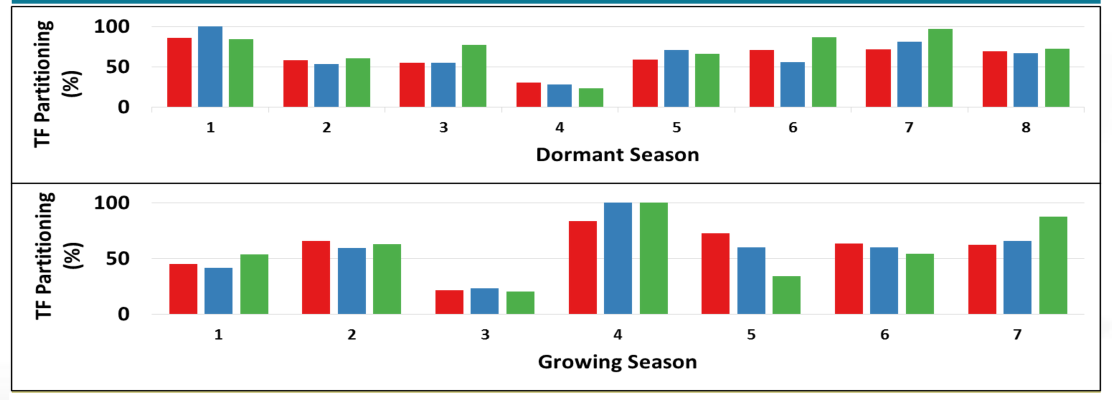
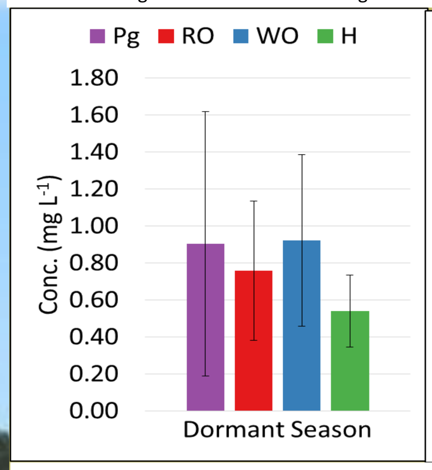


Figure 7: Throughfall (TF) partitioning for each species group during the dormant (Jan.-Mar.) and growing (Apr.-Sept) season. There was no significant difference between species, however, the average throughfall volumetric flux was greater during the dormant season.

	Dormant Season					Growing Season			
	Pg	RO	WO	H		Pg	RO	WO	H
Na^+	2.07 (2.05)	3.47 (6.89)	1.60 (1.10)	1.46 (1.23)	Na^+	1.07 (0.44)	1.55 (0.83)	1.68 (0.95)	1.42 (0.38)
K^+	3.25 (4.27)	2.29 (2.16)	1.26 (0.44)	2.70 (1.41)	K^+	3.74 (4.99)	7.31 (5.05)	9.25 (5.38)	8.39 (4.63)
Ca^{2+}	2.01 (0.93)	2.52 (2.74)	2.11 (0.47)	2.83 (0.71)	Ca^{2+}	3.28 (2.17)	3.68 (2.26)	4.33 (1.43)	4.63 (2.88)
Mg^{2+}	0.17 (0.05)	0.32 (0.35)	0.26 (0.09)	0.41 (0.17)	Mg^{2+}	0.43 (0.42)	0.79 (0.51)	0.72 (0.31)	0.70 (0.29)
NH_4^+	3.64 (5.37)	0.63 (0.58)	0.22 (0.22)	0.18 (.017)	NH_4^+	1.79 (2.22)	1.43 (2.97)	1.53 (2.48)	0.66 (0.44)
Cl^-	2.54 (4.74)	1.33 (0.85)	1.65 (1.45)	1.60 (0.94)	Cl^-	4.37 (7.06)	1.83 (1.02)	1.79 (0.76)	1.90 (0.71)
SO_4^{2-}	1.72 (0.82)	3.39 (2.99)	3.82 (2.63)	4.87 (2.88)	SO_4^{2-}	10.82 (9.57)	5.09 (3.21)	6.08 (4.00)	4.61 (2.70)
NO_3^-	0.13 (0.11)	0.15 (0.21)	0.24 (0.20)	0.20 (0.14)	NO_3^-	0.22 (0.17)	0.12 (0.12)	0.13 (0.09)	0.06 (0.07)

Figure 8: Average values for major ion concentrations (mg L^{-1}) in precipitation (Pg) and throughfall during the dormant (Jan.-Mar.) and growing (Apr.-Sept.) season. Ca^{2+}, K^+, SO_4^{2-}, and Mg^{2+} concentrations were higher during the growing season. Mg^{2+} concentrations were significantly different between Pg and species group.



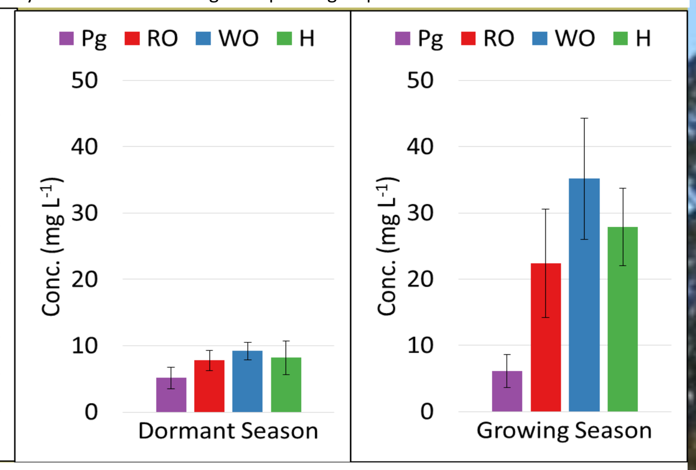


Figure 9: TKN concentrations in Pg and throughfall for each species group during the dormant season. TKN was greatest in *Quercus* species.

Figure 10: Average TOC concentrations in Pg and throughfall for the dormant and growing season. TOC was significantly greater during the growing season. TOC was greater underneath each species group canopy compared to Pg.

Results: Leaf Litter

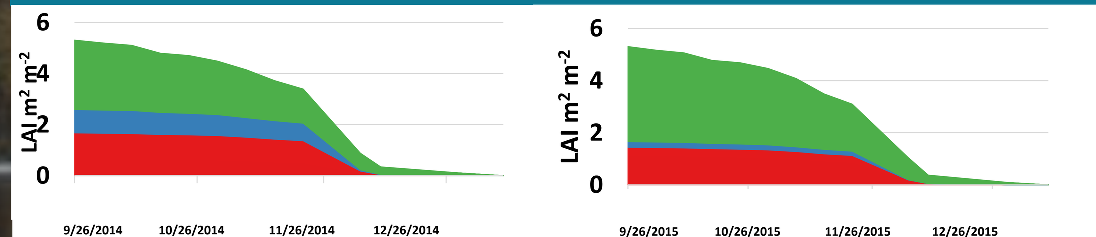


Figure 11: LAI of each species group during leaf fall in 2014 and 2015. *Carya* and other non-*Quercus* species had the largest LAI during leaf fall but leaves were lost at a much faster rate compared to *Quercus* species.

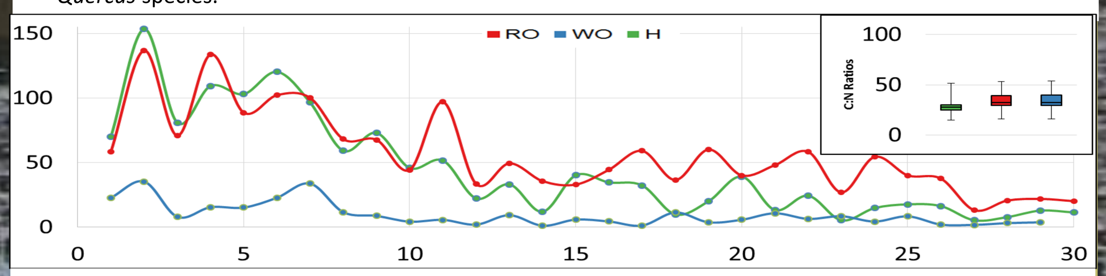


Figure 12: Leaf mass and C:N ratios of leaf litter of each species group during 2015 (Jan.-Sept.). Leaf mass was lost at a faster rate in *Carya* compared to *Quercus* species. This can be correlated with the higher C:N ratio in *Quercus* species.

Conclusion

Throughfall partitioning correlated with seasonal changes in vegetation cover rather than interspecific differences between species. Ion and TOC concentrations were greatest during the growing season underneath a leafed canopy. This could be caused by atmospheric scavenging leaching interactions. TKN concentrations were highest in *Quercus* species which may correlate with the wide canopies that can capture more atmospheric deposition. Leaf area index was greatest in other species throughout leaf fall, but *Quercus* lost leaf area at a much slower rate. This slower leaf loss may correlate with greater ion concentrations in TKN for *Quercus* because the retention of leaves may increase atmospheric scavenging during this phenoseason. The higher C:N ratio and slower decay rate in *Quercus* litter indicate a slower nutrient release which may be beneficial when other litter has already decomposed during the growing season. This research suggests that *Quercus* are an important species for hydrologic and biogeochemical cycling. Future management practices in historically oak-hickory dominated ecosystems should continue protecting this species.