Changes in Forest Floor and Soil Nutrients in a Mixed Oak Forest 33 Years after Stem Only and Whole-tree Harvest

D.W. Johnson[a]*, C.C. Trettin[b], and D.E. Todd, Jr.[a]

[a]Natural Resources and Environmental Science, University of Nevada, Reno, Nevada USA 89557. [b]USDA Forest Service, Charleston, South Carolina USA 29141

Abstract

Vegetation, forest floor, and soils were resampled at a mixed oak site in eastern Tennessee that had been subjected to stem only (SOH) and whole-tree harvest (WTH) 33 years previously. Vegetation biomass and nutrient contents did not differ between harvest treatments over the first 15 years, but were lower in the WTH treatment at 33 years. Forest floor biomass and nutrient contents did not differ between harvest treatments over the first 15 years, but were greater in the WTH treatment at 33 years. Soil total C and total N contents increased in both harvest treatments over the first 15 years. Soil and total ecosystem N contents increased during this time by amounts that could not be explained by atmospheric deposition or N fixation. Between years 15 and 30, soil C and N contents decreased in the WTH treatment but not in the SOH treatment. Soil extractable P decreased continuously over time in both harvest treatments. Part of these decreases could be accounted for by increases in vegetation and detritus. Soil exchangeable K^+ contents fluctuated over time but neither the changes nor treatment effects were statistically significant. Soil exchangeable Ca^{2+} and, to a lesser extent, Mg^{2+} contents changed considerably over time, reflecting inputs from decomposing logging residues and increments in vegetation and detritus.

Site:

- Vegetation: Mixed deciduous forest (*Quercus* spp, *Carya* spp, *Liriodendon tulipifera*, *Pinus echinata*)
- Soils: Paleudults derived from dolomite

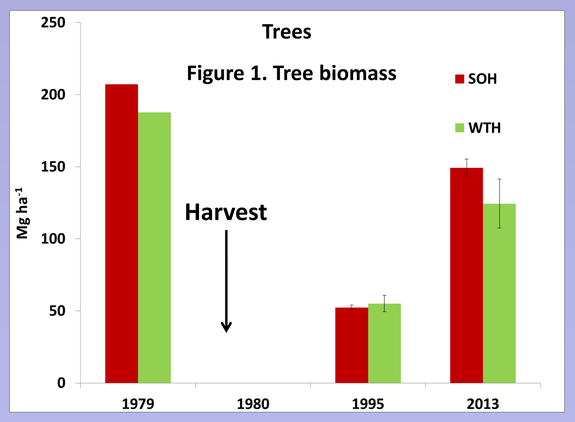
Treatments and Sampling

- Stem only (SOH) and whole tree harvest (WTH) in 1980
- Vegetation and soil sampling in 1979 (pre-harvest), 1980 (immediate post harvest), 1995 (15 years post-harvest) and 2013 (33 years post harvest)

Results and Discussion: Trees and Detritus

- No differences in regeneration biomass in 1995 (15 years post-harvest) but slightly lower in WTH than SOH in 2013 (33 years post-harvest (Figure 1)
- Coarse woody debris (CWD; mostly logging residues) in SOH 90% decomposed by 1995; CWD increased in both treatments in 2013 due to tree mortality (Figure 2)
- No differences in forest floor until 2013 when large increase in WTH was observed (Figure 2)

Figure 1. Tree biomass



- Forest floor increase in WTH in 2013 was due to buildup of Oa horizon (Figure 3)
- Oa horizon nutrient contents in WTH were 7-10 times greater than in SOH
- Oa horizon in WTH also had greater K, Ca, and Mg concentrations (Table 1)
- However, surface soil Ca and Mg concentrations directly below Oa horizon were lower in WTH than SOH (Table 2).

Figure 2. Detritus biomass

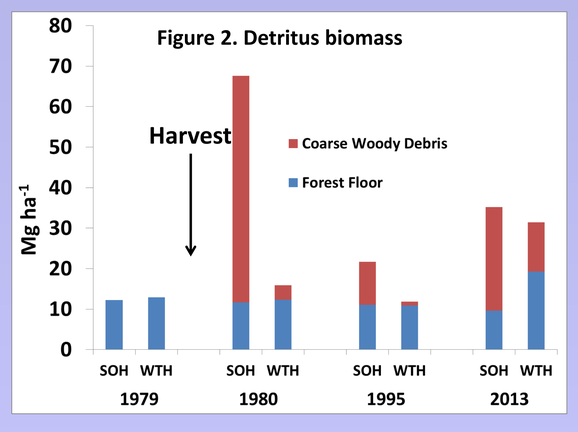


Figure 3. Forest floor mass and nutrient content in 2013

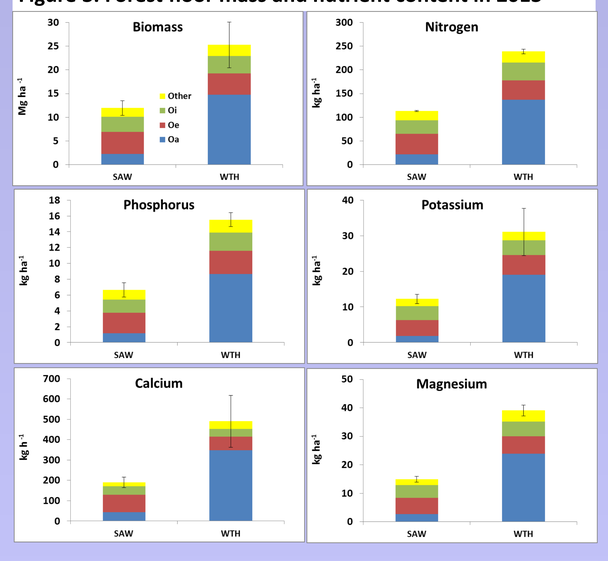


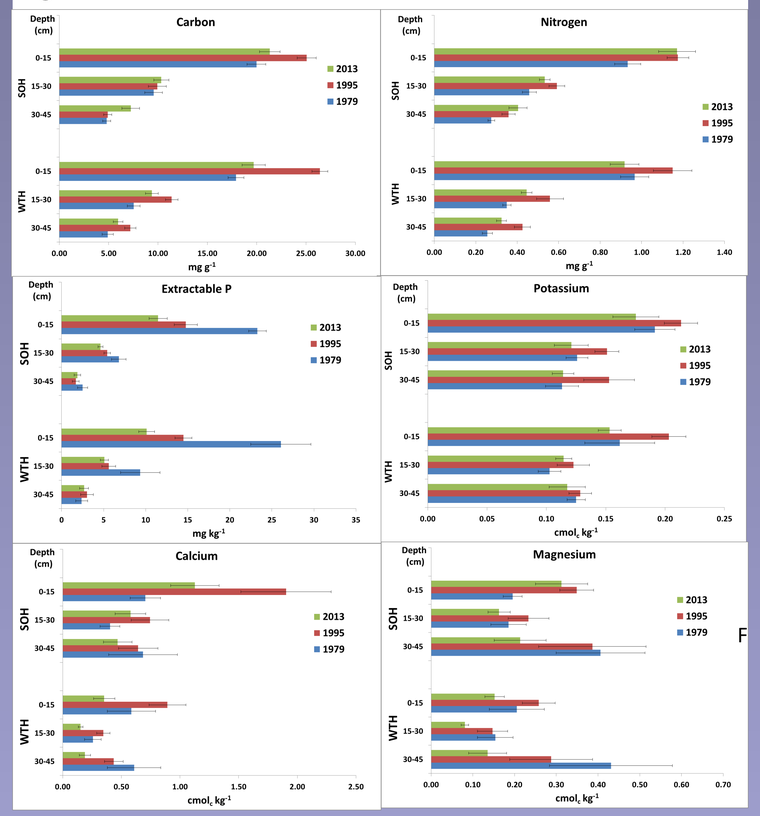
Table 1. Nutrient concentrations in Oa horizon in 2013 (mg g^{-1})

	N	P	K	Ca	Mg
SOH	9.8	0.52	0.83	18.5	1.18
WTH	10.2	0.62	1.40*	24.1*	1.74*

Table 2. Nutrient concentrations in A horizon in 2013 (mg g^{-1})

	N	P	K	Ca	Mg
	mg g^{-1}	mg kg^{-1}	---------- $cmol_c$ kg^{-1} ----------		
SOH	1.2	11.5	0.18	1.13	0.31
WTH	0.9	10.1	0.15	0.35*	0.15*

Figure 4. Soil nutrient concentrations



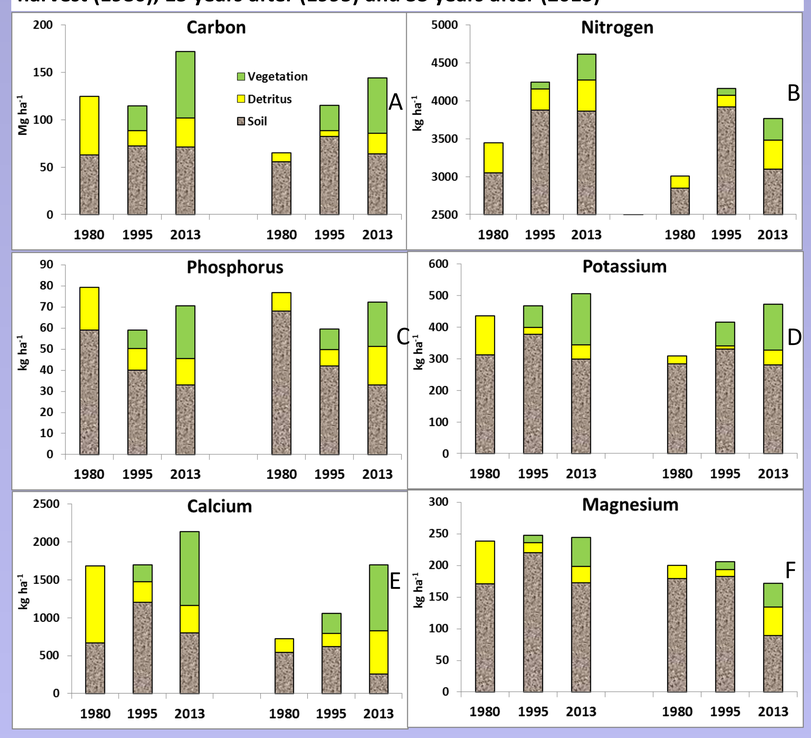
Results and Discussion: Soil Concentrations

- Total C increased from 1979 to 1995 then decreased in 2013 in surface (0-15 cm). No treatment effects (Figure 4A)
- Total N increased in both treatments from 1979 to 1995. Total N decreased between 1995 and 2013 in WTH but remained stable in SOH (Figure 4B). No treatment effects.
- Bray P decreased over time in all treatments. No treatment effects (Figure 5C)
- No significant treatment effects or significant changes over time in soil K^+ (Figure 4D)
- Ca^{2+} increased in surface soils by 2x between 1979 and 1995 in SOH due to inputs from decomposing slash. Ca^{2+} decreased between 1995 and 2013 in both treatments due to tree uptake (Figures 4E and 5E)
- Mg^{2+} increased in surface soils between 1979 and 1995 in SOH due to inputs from decomposing slash. Mg^{2+} decreased between 1995 and 2013 in WTH due to uptake and also (presumably) by leaching (Figures 4F and 5F)

Results and Discussion: Carbon and Nutrient Budgets Since Harvest

- No net ecosystem C gain in SOH until 2013; steady increases over time in WTH (Figure 5A)
- Inexplicably large increases in soil N in both treatments in 1995; in 2013, soil N remains elevated in SOH but declined again in WTH (Figure 5B)
- Steady declines in soil extractable P in both treatments; changes from 1995 to 2013 accounted for by uptake (Figure 5C)
- Relatively constant ecosystem K* in SOH with redistribution from CWD (logging residues) to soil to trees over time; increase in ecosystem K in WTH over time in trees (deep uptake?) (Figure 5D)

Figure 5. Ecosystem nutrient distribution (to 45 cm soil depth) immediately after harvest (1980), 15 years after (1995) and 33 years after (2013)



- Redistribution of Ca from CWD (logging residues) to soil in 1995 and then to trees in 2013 in SOH; redistribution of Ca from soil to trees in WTH in 2013 (Figure 5E)
- Increases in ecosystem Ca* in 2013 in both treatments (deep uptake?) (Figure 5E)
- Redistribution of Mg from CWD (logging residues) to soil in 1995 and then to trees in 2013 in SOH; redistribution of Ca from soil to forest floor and trees in WTH in 2013 (Figure 5F)
- Ecosystem Mg* declines in SOH from 1995 to 2013 and steady declines over time in WTH (leaching?) (Figure 5F)

*Including exchangeable amounts only, not total soil contents

Summary and Conclusions

33 Years After Harvest:

- Slightly lower tree biomass in WTH than SOH; are treatment effects on growth beginning to appear?
- Much larger forest floor (Oa horizon) mass and nutrient content in WTH than in SOH
- Oa horizon K, Ca, and Mg concentrations higher in WTH than SOH, but reverse is true for Ca and Mg in soils directly below

Overall Changes with Time:

- Cause(s) of increased Oa horizon mass in 2013 unknown
- Soil P, K, Ca and Mg changes consistent with known processes (slash decomposition, uptake) or could be explained by deep uptake
- Large soil N increases over the first 15 years remain inexplicable

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