Tracking forest soil health: 25 years of soil monitoring by the U.S. Forest Inventory and Analysis program

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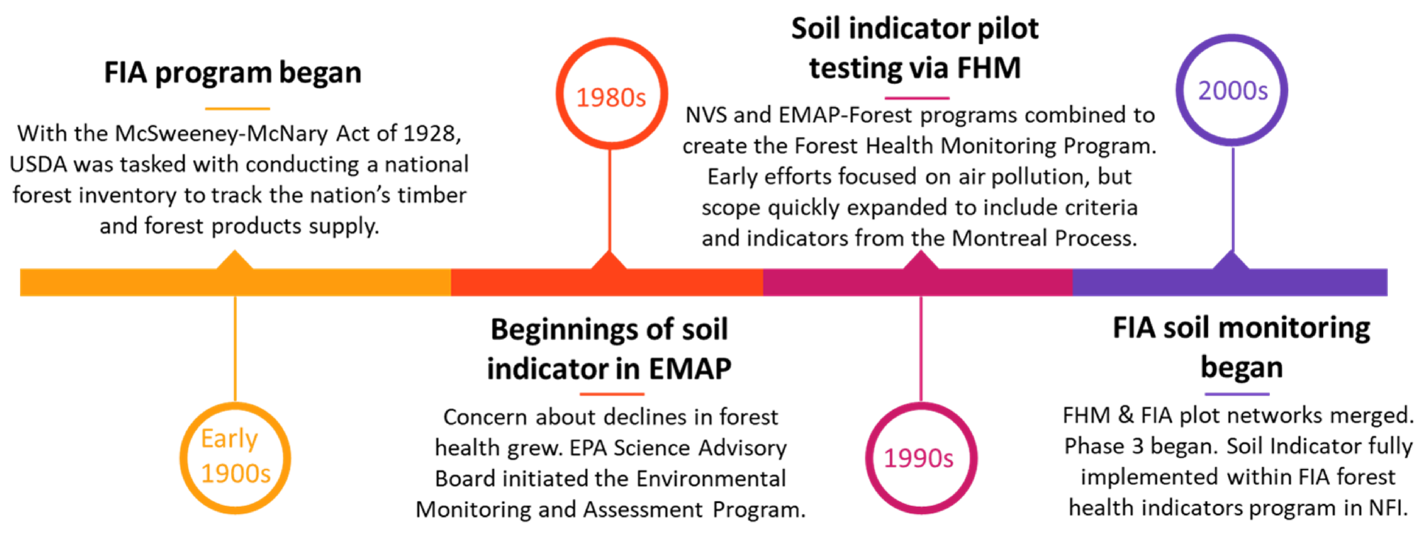
Program History

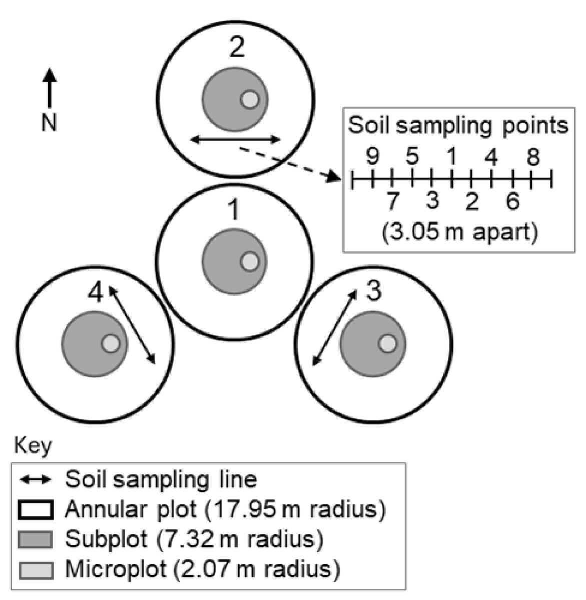


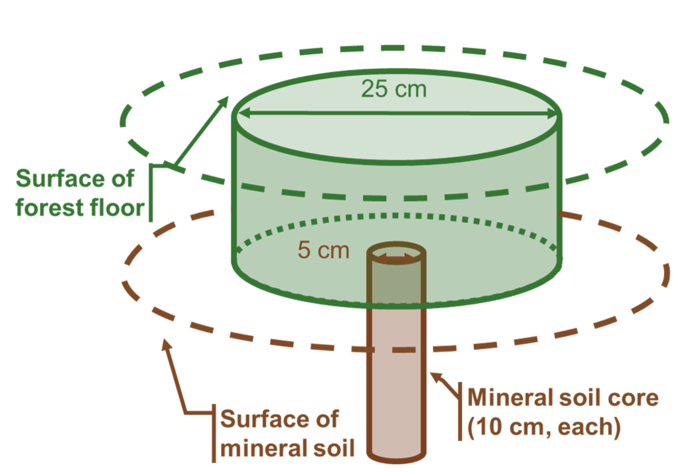
Overview and Design

The FIA National Forest Inventory (NFI) is based on a grid of 2,428-ha hexagons covering the U.S., with one permanent plot in each hexagon, creating an equal-probability sample of the nation's forested lands. The soil monitoring component uses a national set of core protocols to monitor a suite of chemical and physical properties while allowing regional flexibility in soil sampling intensity to accommodate budgets and priorities. For example, the Northern Research Station (NRS) samples alternating 1/16 subsets of NFI plots (totaling 1/8 overall), while other stations vary from full-coverage approaches to limited regional sampling.

Chemical Properties
- % C, % N
- pH
- Extractable P
- Effective cation exchange capacity
- Exchangeable Na, K, Mg, Ca, Al, Mn, Fe, Ni, Cu, Zn, Cd, Pb, S

Physical Properties
- Litter & forest floor thickness
- Bulk density
- Coarse fraction %
- Soil weights (field, air-dry, oven-dry)
- Water content %
- Soil texture
- Depth to restriction
- Bare soil %
- Soil compaction % and type



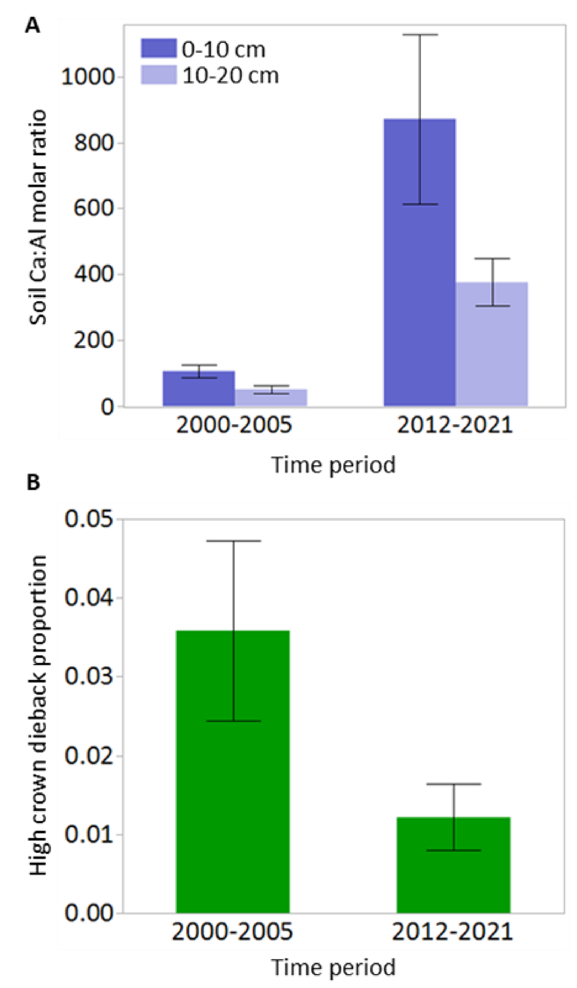


- Forest floor (i.e., combined litter and duff) samples collected adjacent to subplots 2, 3, and 4
- Mineral soil (0-10 and 10-20 cm) samples collected adjacent to subplot 2
- First sample collected at soil sampling site 1, with subsequent samples in following years taken from alternating positions on opposite sides of the initial sampling point

Diverse Applications: Case Study Examples

Pairing aboveground and belowground data to assess forest health

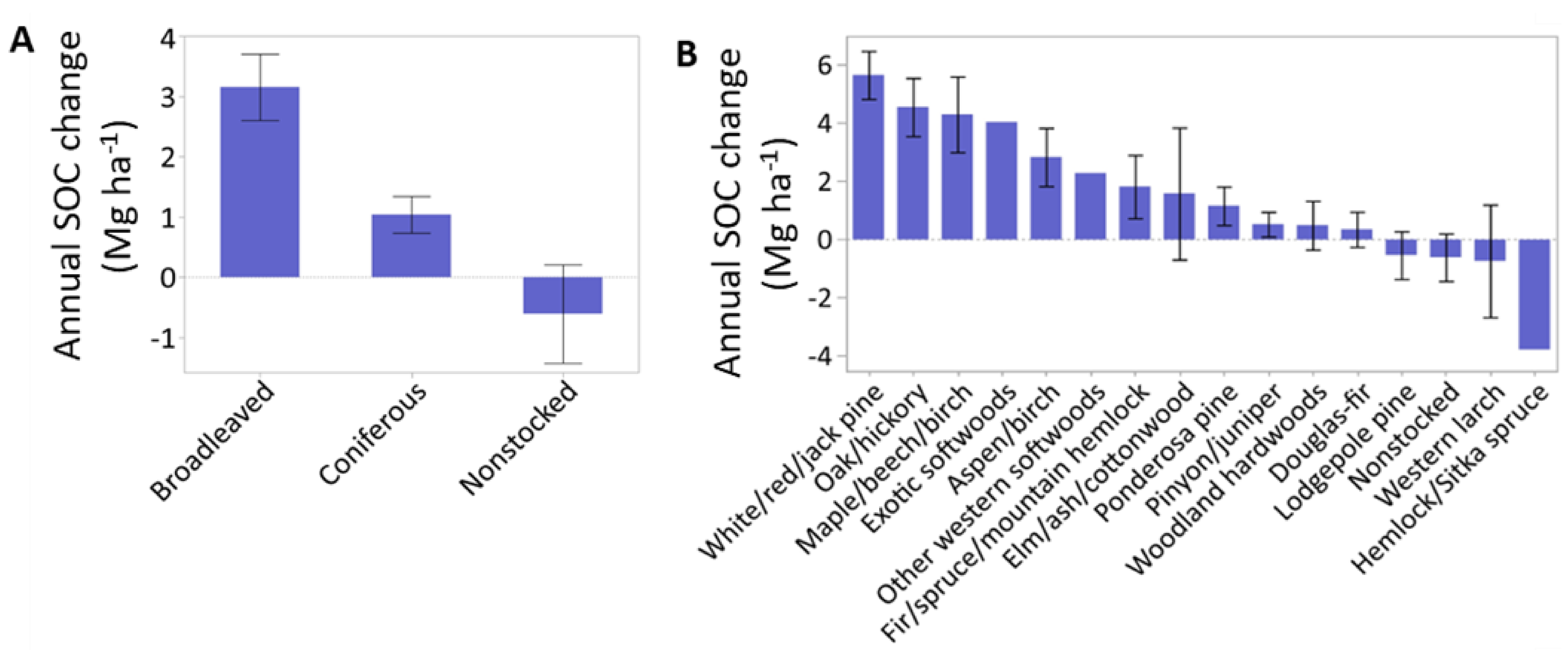
Figure 1: Sugar maple dieback and soil Ca:Al ratios



- NY, PA, WV, and OH experienced strong deposition of sulfur dioxide and nitrogen oxides during the early 2000s, which has since improved[2].
- Soil Ca:Al increased from the early 2000s period (2000-2005) to the later period (2012-2021) by 7x at a depth of 0-10 cm and by 6x at a depth of 10-20 cm (Fig. 1a), while the proportion of sugar maple crowns with high (>15%) crown dieback declined by 67% (Fig. 1b)[1].
- Increases in soil Ca:Al were due to both declines in Al and increases in Ca over time. Specifically, the average annual rate of change in soil exchangeable Al was -4.9 mg kg^{-1} y^{-1} at 0-10 cm and -3.8 mg kg^{-1} y^{-1} at 10-20 cm. For soil exchangeable Ca, the average annual rate of change was +18.9 mg kg^{-1} y^{-1} at 0-10 cm and +11.4 mg kg^{-1} y^{-1} at 10-20 cm[1].

Exploring temporal soil dynamics using direct field measurements

Figure 2: Changes in soil organic carbon over time and across forest types



- In plots across the U.S. with soil data available from two measurement times, soil organic carbon (SOC) increased by 1.9 ± 0.3 Mg ha^{-1} per year on average[1].
- Mean annual SOC gains were 4x greater in deciduous dominated plots compared to coniferous dominated plots (Fig. 2), possibly because coniferous forests may be more prone to fire and pest outbreaks[1].

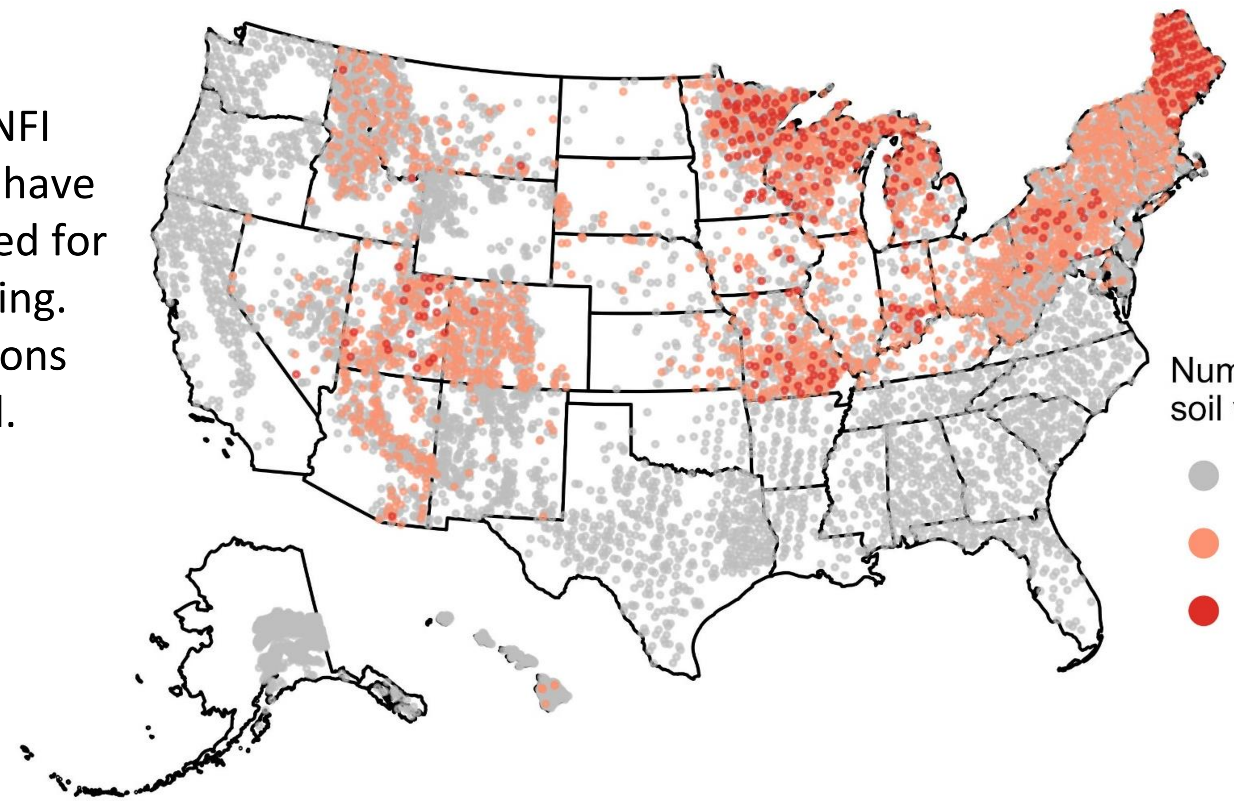
Interested in carbon? Check these papers out…

New frameworks for estimating soil carbon stocks across the U.S. were developed with NFI and International Soil Carbon Network data[3,4,5]. These new methods resulted in a 44% decrease (-2 Pg) in estimates of forest floor carbon stocks[3] and a 65% increase (+11 Pg) in estimates of mineral soil organic carbon stocks (to a depth of 100 cm)[4] on U.S. forestlands. New calculation methods may further refine these estimates[6].

Data Availability and Status

About 10,000 forested NFI plots have been sampled for soil analyses nationwide (Fig. 3), representing about 7% of NFI base plots containing forestland. The number of plots with 2+ soil visits is rapidly growing in the NRS and RMRS regions, but soil remeasurements are scarce in the SRS and contiguous PNWRS regions, where soils are not currently being sampled (Table 1).

Figure 3. NFI plots that have been visited for soil sampling. Plot locations are fuzzed.



	NRS	RMRS	SRS	PNWRS-Contiguous	PNWRS-Coastal Alaska	PNWRS-Interior Alaska	PNWRS-Hawai'i
Visits	2000-2005, 2012-2024	2000-2024	2003-2006, 2009-2010	2001, 2003-2008	2008-2010	2014, 2016-2024	2011-2012, 2019-2022
Lab	2000-2005, 2012-2021	2000-2010, 2012-2023	2003-2006	2001, 2003-2006, 2008	2008-2010	2014, 2016-2020	2011, 2019-2022
Field-General	2000-2005, 2012-2023	2000-2023	2003-2006, 2009-2010	2001, 2003-2008	2008-2010	2014, 2016-2020	2011-2012, 2019-2022
Field-Erosion	2000-2005, 2012-2023	2000-2023	2003-2006, 2009-2010	2001, 2003-2008	2008-2010	NA	NA

Table 1. Summary of measurement years with plot visits for soil sampling and lab or field data availability.

Potential Future Advances

- Full national implementation of soil sampling
- Increase soil sampling intensity of NFI plots
- Increase number of mineral soil cores extracted per plot to a minimum of 3 cores
- Increase depth of mineral soil core sampling to a minimum of 30 cm
- Separately analyze litter and duff layers
- Use advanced soil texture analyses
- Characterize soil microbial communities
- We'd love to hear your ideas!

Acknowledgments

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