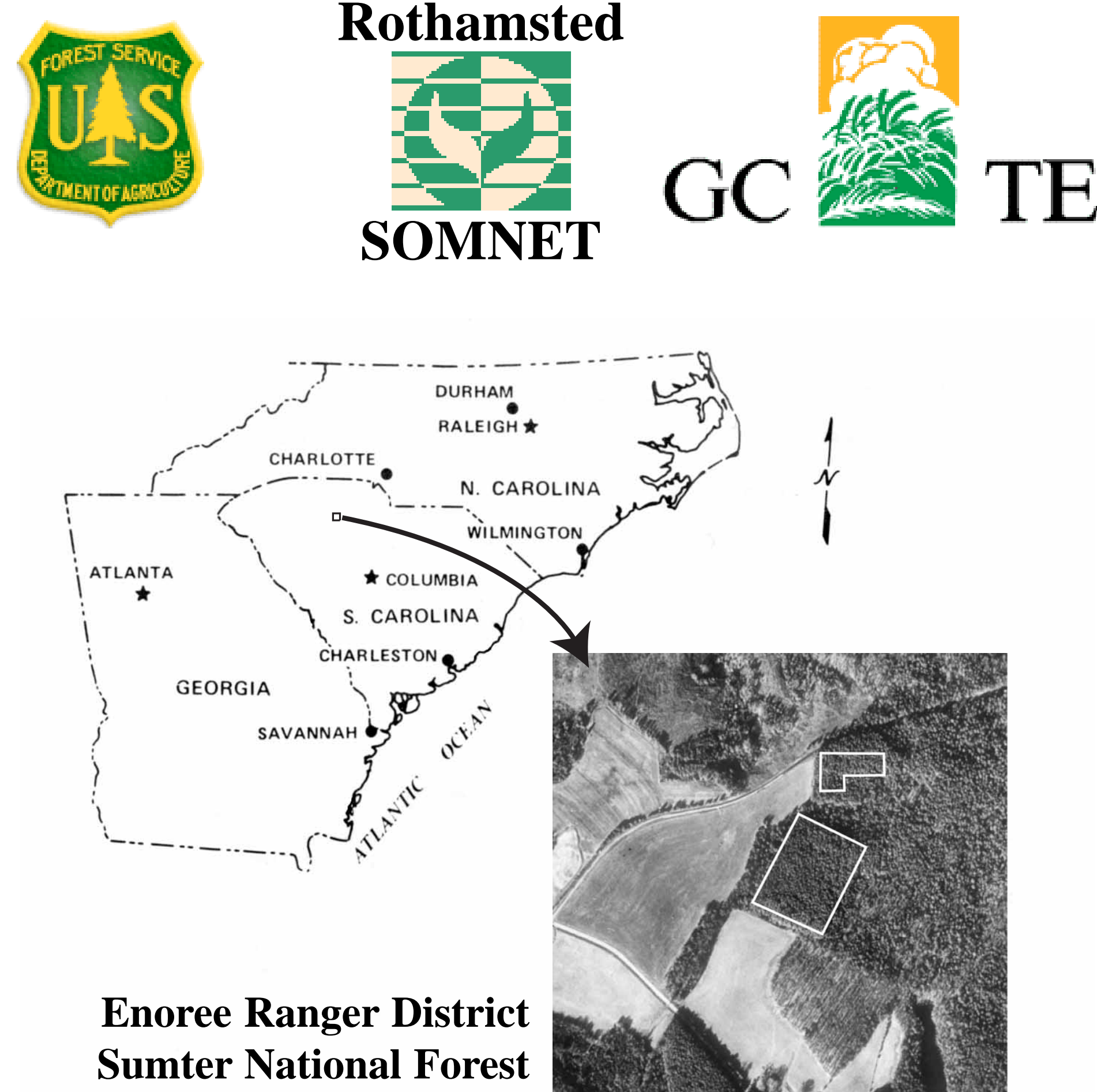


# Five Tales from the Calhoun and a Proposal for a Network of Soil-Ecosystem Experiments

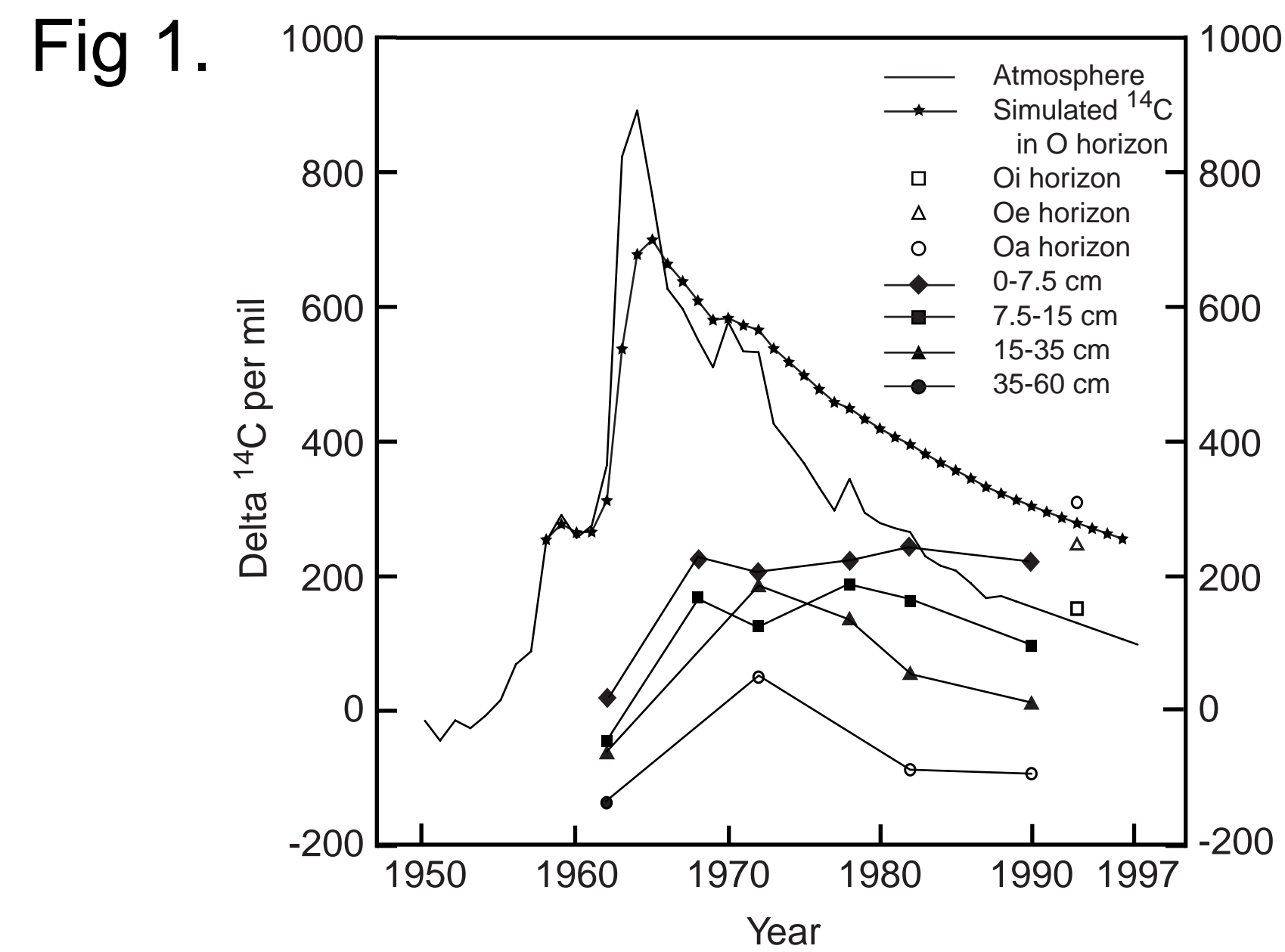
D.D. Richter<sup>1</sup>, M. Hofmockel<sup>1</sup>, and D. Markewitz<sup>2</sup>  
 1 Duke University, 2 University of Georgia, USDA Forest Service

## USFS Calhoun Exp. Forest



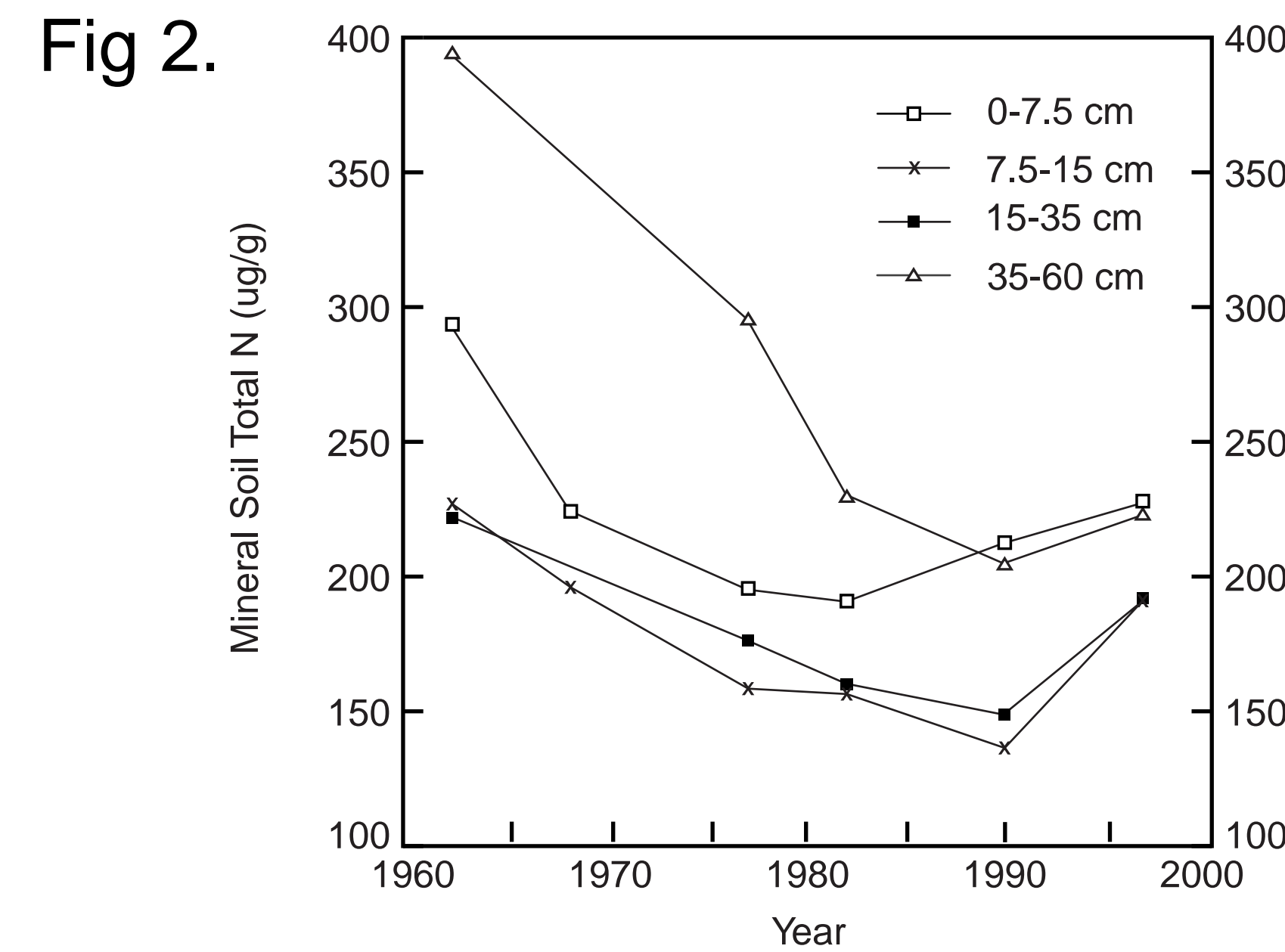
- In 1957, two old fields planted with pine seedlings in 16 plots
- Soils sampled during forest growth: 1962, 68, 72, 78, 82, 90, 97
- Intensive within-plot sampling and all soils archived

## C Sequestration



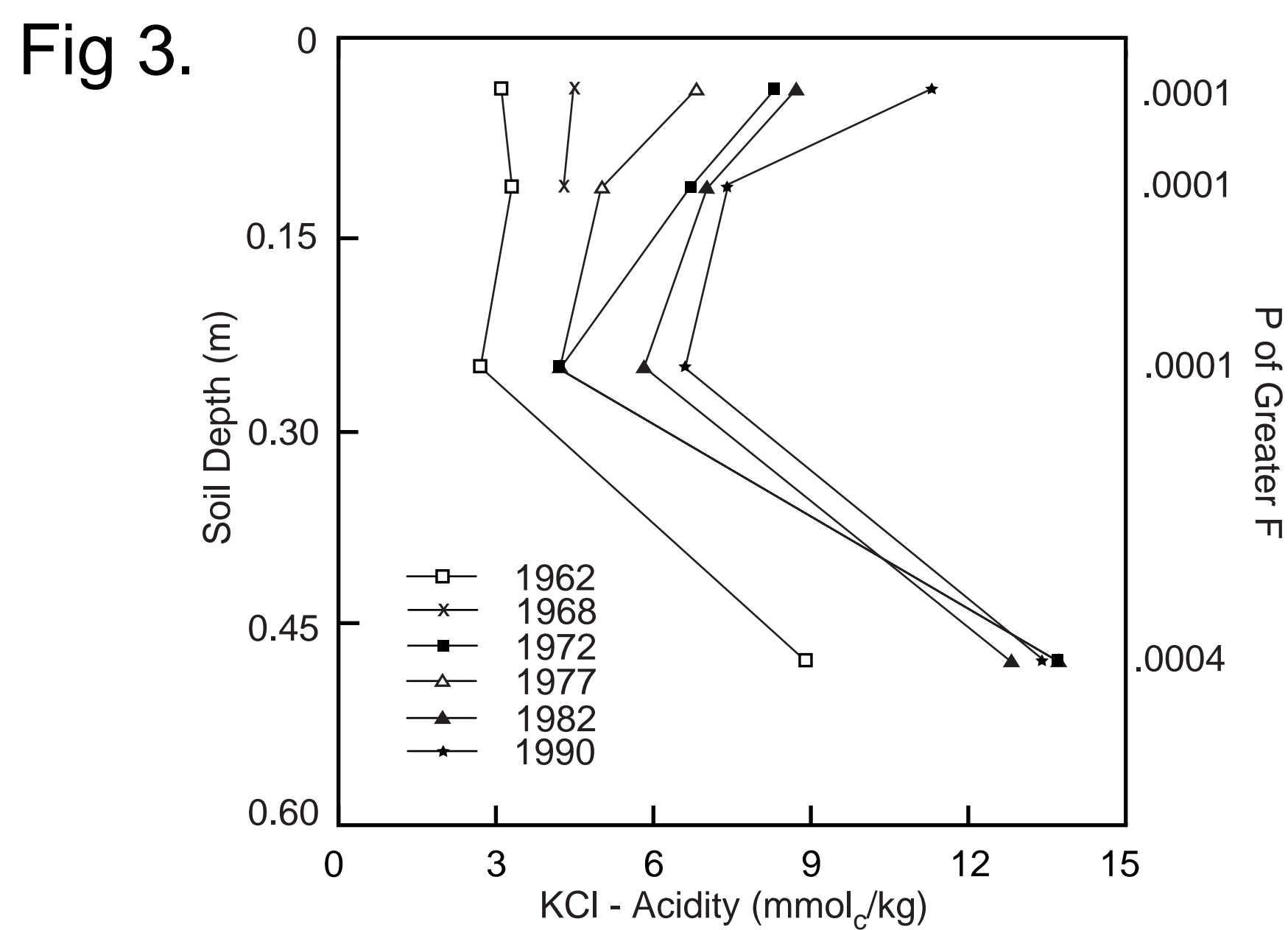
C sequestration in the Calhoun forest totaled 165 Mg ha<sup>-1</sup> (CV = 7.2% among eight plots) over four decades, 61 Mg ha<sup>-1</sup> of which was belowground C in roots, forest floor and mineral-soil OM. Biomass C amounted to 75% of the total accretion, 25% was in the forest floor, and less than 1% was in new mineral-soil OM. Rates of decomposition were high in the coarse sandy loam A and E horizons, limiting SOM accumulation despite high C inputs. Despite modest accumulations of SOC, bomb <sup>14</sup>C rapidly labeled mineral soil organic matter even at 35 to 60-cm depth (Fig. 1). Delta <sup>14</sup>C has remained elevated in Oa and upper A horizons. [Richter et al. 1999]

## N Uptake & Depletion



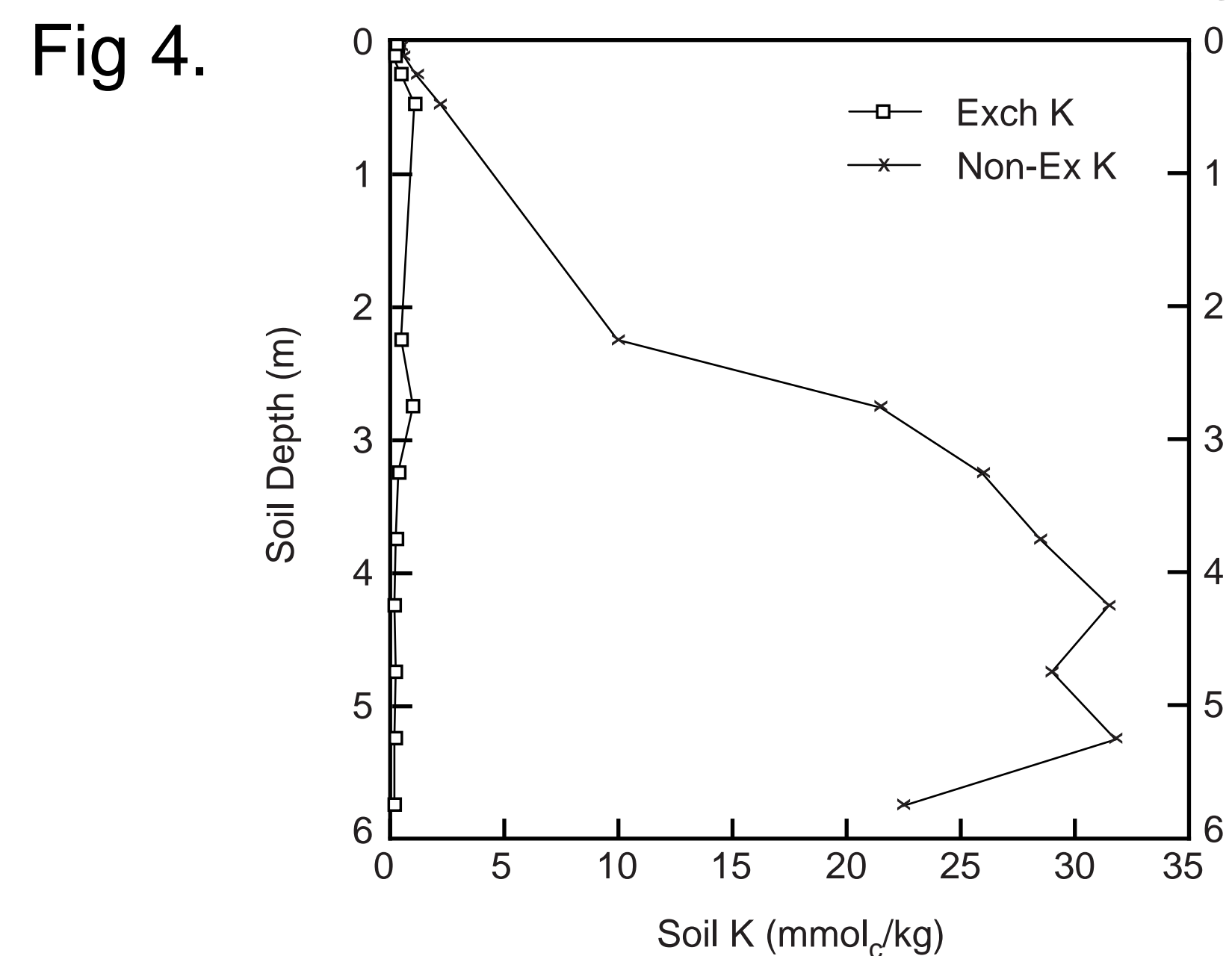
Soil N was depleted substantially over four decades (Fig. 2) as tree biomass and forest floor rapidly accumulated >1100 kg ha<sup>-1</sup> of N. The ecosystem was a strong N sink with insignificant N leaching loss; trees have grown into N deficiency with low N mineralization in the forest floor. Ecosystem accretion of N (plants plus soil) was estimated to be 205 kg ha<sup>-1</sup> over the four decades, significantly different from 0 at a p<0.07. This N accretion amounted to 5.9 kg ha<sup>-1</sup> y<sup>-1</sup>, in the same range as atmospheric N deposition. There was little indication of "occult N." [Richter et al. 2000]

## Acidification



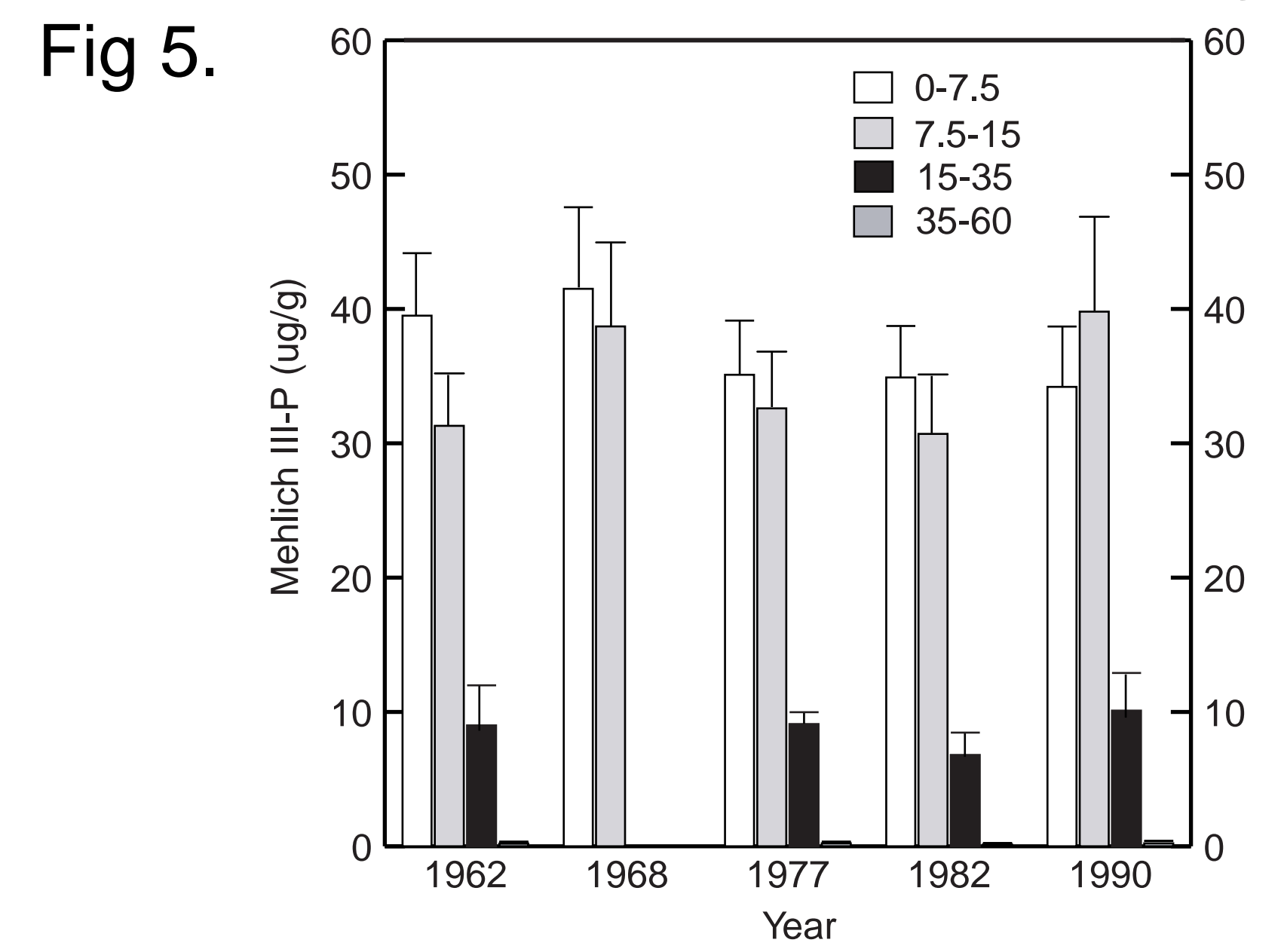
Decreases in pH have been prominent during growth of the Calhoun forest. Between 1962 and 1990, exchangeable Ca decreased by about 1.25 kmolc ha<sup>-1</sup> y<sup>-1</sup> in the upper 0.6-m soil, and exchangeable acidity accumulated at about 1.33 kmolc ha<sup>-1</sup> y<sup>-1</sup> (Fig. 3). The Calhoun Ultisol is readjusting to a pre-agricultural acidic state due to: suspension of lime inputs, growth of the forest, and atmospheric deposition. Atmospheric deposition contributed 40% of the acidification in the upper 60-cm soil. Acidification from the atmosphere translocates sulfate and cations from surface soils to sub-soils where the ions are adsorbed rather than leached from the ecosystem. [Markewitz et al. 1998]

## K Uptake & Re-supply



Soil K removals (K accumulations in forest biomass and forest floor plus leaching loss), exceeded depletions of exchangeable K by 20-fold in the surficial 60-cm over 28-years of forest development. Weathering resupply buffered exchangeable K, and K-bearing minerals including muscovite micas were identified by XRD in mineral soils. Non-exchangeable K (Fig. 4) was demonstrated by greenhouse studies and chemical analyses to release bioavailable K. [Markewitz et al. 1998]

## P Uptake & Re-Supply

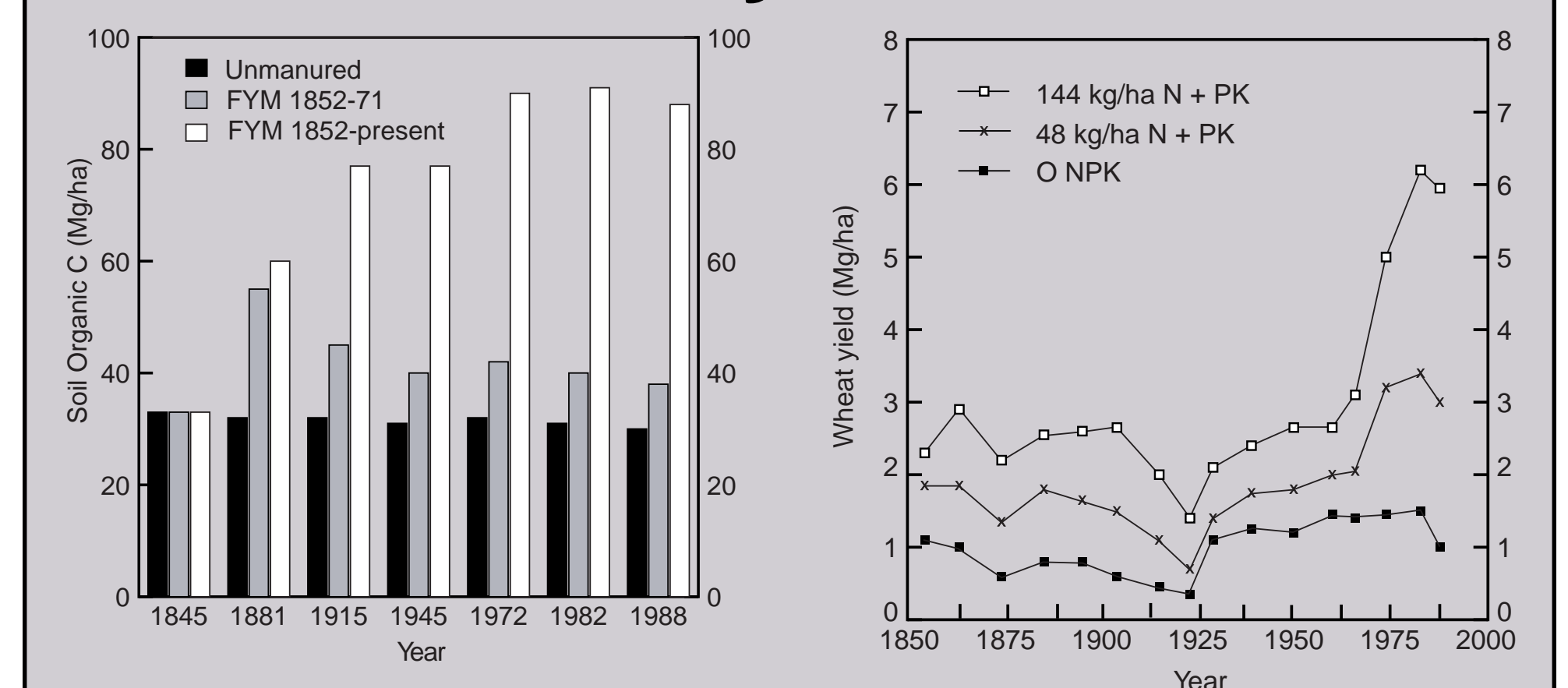


When the site was under cotton (pre-1955), P fertilization increased labile and recalcitrant fractions of soil P. During growth of the forest, labile fractions of soil P remained elevated, as indexed by resin-extractable, bicarbonate, and Mehlich P (Fig. 5). Significant decreases were detected, however, in more recalcitrant Ca-associated P (49 kg ha<sup>-1</sup>) and NaOH-organic P (23 kg ha<sup>-1</sup>). Ca-associated P and organic P, elevated under cotton by fertilization and liming, appear to be supplying both plant uptake and readily available P fractions in soil (Fig. 5). The transfer of mineral-soil P to plants and forest floor totaled 82 kg ha<sup>-1</sup>. [Richter and Markewitz 2000]

## The Soil-Network Rational:

- Soil is being used at a geographic scale never before attempted.
- Few studies can observe soil change, and most of these are of agricultural soils with high native fertility
- A network of soil studies is vital to quantifying soil change and ensuring soil management in the foreseeable future

## Rothamsted: The Wellspring of Soil-Ecosystem Studies



## Invaluable Soil-Ecosystem Studies

Ecosystem	Location	Origin	Reference
Winter wheat, Alfisol	Broadbalk, Rothamsted	1843	Jenkinson 1991
Hayfield, Alfisol	Park Grass, Rothamsted	1856	Tilman et al. 1994
Crop rotations, Inceptisol	Askov Exp. Sta., DENMARK	1893	Christensen et al. 1994
Cotton rotation, Ultisol	Old Rotation, AL, USA	1896	Mitchell et al. 1996
Wheat rotation, Alfisol	Bretton Plots, Alberta, CANADA	1930	McGill et al. 1986
Loblolly pine forest, Ultisol	Calhoun Exp. Forest, SC, USA	1957	Wells & Jorgensen 1975
Com, Mollisol	Arlington Plots, WI, USA	1958	Vanotii & Bundy 1995
Legume-cereal, Vertisol	Tamworth, NSW, AUSTRALIA	1966	Holford 1981
Millet-rotation, Inceptisol	Haryana, Hisar, INDIA	1967	Gupta et al. 1992
Hardwood forest, Ultisol	Coweeta Hydro Lab, USA	1970	Knoepp & Swank 1994

## The Proposed Soil-Ecosystem Network:

- Sites located in different biomes with contrasting soil textures, mineralogies, climates, and land uses
- Archived soil and plant-tissue samples
- Whole-ecosystem studies with targeted process studies
- Observations of LT soil change will be critical to ecosystem-simulation models

# **Five Tales from the Calhoun and a Proposal for a Network of Soil-Ecosystem Experiments**

**D.D. Richter<sup>1</sup>, M. Hofmockel<sup>1</sup>, and D. Markewitz<sup>2</sup>**

**1 Duke University, 2 University of Georgia, USDA Forest Service**

**Is available for download as a \*PDF file from <ftp://sedimentary.env.duke.edu/pub/Calhoun/LTER00.pdf>**

**Other Calhoun information, Posters and Data are available at**

**The Forest, Soil and Water Lab @ Duke University (<http://sedimentary.env.duke.edu>)**

## **References**

- Anderson, D.W. 1991. Long-term ecological research: A pedological perspective. pp. 115-134. In P. G. Risser (ed.). *Long-term Ecological Research*. Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (IUCN). Wiley, New York.
- Christensen, B.T., J. Petersen, V. Kjellerup, and U. Trentemøller. 1994. The Askov long-term experiments on animal manure and mineral fertilizers: 1894-1994. SP Report 43, Danish Inst. of Plant and Soil Science. Skovbrynet, Lyngby.
- Clements, F.E. 1916. *Plant Succession*. Carnegie Institution of Washington, Publication No. 242, Washington, D.C.
- Gupta, A.P., R.P. Narwal, R.S. Antil, and S. Dev. 1992. Sustaining soil fertility with organic-C, N, P, and K by using farmyard manure and fertility-N in a semiarid zone: a long-term study. *Arid Soil Research and Rehabilitation* 6: 243-251.
- Holford, I.C.R. 1981. Changes in nitrogen and organic carbon of wheat-growing soils after various periods of grazed lucerne, extended fallowing and continuous wheat. *Australian Journal of Soil Research* 31: 239-249.
- Jenkinson, D.S. 1991. The Rothamsted classical experiments: Are they still of use? *Agronomy Journal* 83: 2-10.
- Knoepp, J.D. and W.T. Swank. 1994. Long-term soil chemical changes in aggrading forest ecosystems. *Soil Science Society of America Journal* 58: 325-331.
- Markewitz, D., D.D. Richter, H.L. Allen, J. B. Urrego. 1998. Three decades of observed soil acidification at the Calhoun Experimental Forest: Has acid rain made a difference? *Soil Science Society of America Journal* 62: 1428-1439
- Mitchell, C.C., F.J. Arriaga, J.A. Entry, J.L. Novak, W.R. Goodman, D.W. Reeves, M.W. Runge, and G.J. Traxler. 1996. *The Old Rotation*. Auburn University Agricultural Experiment Station, Alabama, USA.
- Richter, D.D. and D. Markewitz. 2000. *Understanding Soil Change*. Cambridge Univ. Press, UK.
- Richter, D.D., D. Markewitz, C.G. Wells, H.L. Allen, R. April, P. Heine, and B. Urrego. 1994. Soil chemical change during three decades in an old-field loblolly pine (*Pinus taeda* L.) ecosystem. *Ecology* 75:1463-73.
- Richter, D.D., D. Markewitz, S.A. Trumbore, and C.G. Wells. 1999. Rapid accumulation and turnover of soil carbon in a re-establishing forest. *Nature* 400:56-58.
- Richter, D.D., D. Markewitz, P.R. Heine, V. Jin, J. Raikes, K. Tian, and C.G. Wells. 2000. Legacies of agriculture and forest regrowth in the nitrogen of old-field soils. *Forest Ecology and Management* (in press).
- Switzer, G.L. and L.E. Nelson. 1972. Nutrient accumulation and cycling in loblolly pine (*Pinus taeda* L.) plantation ecosystems: the first twenty years. *Soil Science Society of America Proceedings* 36: 143-147.
- Tilman, D., M.E. Dodd, J. Silvertown, P.R. Poulton, A.E. Johnston, and M.J. Crawley. 1994. The Park Grass experiment: insights from the most long-term ecological study. pp. 287-303. In R.A. Leigh and A.E. Johnston (eds.). *Long-term Experiments in Agricultural and Ecological Sciences*. CAB International, Oxon, UK.
- Vanotti, M.B. and L.G. Bundy. 1995. Soil organic matter dynamics in the North American corn belt: The Arlington plots. pp. 409-418. In D. Powlson, P. Smith, and I. Smith. (Eds.) *Evaluation of Soil Organic Matter Models*. NATO Advanced Science Series, Springer-Verlag, Berlin.
- Wells, C.G. and J.R. Jorgensen. 1975. Nutrient cycling in loblolly pine plantations. pp. 137-158. In B. Bernier and C.H. Winget (ed.). *Forest Soils and Forest Land Management*, Fourth North American forest soils conference. Laval Univ. Press, Quebec, Canada.

**\*PDF files can be read with the Free Adobe Acrobat Reader available at <http://www.adobe.com/products/acrobat/readstep.html>**