TITLE: Yellow Birch in the Southern Appalachians as an Indicator of Climate Change Risk
LOCATION: National and Private Forests in Southern Appalachian Mountains in NC
DURATION: Year 2 of 3 **FUNDING SOURCE:** EM-SRS-Base Plan
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PROJECT OBJECTIVES: (1) Determine relationships between condition of yellow birch trees, associated low-soil-calcium tolerant tree species, and associated soil chemistry (pH, Al/Ca, toxins, etc.) in the Southern Appalachians (SoApps); (2) assess the potential of yellow birch to indicate forested areas susceptible to climate change and other regional stressors (e.g., insects and pathogens, etc.) and increased buildup of wildfire fuels and fuel ladders from high yellow birch mortality; (3) and develop maps of forest areas at highest risk to regional stressors based on condition of yellow birch and associated soil chemistry.
JUSTIFICATION: Yellow birch (*Betula alleghaniensis* Britt.) is a common tree species found from ME to GA, typically at higher elevations on cooler and moisture slopes in the Southern Appalachians (SoApps). This project examines *in-situ* relationships between the condition of yellow birch in SoApps and associated soil chemistry. In the Northeast yellow birch is impacted (e.g., degraded crowns, reduced growth, increased mortality rates of larger dbh trees) by low soil pH and nutrient cations; and high available aluminum (Al) and toxic metals (e.g., lead, zinc, etc.) linked to long-term acidic deposition on soils with low buffer capacity (pers. comm. Wally Shortle[1]). Decades of acidic precipitation, sulfates, nitrates, and toxic metals have also been deposited on Southern Appalachian forests (Fig. 1); acidic soils have also been implicated in the decline of red spruce on high elevation mountain ridges of the SoApps, and with extensive mortality of overstory red spruce in the Northeast (Driscoll and others, 2001). Aerial observations of loose clusters of large, standing dead trees in 2005 were later identified in ground surveys as yellow birch (YB) growing on SoApps slopes below areas with severe red spruce decline. Mineral soil samples (by FIA protocols) taken near 3 large, dead YB from a typical survey site were found to have very low pH ($\leq$3.5), low cation exchange capacity, low soil Ca, Mg, and K, high Al:Ca ratios; and high concentrations of Zn, Pb, and S (Table 1)and other pollutants typically associated with high acid deposition (Mike Amacher[2]). In 2008 an FIA soil report showed large areas of the SoApps were highly acidified (pH<4.0); had low Ca:Al ratios (Fig. 2); and many sites with an overall poorer soil quality index (SQI) based on a number of soil fertility/toxicity factors then many of the Northeast mountain areas where YB, sugar maple, red spruce, and other tree species have been shown to be degraded by soil-calcium depletion,. This study is geographically important because the results will be relevant to yellow birch and other Ca-sensitive tree species in the higher Southern Appalachians and surrounding forests. The biological impact and political implications are significant because it will identify whether yellow birch is an *acid-rain canary* of high-elevation Southern forests; identify areas where soil acidification has weakened a low-calcium intolerant species; and will identify areas where soil acidification is threatening other trees species in these impacted areas. This study has a high probability of successful completion for several reasons: (1) There is available FIA P3 data on soil chemistry (Mike Amacher[2]) and yellow birch condition in the SoApps (Liz LaPoint[3]); (2) recently large, dead yellow birch in SoApps were associated with extremely acidic, calcium-leached soils containing high levels of Al, Pb, and Fe; (3) the PI and collaborators collectively have extensive expertise in conducting regional forest surveys and monitoring, analyses and interpretation of forest trees and soils data, and linking Ca-depleted soils to the condition and mortality of yellow birch and other Ca-sensitive

species; (4) we can evaluate YB and associated soils across a gradient of conditions in the SoApps. .

DESCRIPTION:

a. Background: Acidic deposition and subsequent soil acidification has markedly reduced available soil Ca^{++} in the cation exchange system of the forest floor and upper mineral soils of mountain forests from Maine to Georgia (Amacher and Perry, 2008). Trivalent Al^{+++} is very phytotoxic and becomes available at low pH levels; it replaces the nutrient mono cation K^{+} and divalent cations Ca^{++} and Mg^{++}, and creates destabilizing effects in forest ecosystems (Driscoll et al., 2001; Shortle et al., 2008). Yellow birch, like sugar maple, red spruce, and some other tree species, is a poor re-absorber of within-tree calcium and thus is negatively affected by low concentrations of soil calcium (pers. comm. Wally Shortle[1]). Yellow birch retains Ca in older tissues and is not able to move it to newer growing tissues because it does not have a functioning Ca-resorption system (Fig. 4). Black cherry, oaks, southern beech, and other species, however, can do this and therefore are relatively tolerant of low soil-calcium conditions. Calcium-intolerant species in low soil calcium soils have a high demand for Ca for growth, maintenance, and in the defense of existing wood from infection because the protective *codit* system in roots, stems, and branches has a high Ca demand. These species also have a high demand for photosynthate to actively absorb available Ca from a decreasing soil Ca pool while excluding available Al from an increasing soil Al pool. This greatly increases stress and vulnerability to damage from drought, cold, insect defoliation (e.g., gypsy moth), winter storm injury, root-rots, etc. The decades of substantial increased acid deposition (Figure 3; NADP) has increased the vulnerability of Eastern forests to these stressors. Loss of Ca-exchange capacity in upper mineral soils reduces protection of trees from Al^{+++} buffering conditions and weakens forest ecosystems. This has been documented in the aluminum-induced calcium deficiency syndrome in red spruce. The exchangeable Al:Ca ratios in the 0-4 inch mineral soils from the SoApps near three large, dead yellow birch trees ranged from 6.7 to 788—some of these very high Al:Ca ratios are because of the complete absence of available Ca in the deeper (4-8") layers (Table 1). Similar soil samples near large, dead and significantly-stressed sugar maples (showing recent 2 decades of narrow growth rings) in the Catskills Mts. in NY had much lower Al:Ca ratios ranging from 6 to 10. We expect to see marked differences in overall tree condition between co-occurring Ca-tolerant and Ca-intolerant species at sites with low soil Ca that should not be present at sites where available soil Ca is much higher. Thus the differences in response of Ca-tolerant and Ca-intolerant tree species will help to differentiate whether poor YB tree condition is caused by other stressors than low soil Ca.

b. Methods: Analyze FIA Phase 2 and 3 data on trees, saplings, and seedlings of yellow birch, black cherry, red spruce, sugar maple, and other relevant species and associated soils data for Bailey's ecoregion province M221 (by and across sections M221 A-D. Stratify data by tree species and 3 dbh classes of >15", 12-15", and 8-12". These dbh classes were chosen because larger dbh yellow birch (>15" dbh) often have the strongest response to low soil Ca; and the other dbh classes were based on FIA thresholds for delineating hardwood sawlogs (8-12" dbh) and hardwood sawtimber (> 12"). Other data stratifications will include physiographic (slope, elevation, and aspect) data, topographic (ridge, slope, bench, cove, etc.) data, and other relevant co-variate factors to minimize 'noise' in discerning differences. Differences in crown condition, damage, growth, mortality, sapling vigor, and seedling regeneration among target tree species Ca-tolerant and intolerant) will be compared to associated soil chemistry. We will identify three strata (high, medium, and low yellow) of yellow birch condition from FIA data and conduct 24 surveys per year.for Years 1 and 2 to obtain a robust sample of current yellow birch and associated soil conditions. FIA proocols will be used to assess condition of yellow birch and associated Ca-tolerant and intolerant tree species; and collect 4 mineral soil samples (3 at 0-4 in.; 1 at 4-8 in.); and collect other relevant FIA and basic site data; Each survey site will be monumented for relocation, and GPS'd for GIS analyses. All survey data will be digitized and analyzed using descriptive. multivariate, regression, ordination, and other data analyses to evaluate the relationships of yellow birch and other tree species condition and soil chemistry. We will determine if yellow birch is a good *in situ* indicator of acidified soils with high soil Al/Ca ratios and declining forest condition. GIS maps of increased vulnerability to climate change (Stolte 2001) and other stressors (e.g., air pollution; invasions of exotic plants and pests; and epidemic outbreaks of native insects and pathogens); high potential for decreased water quality and biotic diversity (Shortle and others, 2008); and increased fuel loading and fire risk. Links will ultimately be explored between survey site information and remotely-sensed MODIS data and TOPs models (e.g., GPP, NPP, evapotranspiration, and others), if feasible.

c. Products: Products will include a report to the FHM program; poster presentation at FHM Workgroup meetings; and one or more peer-reviewed journal articles on most interesting results.

d. Progress to Date: Completed competitive-bid contract—awarded to Equinox Environmental. Signed MOU with FIA and obtained true FIA coordinates for all FIA plots in province M221. Acquisition of plot data for M221 from FIADB database (www.fia.fs.fed.us) partially completed. Acquisition of FIA soils data (not yet in FIADB) initiated. Many surveys scheduled for Year 1 will be conducted in Year 2 due to late starting date of contract agreement with Equinox. Conducted initial surveys of yellow birch in So. Apps. (Nantahala NF) in 2009 to refine survey methods for 2010.

d. Schedule of Activities:

2010 (Year 2)

January-March: Revise survey methods based on initial 2009 surveys. Analyze FIA P2/P3 data from M221 province. Identify 50 survey sites from FIA plot and soils data, and information from National Forests (Pisgah, Nantahalia, Cherokee,GWJ).

March-May: GIS survey sites. Obtain owner permission for sampling.

June-August: Sample approximately 50 sites identified in FIA data.

September-October: Digitize all survey data

October-November: Analyze and interpret survey data

December: Write interim report; develop poster for FHM annual meeting

2011 (Year 3)

January-March: Write interim report on survey data;

April-June: Complete soil analyses; combine and analyze soils and survey data

July-September: Write final report; develop journal articles; develop poster for FHM

References

[1]Wally Shortle, Senior Research Plant Pathologist,, Northern Research Station, Durham, NH

[2]Michael Amacher, FIA National Soils co-lead, Rocky Mountain Research Station, Ogden Utah

[3]Elizabeth LaPoint, FIA National Spatial Data Services, Durham, NH

[4]National Atmospheric Deposition Program (NADP) http://nadp.sws.uiuc.edu/

Amacher MA and Perry CH. 2008. Criterion 4. 2010 National Report on Sustainable Forests. In review.

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, K.C. Weathers. 2001. Acid Rain Revisited: Advances in scientific understanding since the passage of the 1970 and 1990 Clean Air Act Amendments. Hubbard Brook Research Foundation. Science Links™ Publication. Vol. 1, no.1. URL: http://www.hubbardbrookfoundation.org/article/view/12940/1/2076/.

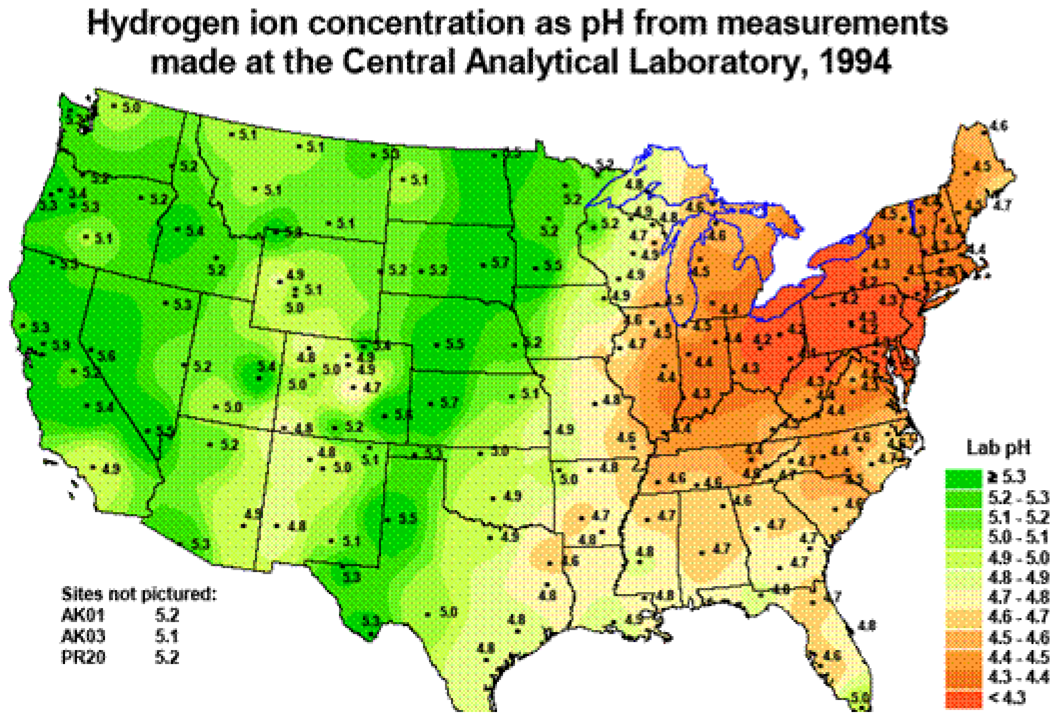
Shortle WC, Murdoch PS, Smith KT, Minocha R, and Lawrence GB. 2008. Monitoring recovery from calcium depletion and nitrogen saturation. In: Murdoch PS, Jenkins JC, and Birdsey RA (eds.). The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative: Foundation Document. Gen. Tech. Rep., NRS-25. New Town Square, PA. USDA Forest Service, Northern Research Station. 93 p.

Shortle WC and Smith KT. 1988. Aluminum-induced calcium deficiency syndrome in declining red spruce. Science. 240(4855): 1017-1018.

Stolte KW. 2001. Forest Health Monitoring and Forest Inventory and Analysis programs monitor climate change effects in forest ecosystems. Human and Ecological Risk Assessment: Vol.7, No. 5, p. 1297-1316.

Budget:

Item **YEAR 2 (FY2010)**	**Requested FHM EM Base Funding**
Administration/Salary	12 field days each for (2) 2-person teams: $20,400.00 YB Survey Data Digitization: $6,240.00 Project Management: $1000.00
Travel: $1392.00 (2 vehicles @ $0.58/mile; average 100 miles roundtrip; 24 survey sites)	
Equipment/Materials: $302.00	
Contracting & Collaboration	SRS-RWU4854 (Travel & Technical): $3000
Soil Analyses: $3648.00 (24 sites X 4 reps/site; three 0-4 in. soil sample per site & one 4-8 in. sample per site=96 samples) X $50/sample = $4800.00	
Total $36,832.00	
Source of In-Kind Support: RMRS-FIA Soils; SRS-EFETAC; NRS-FIA Soils & Plant Pathologist	



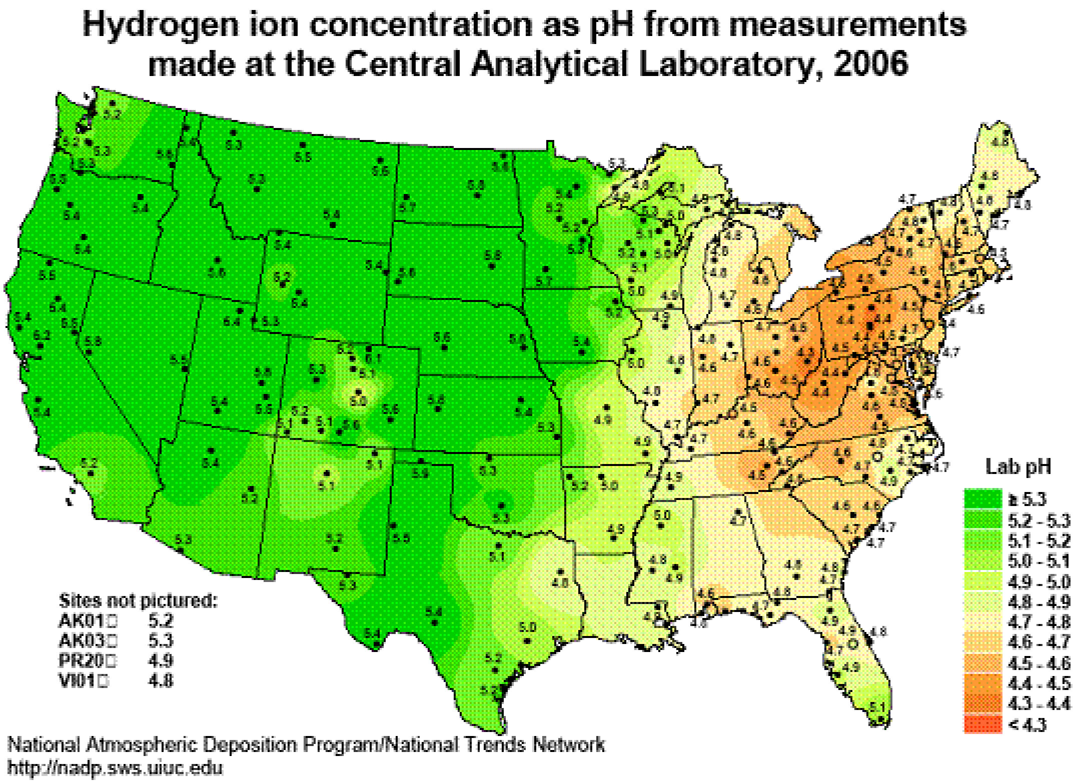


Figure 1. Acidic deposition in the U.S. in 1994 and 2006 Note that even though precipitation acidity has decreased significantly from 1994 to 2006, much of the Eastern U.S. still receives highly acidic precipitation.

Source: National Atmospheric Deposition Network, 2008. http://nadp.sws.uiuc.edu

Table 1. Analysis of 3 soil samples (2 depths each: 0-4”; 4-8”) collected in Southern Appalachian forests at site with scattered, large, dead yellow birch trees. Samples collected using FIA protocols and analyzed by FIA soil co-lead.

			Exchangeable cations (mg/kg)					Trace elements (mg/kg)							
Sample Tree ID (U=0-4”) (L=4-8”)	Soil pH (H_2O)	ECEC cmolc/ kg	K	Mg	Ca	Al	Al/Ca	Mn	Fe	Ni	Cu	Zn	Cd	Pb	S
181(U)	3.37	11.1	70	66	129	870	6.7	11.5	155.0	0.4	0.0	6.3	0.1	5.6	72.3
181 (L)	3.81	7.1	38	0	0	627	627	4.4	55.1	0.1	0.0	0.1	0.0	1.3	32.2
88 (U)	3.59	9.5	53	16	5	819	163.8	4.8	107.2	0.3	0.0	0.8	0.0	4.2	65.0
88 (L)	3.82	7.3	36	6	8	634	79.3	4.1	55.4	0.0	0.0	1.3	0.0	1.6	32.7
186 (U)	3.45	9.6	50	33	38	806	21.2	4.9	175.4	0.2	0.0	2.7	0.1	7.9	69.8
186 (L)	3.71	8.9	31	2	0	788	788	3.5	66.3	0.1	0.0	0.4	0.0	1.3	31.4

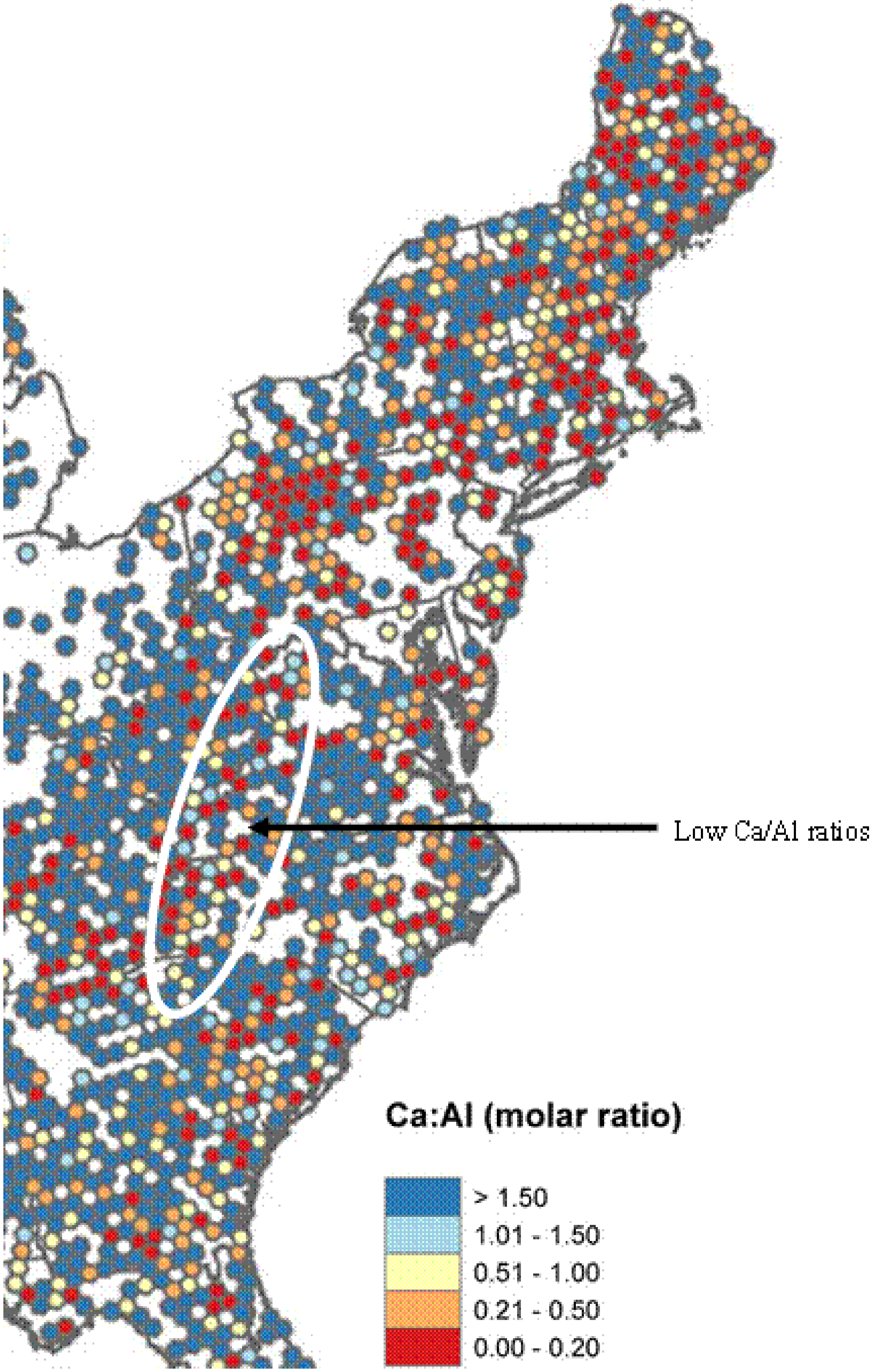


Fig.2. Spatial distribution of exchangeable Ca:Al molar ratios at 0-4 inch soil depth by EMAP/FIA hexagon in 2000-2004. Source: Adapted from Amacher and Perry, 2008. US Forest Service, Forest Inventory and Analysis Soil Indicator,. Geographic base data provided by the National Atlas of the USA. EMAP hexagons provided by the US EPA. Map prepared by Charles H Perry, USFS-NRS.

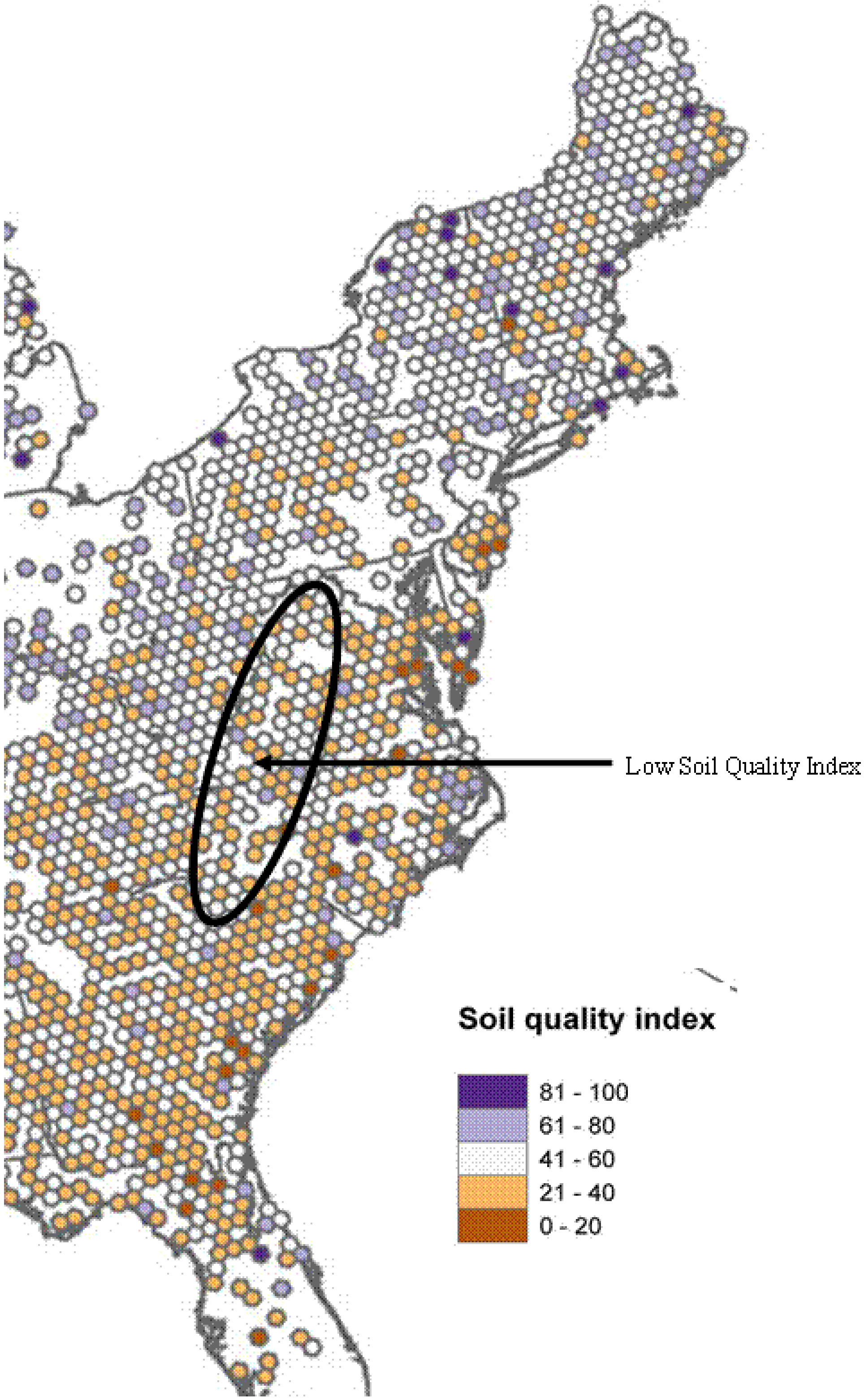


Fig.3. Spatial distribution of Soil Quality Index QI by EMAP hexagon and 0-4 inch soil depth from 2000-2004 data. Source: Adapted from Amacher and Perry. 2008. US Forest Service, Forest Inventory and Analysis Soil Indicator, draft 2010 National Report on Sustainable Forest. Geographic base data provided by the National Atlas of the USA. EMAP hexagons provided by the US EPA. Map prepared by Charles H Perry, USFS-NRS.

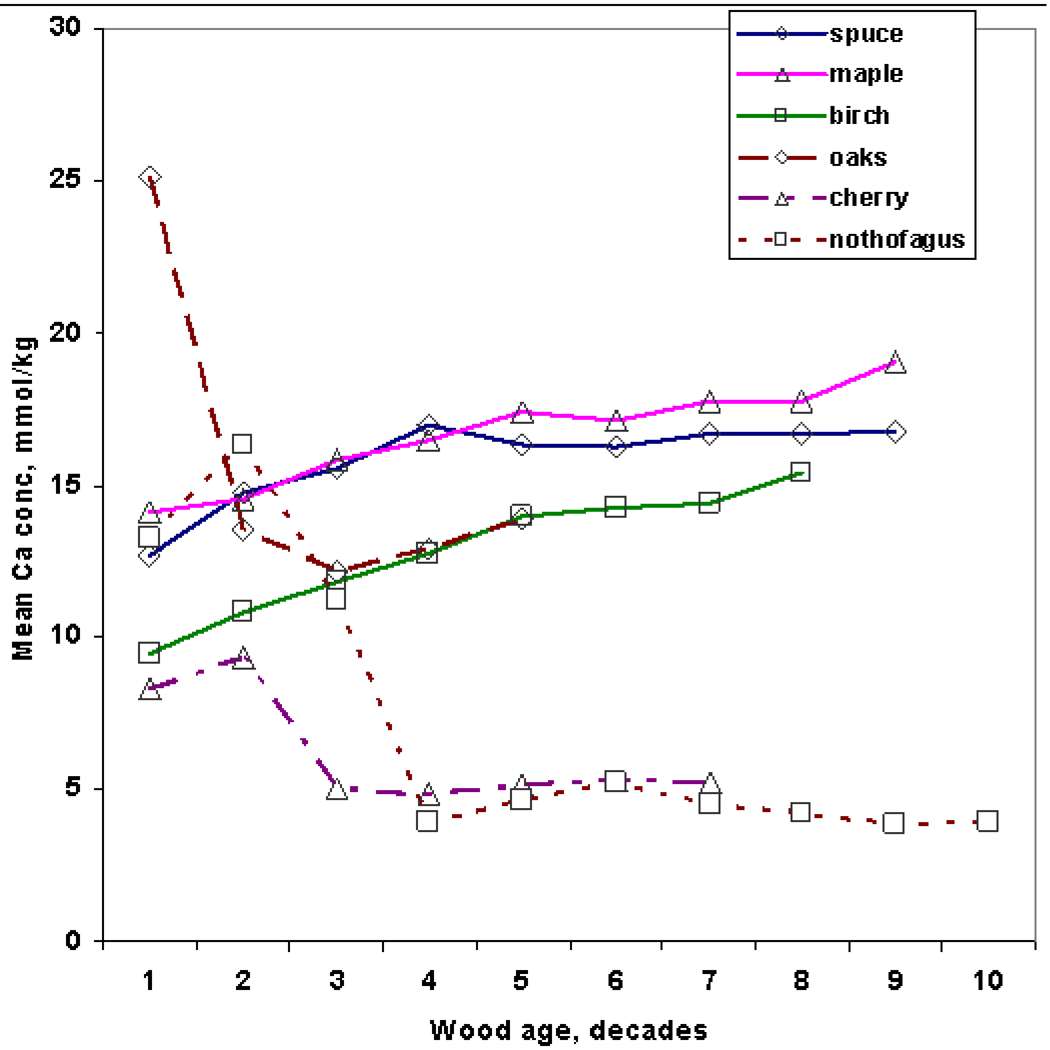


Figure 4. Radial patterns of six tree species - red spruce from the Adirondacks, NY and White Mountains, NH (26 trees); sugar maple from the Catskills, NY (14 trees); yellow birch from the Catskills, NY (11 trees); red and white oaks, a composite of 4 species, 2 trees of each species from Ohio (8 trees); black cherry from the Catskills, NY (5 trees); and Nothofagus pumilio from Chilean Tierra del Fuego (6 trees). Spruce, maple and birch retain Ca as their wood ages; whereas, oak, cherry, and Nothofagus recover Ca. It is likely that Ca-retaining species are less tolerant of Ca depletion and Al mobilization associated with acid deposition than Ca-recovering species. Large mature sugar maple and yellow birch die in places where acid deposition is high, while associated black cherry thrives. Source: Wally Shortle, USDA Forest Service, Northern Research Station.