Nutrient Changes in Ozark Highland Soils Due to Forest Harvest Management

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MOFEP
Missouri Ozark Forest Ecosystem Project

Introduction

- The Missouri Ozark Forest Ecosystem Project (MOFEP) is a 3,800 ha long-term experiment established in 1989 by the Missouri Department of Conservation to investigate management effects on forested ecosystems.
- Upland oak (*Quercus* L.)-dominated systems at MOFEP are managed with even-aged (EAM), uneven-aged (UAM), and no harvest (NHM) management over a 100-year rotation.
- Ozark Highland soils are highly weathered, thus cation exchange capacity (CEC) and % base saturation (BS) are often low (Kabrick et al., 2000). High coarse fragment content (background image) also contributes to lower quantities of available nutrients.
- The combination of low soil nutrient status and nutrient losses during and after harvest (i.e., sawlog removal and leaching) have raised concerns regarding the sustainability of forest harvest practices in the Ozark Highlands.

Objectives

Overall Objective: To elucidate the impact of forest harvest management on soil nutrient pools ten years post-harvest.

- Ascertain the influence of harvest intensity on soil base cations and pH.
- Determine the effect of clear cutting and single tree removals on soil nitrogen (N) pools (*in progress*).

Study Site and Sampling Design

- The experimental design of MOFEP is a randomized complete block design consisting of nine experimental sites ranging in size from 291 to 514 ha (Fig. 1).
- Groups of three sites were allocated to a block based on spatial location to one another, and each site within a block was randomly assigned a treatment (EAM, UAM, or NHM) (Brookshire and Day, 2000).
- Based on data collected previously (Kabrick et al., 2000), three common soil map units with varying degrees of BS were identified at each site: low (< 20% BS); moderate (20 – 50% BS); and high (> 50% BS) nutrient status.
- Within soil mapping units, areas harvested 10 years ago and nearby non-treated stands were identified for sampling (i.e., paired sampling).
- In treated and non-treated areas, three shallow pits were hand dug within an ~ 10 m radius and sampled in 10 cm increments to a depth of 30 cm. A stump or tree was used as a center point around which samples were collected in UAM sites and non-treated pairs (Fig. 2).
- 9 sites x 3 soils x 2 paired samples x 3 subsamples x 3 depths = 486 total samples

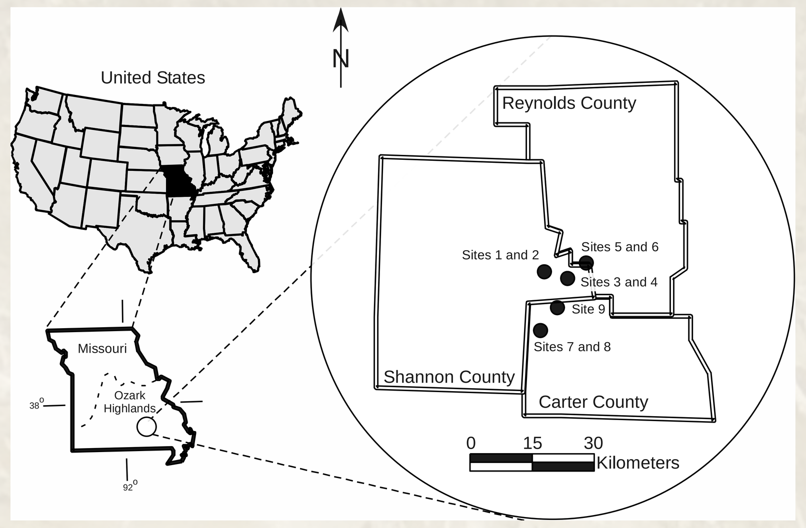

Figure 1. Location of Missouri Ozark Forest Ecosystem Project (MOFEP) and spatial arrangement of the nine sites (Kabrick et al., 2009).

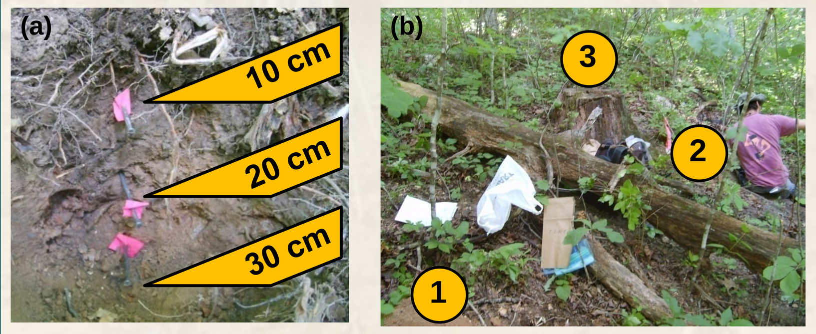

Figure 2. Photos illustrating sampling (a) by depth and (b) around a stump in uneven-aged mgt. sites.

Laboratory and Statistical Analyses

- Soils were analyzed by the University of Missouri Soil Characterization Laboratory using methods described in Burt (2004) for the following parameters: (1) CEC and exchangeable cations; (2) salt and water pH; (3) exchangeable acidity; and (4) total organic carbon (TOC) and total nitrogen (TN).
- In an effort to characterize labile and stabile pools of N in the soil, samples are being analyzed for water soluble N, potassium permanganate extractable N, and potentially mineralizable N (84 d total incubation period).
- Statistical analyses were performed in SAS (Cary, NC) using a split-plot analysis of variance model to test for the effects of (1) harvest mgt., (2) harvest mgt. * soil, and (3) harvest mgt. * soil * depth. Field subsample values from a given location were averaged, and analyses were preformed on difference values (Treated – Paired Control).

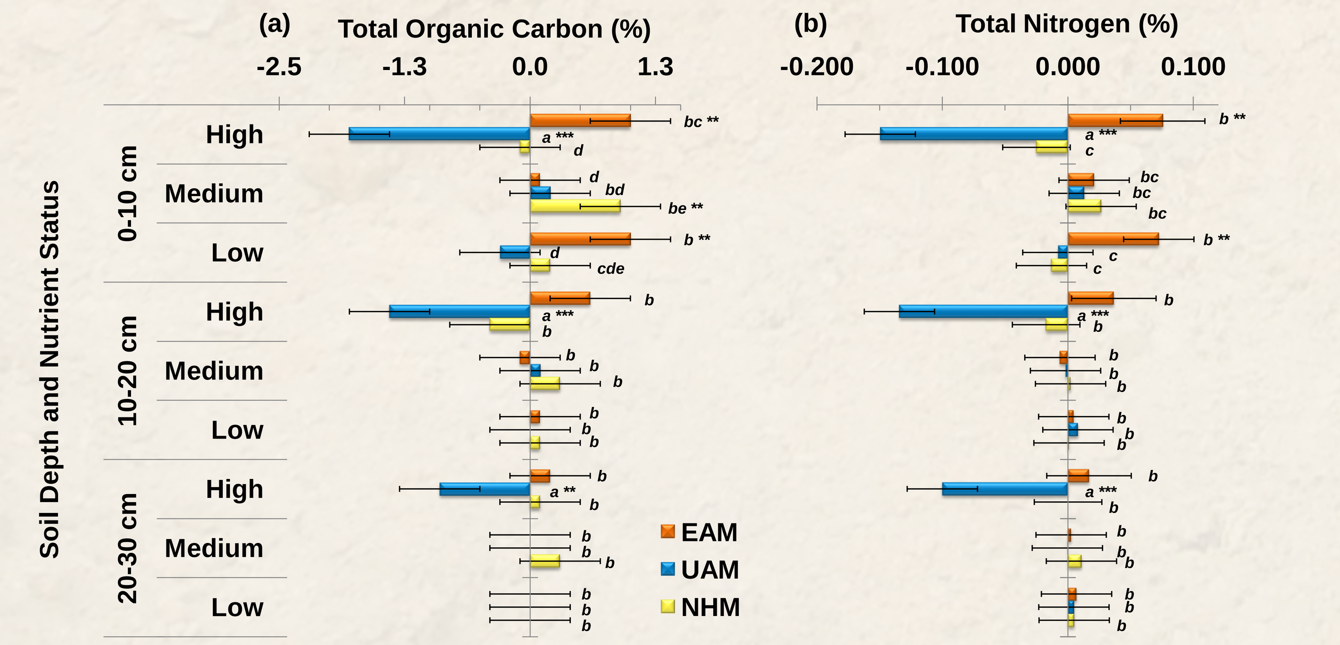

Figure 3. Differences in (a) total organic carbon and (b) total nitrogen between treated and untreated pairs. Letters indicate significant difference (α=0.1) between least square mean values within depth class. Means significantly dfferent from zero α=0.05 (**) and α=0.01 (***).

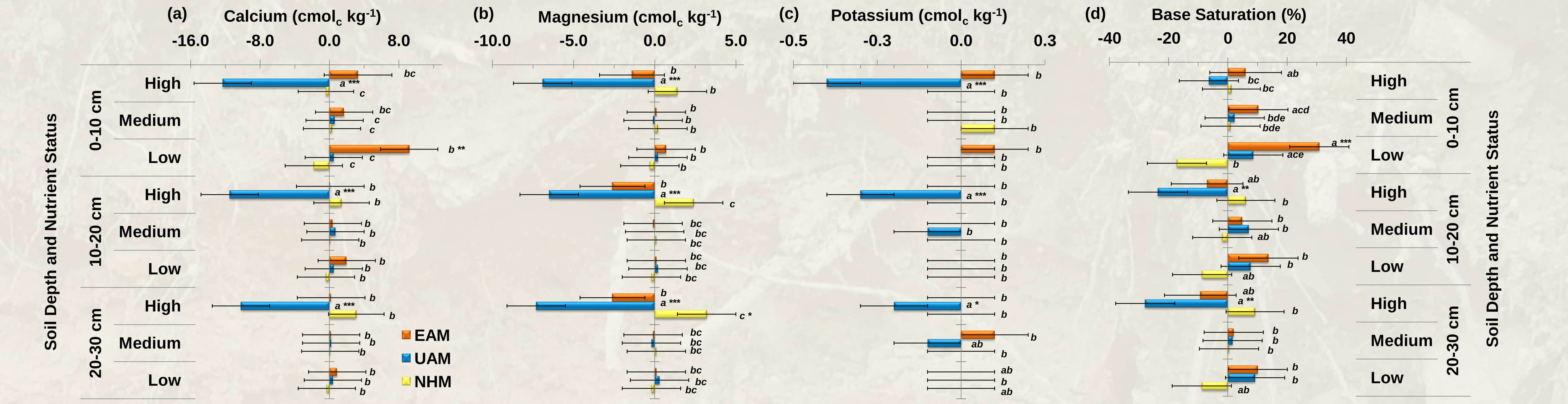

Figure 4. Differences in exchangeable base cations, (a) calcium, (b) magnesium, (c) potassium, and (d) base saturation of cation exchange sites between treated and untreated pairs. Letters indicate significant difference (α=0.1) between least square mean values within depth class. Means significantly different from zero at α=0.1 (*), α=0.05 (**) and α=0.01 (***).

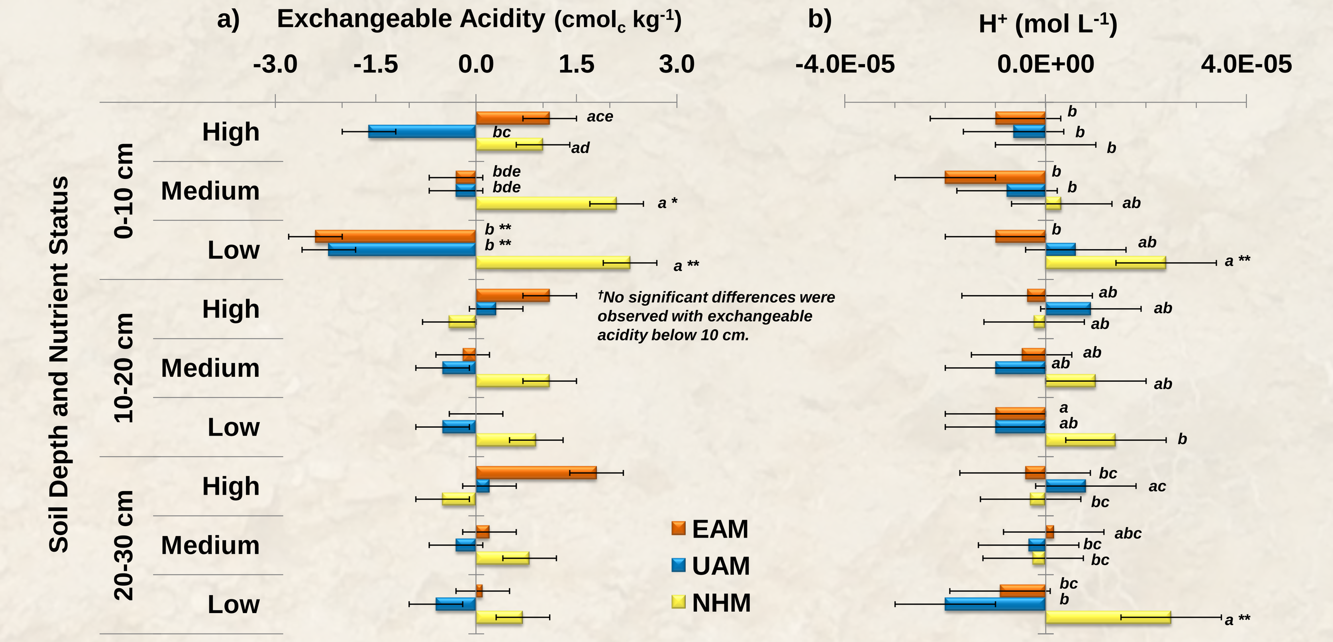

Figure 5. Differences in (a) exchangeable acidity and (b) hydrogen concentration between treated and untreated pairs. Letters indicate significant difference (α=0.1) between least square mean values within depth class. Means significant ly different from zero at α=0.1 (*), α=0.05 (**) and α=0.01 (***).

Table 1. Soil chemical properties of treated soil samples. Values are arithmetic mean values and standard error by soil nutrient status, treatment and depth.

Soil Nutrient Status	Treatment	Depth	Calcium	Magnesium	Potassium	Base Saturation	Exchangeable Acidity	Salt pH	Total Organic Carbon	Total Nitrogen
		cm	-- -- -- --	-- $cmol_c$ kg^{-1} --	-- -- -- --	%	$cmol_c$ kg^{-1}	(SE: mol H^+L^{-1})	-- -- -- --	% -- -- -- --
High	EAM	0-10	10 ± 3.6	3 ± 1.4	0.4 ± 0.1	61 ± 7	6.2 ± 0.9	5.6 ± 9.8E-07	3.4 ± 0.8	0.23 ± 0.06
		10-20	6 ± 2.8	3 ± 1.4	0.3 ± 0.1	49 ± 9	5.7 ± 0.7	5.1 ± 3.6E-06	1.6 ± 0.4	0.10 ± 0.04
		20-30	8 ± 2.7	5.0 ± 2.0	0.3 ± 0.1	55 ± 8	7 ± 1.4	5.1 ± 2.7E-06	1.0 ± 0.2	0.09 ± 0.02
	UAM	0-10	7.0 ± 0.7	2.1 ± 0.3	0.2 ± 0.0	63 ± 3	5.3 ± 0.4	5.8 ± 4.6E-07	2.2 ± 0.2	0.14 ± 0.01
		10-20	5 ± 1.1	2.8 ± 0.8	0.2 ± 0.1	52 ± 7	5.6 ± 0.5	4.9 ± 6.9E-06	1.0 ± 0.1	0.07 ± 0.01
		20-30	6 ± 1.6	3.7 ± 1.1	0.2 ± 0.1	54 ± 7	5.9 ± 0.7	4.8 ± 9.4E-06	0.8 ± 0.1	0.06 ± 0.01
	NHM	0-10	11 ± 1.5	5.1 ± 0.9	0.3 ± 0.0	69 ± 3	6.5 ± 0.7	5.5 ± 1.1E-06	2.9 ± 0.3	0.22 ± 0.02
		10-20	10 ± 1.8	7 ± 1.5	0.3 ± 0.0	74 ± 5	4.9 ± 0.4	5.8 ± 4.8E-07	1.6 ± 0.2	0.13 ± 0.02
		20-30	11 ± 1.7	8 ± 1.4	0.3 ± 0.0	77 ± 5	4.7 ± 0.5	5.8 ± 6.4E-07	1.3 ± 0.2	0.11 ± 0.02
Medium	EAM	0-10	3.8 ± 0.8	0.8 ± 0.1	0.3 ± 0.0	35 ± 5	9.0 ± 0.6	4.9 ± 4.0E-06	2.6 ± 0.2	0.16 ± 0.01
		10-20	1.1 ± 0.2	0.4 ± 0.0	0.2 ± 0.0	21 ± 3	6.6 ± 0.5	4.5 ± 8.2E-06	1.1 ± 0.1	0.07 ± 0.01
		20-30	0.9 ± 0.1	0.4 ± 0.0	0.2 ± 0.0	23 ± 4	5.3 ± 0.6	4.4 ± 1.3E-05	0.6 ± 0.1	0.05 ± 0.00
	UAM	0-10	3 ± 1.0	0.6 ± 0.1	0.2 ± 0.0	30 ± 5	6.9 ± 0.4	4.9 ± 4.2E-06	2.0 ± 0.2	0.13 ± 0.02
		10-20	1.3 ± 0.4	0.3 ± 0.1	0.1 ± 0.0	22 ± 5	5.8 ± 0.5	4.5 ± 9.6E-06	0.9 ± 0.1	0.06 ± 0.01
		20-30	1.0 ± 0.3	0.3 ± 0.1	0.1 ± 0.0	20 ± 4	6 ± 1.0	4.4 ± 9.0E-06	0.5 ± 0.1	0.05 ± 0.00
	NHM	0-10	2.9 ± 0.4	0.9 ± 0.1	0.4 ± 0.1	31 ± 4	10 ± 1.1	4.7 ± 7.1E-06	2.9 ± 0.2	0.16 ± 0.01
		10-20	1.3 ± 0.5	0.6 ± 0.1	0.2 ± 0.0	21 ± 5	7.2 ± 0.5	4.5 ± 8.6E-06	1.3 ± 0.1	0.08 ± 0.01
		20-30	0.9 ± 0.2	0.5 ± 0.1	0.2 ± 0.0	20 ± 4	6.1 ± 0.5	4.4 ± 8.2E-06	0.9 ± 0.1	0.07 ± 0.01
Low	EAM	0-10	10 ± 3.6	1.5 ± 0.1	0.3 ± 0.0	59 ± 8	7.1 ± 0.9	5.4 ± 1.7E-06	3.5 ± 0.5	0.23 ± 0.03
		10-20	3 ± 1.0	0.6 ± 0.1	0.2 ± 0.0	30 ± 7	7.5 ± 0.7	4.7 ± 5.4E-06	1.3 ± 0.1	0.08 ± 0.01
		20-30	1.6 ± 0.4	0.5 ± 0.1	0.2 ± 0.0	28 ± 6	6.2 ± 0.7	4.6 ± 6.9E-06	0.7 ± 0.1	0.06 ± 0.00
	UAM	0-10	2.7 ± 0.6	0.8 ± 0.1	0.3 ± 0.0	32 ± 5	7.9 ± 0.6	4.7 ± 5.3E-06	2.2 ± 0.3	0.15 ± 0.02
		10-20	1.5 ± 0.4	0.6 ± 0.1	0.2 ± 0.0	25 ± 4	6.3 ± 0.2	4.6 ± 6.0E-06	1.1 ± 0.1	0.08 ± 0.01
		20-30	1.2 ± 0.2	0.7 ± 0.1	0.2 ± 0.0	27 ± 3	5.3 ± 0.1	4.6 ± 4.0E-06	0.5 ± 0.1	0.05 ± 0.00
	NHM	0-10	1.5 ± 0.4	0.5 ± 0.1	0.2 ± 0.0	17 ± 3	9.4 ± 0.7	4.4 ± 8.9E-06	2.5 ± 0.2	0.14 ± 0.01
		10-20	0.7 ± 0.2	0.3 ± 0.1	0.2 ± 0.0	14 ± 2	6.3 ± 0.4	4.5 ± 7.2E-06	1.2 ± 0.1	0.07 ± 0.01
		20-30	0.3 ± 0.1	0.2 ± 0.0	0.2 ± 0.0	11 ± 2	4.8 ± 0.4	4.3 ± 8.2E-06	0.5 ± 0.1	0.05 ± 0.00

Results

(*, **, ***, **** indicate significant differences at α=0.1, 0.05, 0.01, and 0.001 levels, respectively)

- Difference values of soil properties are consistently *lower in UAM sites compared to EAM sites*, indicating an effect of harvest practices on soil nutrients (Figs. 3 – 5). Overall, values are lower for exchangeable Ca*, K* TOC** and TN**. Values are significantly lower across high nutrient status soils (HNS) for exchangeable Ca** and Mg****, K**, TOC**** and TN***. With exception for Mg, lower values are observed for UAM in the 0-10 cm depth across soil types (Ca***, K**, TOC**** and TN***).
- Difference values are also consistently *lower in UAM sites compared to NHM sites*. This result appears to arise from (1) the effect of UAM on nutrient distribution and (2) a high degree of variability in NHM which results in positive difference values between paired samples. Difference values are lower for TOC*** and TN*** overall. Values for Ca***, Mg****, K** and percent base saturation (% BS) are lower in UAM NHS. Exchangeable acidity (EA) and hydrogen ion concentrations (H^+) are lower in UAM LNS (EA**, H^{+**}). Across all UAM soils in the 0-10 depth, EA are consistently lower** compared to NHM.
- Difference values in EAM sites compared to NHM sites show no consistent increasing or decreasing trends.
- Additionally, within the UAM sites, difference values are significantly lower in HNS compared to LNS and medium nutrient status (MNS) soils. This was true for Ca **, Mg **, K *, TOC **, TN ** and % BS* (LNS only).

Conclusions

Forest harvest management is affecting pools of soil nutrients and associated properties in Ozark soils. Although the NHM data reflect the highly variable nature of Ozark soils, consistently lower values in UAM sites compared to EAM and NHM sites indicate a relative depletion of soil nutrients after single tree removal. This is likely due to the difference in slash distribution that occurs in UAM sites. When a single tree is felled in UAM sites, slash is relocated away from the tree stump resulting in a localized zone of nutrient loss. This effect should be minimized as the entire stand is harvested over time. However, nutrients mineralized from slash may not be available around an isolated stump which could result in vegetative growth variations between UAM and EAM.

Acknowledgments

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