Estimates of Storage, Sequestration, Harvest-Related Removals and Transport-Related Emissions of Carbon in the Nash Stream Forest, 1997 to 2024

FEMC State Sprint Project: Carbon Inventory for Nash Stream Forest, NH

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Forest Ecosystem Monitoring Cooperative
South Burlington, VT, USA
femc@uvm.edu
(802) 656-2975
Authors: Soren Donisvitch, Alison Adams, Larissa Robinov (NH DNCR), Elissa Schuett

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Table of Contents

Key Findings

In comparing the various forest inventory and growth datasets available for Nash Stream Forest, no single source provides a complete picture on its own, but the combination of CFI plots, annual scale slip, summary harvest removal data, FIA calibration data, and FVS modeling produces a sturdy estimate of both carbon stocks and annual sequestration for the property as a whole.

Across harvests conducted between 1997 and 2024, an average of 66.3 acres were treated per year (1,856 total acres) over the 28-year period. This level of activity corresponds to average annual carbon removals of 2,561 ± 413 Mg C yr^{-1}, or about one-tenth of the forest's modeled live-tree carbon sequestration rate. When combined with approximately 21 Mg C yr^{-1} in transport emissions, total annual removals remain far below modeled sequestration.

At current harvest intensities, sequestration in unharvested forest, approximately 38,241 acres in 2024, exceeds the carbon removed in harvested wood products by nearly an order of magnitude. Depending on the growth model (CFI or FIA+CFI), unharvested stands are estimated to sequester 24,990-25,239 Mg C yr^{-1} of total live-tree carbon, producing offset ratios of roughly 9.9:1 (full model range 8.3-11.4:1) under baseline conditions.

Across the full 1997-2024 record, combined harvest removals (2,561 Mg C yr^{-1}) and log-haul transport emissions (~21 Mg C yr^{-1}) total approximately 2,582 Mg C yr^{-1}, equal to ~9.8-9.9% of modeled whole-forest live-tree sequestration (26,100-26,400 Mg C yr^{-1}). Even in the heaviest harvest year (2022), total removals, including transport, were less than 27% of modeled growth on the remainder of the property.

Taken together, these findings indicate that Nash Stream Forest remains a strong and persistent net carbon sink under current management, a stable sequestration surplus that outweighs annual harvest-related carbon losses.

Executive Summary

Nash Stream Forest (NSF) is New Hampshire's largest state-owned forest, encompassing nearly 40,000 acres of northern hardwood and spruce-fir systems in the headwaters of the Upper Ammonoosuc River. Like many public forests in the Northeast, it is managed for multiple values, including timber production, recreation, and ecological integrity. Increasingly, these goals are considered in the context of climate change, with growing attention to whether active management can maintain forest carbon stocks and sustain the forest as a net carbon sink. This analysis integrates nearly three decades of data (1997-2024), including the state-run Nash Stream Continuous Forest Inventory (CFI) plots, Forest Inventory and Analysis (FIA) data, Forest Vegetation Simulator (FVS) growth modeling, and detailed harvest scale-slip ledgers. By also quantifying transport emissions from log hauling, this report provides one of the most comprehensive carbon accounting efforts yet for a New Hampshire Forest. Results are summarized below in the same question-driven format used in FEMC's earlier analysis of Pisgah State Park (PSP), allowing direct comparison across properties while being able to compare across differing forest types.

- ***What is the best estimate of carbon sequestration for Nash Stream Forest?***
  Continuous Forest Inventory (CFI) plots and FIA-enhanced FVS runs converge on a live-tree (above + belowground) growth rate of 0.65 Mg C ac^{-1} yr^{-1} (CFI: 0.660 ± 0.106; FIA: 0.653 ± 0.095 Mg C ac^{-1} yr^{-1}), yielding whole-forest live-tree sequestration of roughly 26,100-26,400 Mg C yr^{-1} (Table 3) for the whole property. When restricted to aboveground live carbon, the pool most directly comparable to harvested wood, the estimated growth rate is 0.55-0.56 Mg C ac^{-1} yr^{-1}, or ~22,000 ± 3,000 Mg C yr^{-1} across the forest. Figure 7 bar chart. These values are consistent with published estimates for mid-successional northern hardwood and spruce-fir forests in New England (Birdsey 1992; Brown et al. 2007; Foster et al. 1998; Pan et al. 2011; Seidl et al. 2023)
- ***Is recent harvesting removing more carbon than is being sequestered?***
  No. Mean annual removals from 1997-2024 were 2,561 ± 413 Mg C yr^{-1}, with a mean removal intensity of 23.6 ± 6.0 Mg C ac^{-1} on harvested acres. Relative to whole-forest live-tree sequestration (~26,000 Mg C yr^{-1}), removals are offset by growth at a ratio of ~10:1 (all-unharvested scenario: 9.9:1; full model range: 8.3-11.4:1). Using aboveground-only sequestration (~22,000 Mg C yr^{-1}) yields a slightly more conservative offset ratio of ~8:1 (mean 8.2:1; range 6.8-9.6:1). Even in the heaviest harvest year (2022), removals plus transport emissions did not exceed ~27% of modeled forest growth. The resulting growth:removal ratios indicate a strong, persistent carbon sink under current management.
- ***How large are emissions from transporting harvested wood?***
  Modeled transport emissions averaged ~21 Mg C yr^{-1} (18-22 Mg C yr^{-1} across years), or ~0.8% of annual harvest removals. While small relative to harvest and sequestration fluxes, they are explicitly quantified here to align with best-practice guidance for forest carbon accounting.
- ***How do Nash Stream results compare to Pisgah State Park?***
  Harvest carbon removals at Nash Stream Forest (1997-2024) averaged 2,561 Mg C yr^{-1}, with transport adding 21 Mg C yr^{-1}. Using both CFI- and FIA-enhanced FVS models, whole-forest live-tree sequestration averaged 26,126-26,387 Mg C yr^{-1}, meaning removals are only 9.7-9.9% of annual growth. Pisgah State Park (FEMC 2022) shows a similar per-acre removal intensity (24.3 Mg C ac^{-1}) but higher removals relative to growth (≈13.6%, ratio 7.3:1). Differences reflect silvicultural systems and slightly higher standing carbon at Pisgah (45.0 ± 0.4 Mg C ac^{-1}) versus Nash Stream (26.5 ± 5.6 Mg C ac^{-1} [CFI-only] to 41.9 ± 1.8 Mg C ac^{-1} [FIA-enhanced]). These differences reflect both forest development stage, forest species mix, and management history (Birdsey 1992; Keeton et al. 2011; Pan et al. 2011).
- ***Do unharvested areas fully offset harvests?***
  Yes. A spatial scenario analysis following FEMC's Pisgah framework shows that sequestration from unharvested areas alone, approximately 38,200 acres in 2024, provides 25,239 ± 4,057 Mg C yr^{-1}, offsetting average harvest removals at ~9.9:1 on a live-carbon basis. Protected lands (18,300 ac) and yet-to-be-harvested manageable areas (19,900 ac) each individually offset current harvest removals (4.7:1 and 5.1:1, respectively). In all scenarios sequestration exceeds harvesting in all years.

Data & Methods

In 2022, the Forest Ecosystem Monitoring Cooperative (FEMC) released the Pisgah State Park Carbon Report, providing the first full-forest carbon assessment for a New Hampshire state property. The Nash Stream analysis follows the same general framework but incorporates several methodological improvements enabled by more complete data, on-property inventory, and a more detailed accounting workflow. Table 1 summarizes the key enhancements relative to the Pisgah assessment and clarifies how each improves the resolution, transparency, or comparability of results. Full data and reproducible code for all analyses, including the harvest ledger, CFI/FIA processing scripts, FVS calibration, and regrowth modeling, are provided in the accompanying Supplementary Materials (Donisvitch & FEMC 2025).

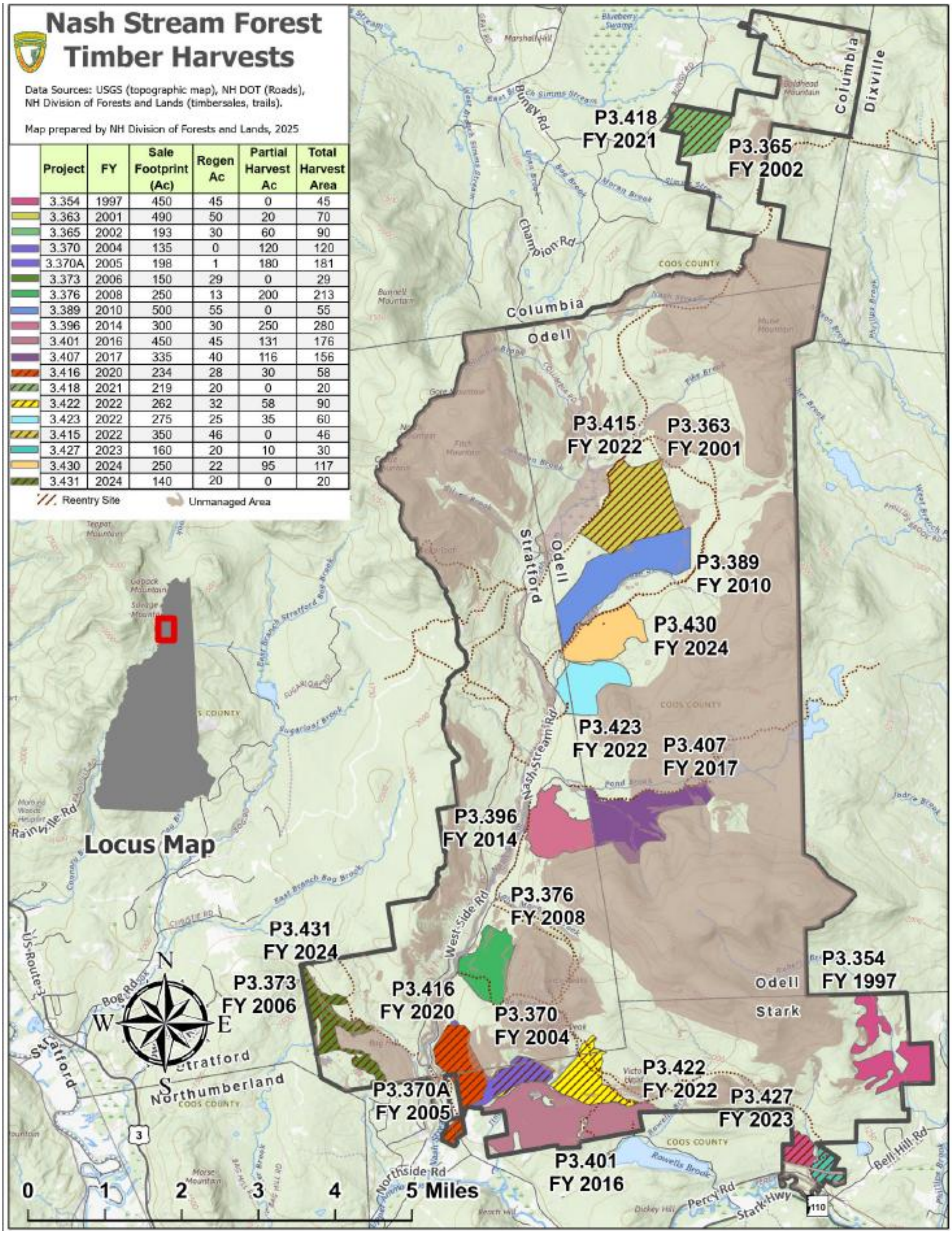
Table 1) Major methodological enhancements relative to the Pisgah State Park analysis

Improvement vs. Pisgah	**What's new in this assessment**
Full harvest ledger	28 years (FY 1997-2024) of project-level scale slips, no extrapolation.
On-property growth data	A permanent Continuous Forest Inventory (CFI) cruise (remeasured 2024) calibrated in FVS.
Regional cross-check	52 FIA subplots within a 1-mile buffer blended with CFI plots to bracket growth and calibrate FVS models.
Quantified uncertainty	Standard errors reported for both stock and growth; Pisgah offered point estimates only.
Operational detail	Harvest intensity expressed in Mg C ac^{-1} and compared with single-tree/group-selection guidelines.
Transport emissions explicitly quantified	28 years of transport emissions (~0.8% of removals) using EPA SmartWay factors; Pisgah only assessed transport for one sale.
Scenario-based spatial analysis	Three allocation scenarios tested (protected, manageable, all unharvested) to stress-test sustainability; Pisgah used a single property-wide balance.
Regrowth credit on treated acres	Regeneration-driven sequestration following harvests explicitly quantified, separating unharvested sequestration from post-treatment regrowth; Pisgah did not isolate or report regeneration credit.
Glossary and transparency	Glossary, unit conversions, and explicit definitions of metrics (growth:removal ratios, per-acre vs. whole-forest numbers) included to reduce ambiguity.
Comparability to offset protocols	Pools restricted to live above- and below-ground carbon, aligning with regional offset accounting protocols.
Management compliance check	Removal intensity and recovery times benchmarked directly against Management Plan targets, demonstrating formal compliance.

Nash Stream Forest at-a-glance

Nash Stream Forest (NSF) spans 39,980 acres in the towns of Columbia, Stark, Stratford, and Odell in Coös County, NH. Acquired by the state in 1988, nearly the entire property (39,601 acres) is encumbered by a federal conservation easement that ensures perpetual public access and mandates management for multiple uses (Map 1). The vision articulated in the 2017 Management Plan emphasizes maintaining a largely uninterrupted northern forest that protects natural communities and rare species, demonstrates ecologically based long-rotation silviculture, sustains low-impact recreation, and involves the public through the Nash Stream Citizens' Committee. Ecologically, NSF is dominated by northern hardwood and spruce-fir systems. Roughly 98% of the property is forested, with the 1988 acquisition cruise reporting 56% hardwood, 7% softwood, and 37% mixed stands. After heavy pre-acquisition cutting, today's stands are largely in pole and small sawtimber size classes, making NSF a predominantly mid-successional forest. Five designated natural areas, together totaling ~18,300 acres (≈46% of the property), are managed as reserves with no commercial harvesting; surrounding buffers and corridors are treated lightly with uneven-aged management.

Map 1) Nash Stream Forest Timber Harvests 1997-2024



Project	FY	Sale Footprint (Ac)	Regen Ac	Partial Harvest Ac	Total Harvest Area
3.354	1997	450	45	0	45
3.363	2001	490	50	20	70
3.365	2002	193	30	60	90
3.370	2004	135	0	120	120
3.370A	2005	198	1	180	181
3.373	2006	150	29	0	29
3.376	2008	250	13	200	213
3.389	2010	500	55	0	55
3.396	2014	300	30	250	280
3.401	2016	450	45	131	176
3.407	2017	335	40	116	156
3.416	2020	234	28	30	58
3.418	2021	219	20	0	20
3.422	2022	262	32	58	90
3.423	2022	275	25	35	60
3.415	2022	350	46	0	46
3.427	2023	160	20	10	30
3.430	2024	250	22	95	117
3.431	2024	140	20	0	20

Infrastructure includes 66.5 miles of roads (42 miles graveled), two Class B public roads that remain open seasonally, and gated spur roads used only for fire and harvest access to reduce costs and protect wildlife. The property also hosts 91 licensed camp lots and supports traditional recreation such as hunting, fishing, hiking, snowmobiling, and limited ATV use under a separate agreement.

The harvest record reflects this conservative approach. The 2025 timber-sale map documents every commercial entry since state acquisition. Between FY 1997 and FY 2024, 19 completed sales treated 1,856 acres, an average of 66.3 acres per year, or 0.16% of the forest annually. This level is well inside the Plan's area-control cap of ≤2% per decade. Of this area, regeneration patches account for ~550 acres (≈30% of treated acres), meeting the Plan's objective of maintaining a modest component of young-forest habitat. All harvest blocks avoid the five natural-area complexes as well as steep slopes, high-elevation zones, and riparian buffers, illustrating ongoing adherence to ecological safeguards set in 2017.

Crucially, the state has paired this long-term harvest record with two complementary monitoring systems: a permanent state-run Continuous Forest Inventory (CFI) network and complete scale-slip records for every sale. Together, these provide an unusually high-quality dataset for evaluating both forest dynamics and carbon outcomes across nearly three decades of management.

The Nash Stream carbon accounting analysis follows the framework developed in the *Pisgah State Park Carbon Report* (FEMC 2022) while incorporating additional datasets that improve temporal resolution and site specificity. In both reports, the Forest Vegetation Simulator (FVS; Crookston and Dixon 2005) serves as the primary modeling tool for projecting forest growth and carbon sequestration. For Nash Stream, however, the availability of a Continuous Forest Inventory (NHDFL CFI) network allows for direct incorporation of plot-level remeasurements into the model. These CFI plots capture site-specific changes in basal area, mortality, and recruitment, offering a more precise estimate of forest dynamics than was possible at Pisgah, where analyses were based primarily on FIA data.

To ensure comparability, FIA plots within a one-mile buffer of the Nash Stream boundary were also included. This step mirrors the approach used at Pisgah but serves an additional purpose here by tempering the growth rates derived from managed northern hardwood plots with data from slower-growing spruce-fir and high-elevation strata that are underrepresented in the CFI network (FIA 2023). Following USDA Forest Service calibration guidelines for FVS, plot-level growth was adjusted using basal area increment multipliers and stratum-level corrections to align modeled outputs with empirical observations (USDA Forest Service 2023).

Harvest removals were reconstructed using project-level records. In years where scale slips were available, we were able to determine volumes removed at the species level and to track loads to mill destinations. For years where slips could not be located, harvest reports still allowed us to reconstruct annual species-level removals, ensuring continuity across the full study period. This represents a significant improvement over Pisgah, which averaged removals across the period of record. Here, annualized removals allow for a more accurate alignment of sequestration and harvesting in any given year.

Scale slips also enabled estimation of transportation-related emissions based on load weight and distance to destination mills, calculated using EPA emissions factors (EPA 2018). For years lacking slips, average transportation emissions from observed years were applied as a proxy. As in Pisgah, transportation emissions represented a negligible fraction of overall removals, rarely registering in figures when compared to sequestration and harvest carbon flows.

Carbon accounting was conducted across the same five pools reported for Pisgah—aboveground live, belowground live, standing dead, down dead, and forest floor organic matter (Smith et al. 2006), to maintain comparability. However, because offset protocols and most management frameworks emphasize live pools, the primary results presented here focus on above- and belowground live carbon, with the broader five-pool totals provided in supplementary tables and figures for context.

Finally, results are presented both in terms of sequestration (modeled annual carbon accumulation) and removals (harvested carbon and associated emissions). While Pisgah's analysis averaged removals over the study period, Nash

Stream's dataset permits annualized comparisons. This allows for a more nuanced assessment of how management activities interact with natural growth in any given year, while still allowing for direct, apples-to-apples comparison with Pisgah when results are aggregated (Table 2).

Table 2) Summary of analyses performed for this project

Description of Analysis	Data source(s)
Carbon storage and sequestration in the landscape encompassing Nash Stream	USDA Forest Inventory and Analysis (FIA 2023); Nash Stream Continuous Forest Inventory (NHDFL CFI 2024)
Calibration of growth and sequestration models	Forest Vegetation Simulator, Northeast Variant (Crookston and Dixon 2005; USDA Forest Service 2023); FIA plots within 1-mile buffer
Estimated carbon removed through harvesting	New Hampshire Division of Forests and Lands harvest reports (NHDFL 2024); Scale slip records (2000-2023, FEMC archive)
Estimated emissions from transport of harvested material	Scale slip records with mill destinations (FEMC archive); U.S. EPA emissions factors (EPA 2018)
Contextual comparison to previous analyses	FEMC Pisgah State Park Carbon Report (FEMC 2022)

Carbon Sequestration

Forest Vegetation Simulator (FVS) growth modeling and calibration

We projected forest growth and live-pool carbon sequestration for Nash Stream Forest (NSF) using the Forest Vegetation Simulator, Northeast Variant (Crookston and Dixon 2005). The modeling framework was designed to replicate the Pisgah State Park analysis (FEMC 2022) while leveraging NSF's permanent Continuous Forest Inventory (CFI) data, collected by NH DNCR. This allowed us to maintain comparability across projects while improving precision for Nash Stream. To bracket uncertainty and assess model robustness, we implemented two runs looking at CFI-only outputs and then FIA+CFI enhanced results to evaluate live carbon (above and belowground) and aboveground-only carbon pools. (Table 3):

Table 3) Model Runs with CFI and FIA Enhanced Models

Model	Data Sources	Plots Used	Growth Rate (Mg C ac^{-1} yr^{-1})	Whole-Forest Sequestration (Mg C yr^{-1})	Notes
CFI-only (Live carbon)	Nash Stream CFI permanent plots	22	0.660 ± 0.106 (Above + Belowground)	26,387 ± 4,242	Purely field-measured; reflects local species mix, site productivity, and age structure.
CFI-only (Aboveground only)	Nash Stream CFI permanent plots	22	0.550 ± 0.091 (Aboveground)	21,989 ± 3,648	Removes estimated belowground biomass; value represents tree stems + branches only.
FIA+CFI (Live carbon)	CFI + FIA plots within 1-mile buffer	74	0.653 ± 0.095 (Above + Belowground)	26,126 ± 3,803	Adds higher-elevation spruce-fir and unmanaged FIA plots, improving representation of forest heterogeneity.

FIA+CFI (Aboveground only)	CFI + FIA plots	74	0.559 ± 0.055 (Aboveground)	22,358 ± 2,193	Aboveground-only carbon; FIA plots increase sample size and reduce uncertainty.

Both runs were calibrated following USFS best practices (USDA Forest Service 2023), using basal-area-increment multipliers and mortality adjustments to align projections with observed increment data. Aboveground growth rates converged tightly between models, indicating stable results across sampling frames. Differences emerged in mortality and pool partitioning, reflecting the greater spruce-fir representation in the FIA+CFI set.

Spatial filtering and plot coverage

The FIA+CFI run incorporated 52 FIA subplots (74 total plots including CFI) selected within a 1-mile buffer of the NSF boundary (Figure 1). This local filter dampens regional drift while capturing unmanaged, high-elevation spruce-fir forests absent from the CFI network. FIA coordinates are fuzzed for privacy, while CFI coordinates are withheld. Together, the two runs provide complementary perspectives: the CFI set anchors projections in intensively measured management units, while the FIA buffer broadens coverage to under-sampled forest types.

Stand density and forest-type representation

The stand density diagram (Figure 2) highlights structural contrasts between the two datasets. CFI plots (orange) cluster around moderate basal area and quadratic mean diameters, consistent with managed northern hardwoods. FIA plots (blue) cluster at higher trees-per-acre and lower quadratic mean diameters, reflecting dense, small-stature spruce-fir stands at higher elevations. These differences help explain why the FIA+CFI run partitions more carbon into mortality and deadwood pools, even though aboveground growth rates remain similar to the CFI-only run.

Growth rates in regional context

Modeled sequestration rates at Nash Stream (0.653 ± 0.095 Mg C ac^{-1} yr^{-1} for live pools; 0.559 ± 0.055 Mg C ac^{-1} yr^{-1} for aboveground only) fall squarely within published values for uneven-aged northern hardwoods in the northeastern United States. Nunery & Keeton (2010) report live-tree carbon accumulation rates of approximately 0.6-1.2 Mg C ac^{-1} yr^{-1} depending on stand structure and harvest intensity, with mid-successional, uneven-aged northern hardwoods typically near the lower end of this range. Janowiak et al. (2017) similarly cite regional sequestration rates of roughly 0.4-0.8 Mg C ac^{-1} yr^{-1} for northern hardwood and mixedwood systems. By contrast, Birdsey (1992, 1996) and Brown et al. (2007) describe carbon stock densities rather than annual increments, but their reported live-tree stocks for northern hardwoods and spruce-fir align with the 26-42 Mg C ac^{-1} observed in the Nash Stream inventory. Together, these sources confirm that the Nash Stream estimates are consistent with regional expectations for forest type, age-class structure, and management regime.

Comparison to Pisgah

Pisgah State Park and Nash Stream Forest represent intentionally different forest systems. Pisgah is dominated by the Hemlock-Beech-Oak-Pine (HBOP) natural community typical of southern New Hampshire, while Nash Stream is overwhelmingly northern hardwood and spruce-fir. Part of the purpose of this study is to compare carbon dynamics across these contrasting ecological systems under a standardized accounting framework. These inherent forest-type differences explain much of the divergence in stocking, growth rates, and sequestration outcomes between the two properties and should be viewed as a feature, not a limitation, of the comparative analysis.

Pisgah's FIA-based analysis reported a higher total live sequestration rate (0.84 ± 0.04 Mg C ac^{-1} yr^{-1}) and above and below ground live carbon rate (0.76 ± 0.03 Mg C ac^{-1} yr^{-1}), reflecting its denser late-successional stands and the presence of even-aged silvicultural treatments (FEMC 2022). HBOP forests often maintain strong annual carbon uptake because of their oak-pine component, deep-crowned hemlock, and warmer southern New Hampshire climate. In contrast, Nash Stream's mid-successional condition, extensive unharvested high-elevation acreage, and exclusive reliance on uneven-

aged prescriptions (NH DNCR 2017) produce slightly lower but regionally appropriate growth rates, consistent with the mid-successional condition and species composition of Nash Stream.
Because Nash Stream incorporates both direct CFI remeasurement data and FIA plots from adjacent unmanaged strata, its estimates bracket the expected range for northern hardwood-spruce-fir systems while remaining directly comparable to Pisgah. The dual-model approach also increases confidence in Nash Stream's sequestration estimates by capturing both managed and unmanaged growth dynamics.

Harvest Carbon Removals

Harvest activity at Nash Stream Forest (NSF) between FY 1997 and FY 2024 was reconstructed from scale slip records, which provided species-level and product-level volumes. These volumes were converted to oven-dry biomass using published species-specific factors (Birdsey 1996), for more information see both Carbon Factors in Appendix as well as published supplementary data on our archive. Importantly, both Pisgah State Park and Nash Stream Forest systems maintain positive carbon balances under their respective silvicultural regimes, but the differences underscore why per-acre comparisons must be interpreted in the context of forest type, stocking, and management history.

Harvested area and intensity

Across the 28-year period, 1,856 acres were harvested across 19 sales, averaging 66.3 acres per year, or 0.16% of the forest annually. This represents only 9.5% of the 693-acre annual cap set in the 2017 Management Plan (543 acres tending + 150 acres regeneration; NH DNCR 2017). Even in the peak years (2010, 2014, 2022), treated area remained well below the cap (Figure 3).

Individual sale footprints averaged 281 acres in total area, of which 97.7 acres were harvested. Harvests included an average of 29 acres of regeneration area and 68.7 acres of partial-harvest area per sale. Average removal intensity was 23.6 ± 6.0 Mg C ac^{-1}, equivalent to roughly half of FIA-estimated live-tree carbon on treated acres and a higher fraction of CFI-only estimates. Live standing stock averaged 26.5 Mg C ac^{-1} on CFI plots, with FIA-enhanced estimates closer to 42 Mg C ac^{-1} (Figure 4). The Nash Stream removal intensity is consistent with single-tree and group-selection systems, which typically extract 20-30% of biomass on 15-20-year cycles with near-total removal within regeneration patches (Leak and Solomon 1975; Nyland 2002).

Carbon removed and growth balance

Cumulative carbon removals over 1997-2024 totaled 40,979 Mg C (45,172 short tons). Average annual removals were 2,561 Mg C yr^{-1}, equivalent to ~10% of modeled live-tree sequestration (Figure 5). In other words, the forest's net sequestration capacity (26,126 ± 3,803 to 26,387 ± 4,242 Mg C yr^{-1} under FVS models) exceeds average annual removals, satisfying the Plan's growth > removal requirement (NH DNCR 2017).

Comparison to Pisgah

At Pisgah, annual removals averaged 1,320 ± 350 Mg C yr^{-1}, representing 13.6% of annual sequestration and producing a growth-to-removal ratio of 7.3:1. Nash Stream's equivalent ratio of ~10:1 indicates a lower harvest footprint relative to forest productivity, and size, with removals equal to only ~10% of annual live-tree growth. This outcome reflects Nash Stream's reliance on uneven-aged systems and its lower standing stocks. Like Pisgah, when evaluated spatially, Nash Stream's unharvested areas provide a sequestration surplus that far exceeds removals even without assigning explicit regrowth credit.

Silvicultural regime

The Pisgah dataset includes shelterwood systems and patch clearcuts, which are designed to regenerate even-aged cohorts and therefore entail larger per-entry biomass reductions. By contrast, Nash Stream is managed under a strict uneven-aged system, using single-tree and small-group selection that rarely removes more than 20-30% of basal area at a time (Nyland 2002).

Stocking levels

Live-tree carbon density at Pisgah averages ~45 Mg C ac^{-1}. Aboveground live carbon ranges from 26-42 Mg C ac^{-1} observed across Nash Stream's stands, depending on data source (CFI vs FIA-enhanced). Higher stocking allows for proportionally larger removals while still retaining significant standing volume. In other words, Pisgah can remove more carbon per acre because it begins from a denser baseline, while Nash Stream starts off with less carbon per acre due to its mid-successional stands in more northern forest types.

Forest type and history

The two landscapes also differ in their ecological and disturbance histories. Nash Stream was heavily logged in the late 19th century pre-state ownership, leaving a largely mid-successional forest today which is comprised of northern hardwood and mixed spruce-fir. Pisgah's dominant natural community HBOP is ecologically distinct from Nash Stream's northern hardwood and spruce-fir matrix. HBOP forests contain higher proportions of oak, pine, and hemlock, which influence basal area, wood density, and per-acre carbon stocks. Pisgah is also reforested farmland that has developed into mature, even-aged stands. These forest types support denser stocking and a broader silvicultural mix, which in turn elevate per-acre removals. Taken together, these contrasts highlight that Pisgah's higher removal intensities are not evidence of unsustainable practice but rather a function of its denser stocking which comes from more diverse silvicultural systems and older forest conditions.

Nash Stream's lighter entries are fully consistent with its management goals and ecological context. Importantly, both systems maintain positive carbon balances, but the differences in stand structure, composition, and management history underscore why per-acre comparisons must be interpreted cautiously (Leak & Solomon 1975; Keeton et al. 2011).

Estimated Emissions from Transport of Harvested Material (1997-2024)

Transport emissions were calculated following EPA SmartWay freight accounting (EPA 2013), adapted to report in Mg C. Each slip was processed to derive trip-level emissions via:

$$Transport\ C\ (Mg\ C)\ =\ Distance(Miles) \times Weight(Short\ Tons) \times 161\ \frac{gCO^2}{ton \cdot mile} \times \frac{12}{44} \times 10^{-6}$$

where Distance was estimated from landing locations to destination mills. Payload weights were recorded as short tons. A standard emission factor of 161 g CO_2 ton^{-1} $mile^{-1}$ was applied consistently, in line with EPA SmartWay guidance and typical forestry LCA practice (e.g., Mathers et al. 2015). Conversion to elemental carbon followed the molecular ratio 12/44.

For illustration, a 28-ton mixed-hardwood load hauled 45 miles produces 202,860 g CO_2 (0.203 Mg CO_2), equivalent to 0.055 Mg C.

Aggregated over the full period (1997-2024), transport emissions averaged 21 Mg C yr^{-1}, or 0.83% of mean annual harvest removals (Figure 6). Cumulative emissions totaled 1,241 Mg CO_2 or 338.5 Mg C, representing 0.83% of cumulative harvest removals (40,979 Mg C). The highest year was 2022, with 81.4 Mg C. This outlier was driven by a fiscal-year rollover that consolidated multiple operational years of activity into a single accounting year.

This analysis includes only direct trips from landings to primary mills; secondary movements (e.g., mill-to-market transport) and return trips were out of scope. Years without recorded distances relied on imputed values flagged in the dataset. Uncertainty related to truck class, routing, and load factors were not propagated, but given that transport represents <1% of removals, this simplification has no effect on interpretation. Results are presented in both Mg CO_2 (for climate context) and Mg C (for consistency with harvest and growth accounting).

For consistency with sequestration accounting, transport emissions were added to harvest removals when computing net carbon balance. Under the CFI growth scenario, live-tree sequestration averaged 26,387 Mg C yr^{-1}, while the FIA+CFI scenario produced 26,126 Mg C yr^{-1}. Combined harvest plus transport removals averaged 2,582 Mg C yr^{-1}, equivalent to roughly 10% of modeled annual growth in both runs. Resulting net balances were 23,805 Mg C yr^{-1} (CFI) and 23,544 Mg C yr^{-1} (FIA+CFI), confirming that transport, although explicitly quantified, remains <1% of removals and does not meaningfully influence the conclusion that Nash Stream Forest is a strong net carbon sink.

Harvest Removals Versus Live Carbon Growth

This analysis compares mean annual harvest removals (1997-2024) with modeled live carbon sequestration from two FVS runs. The approach is intentionally simple: we ask whether Nash Stream Forest is growing more live carbon than it is harvesting. Put another way, the objective is to determine whether Nash Stream Forest (NSF) is adding more carbon to live-tree pools each year than it is harvesting and transporting, not whether alternative management futures might alter long-term carbon trajectories.

Across the 28-year record, harvest removals averaged 2,561 Mg C yr^{-1}, with an additional 21 Mg C yr^{-1} emitted from log-haul transport. Together, this yields a combined carbon removal of 2,582 Mg C yr^{-1}.

Growth estimates from the two calibrated FVS runs fall within a narrow range of each other. The CFI-only run projects 26,387 Mg C yr^{-1} of live-tree sequestration (0.660 Mg C ac^{-1} yr^{-1}), while the FIA+CFI model estimates 26,126 Mg C yr^{-1} (0.653 Mg C ac^{-1} yr^{-1}). Both models therefore indicate that NSF's live-tree growth exceeds combined harvest and transport removals by roughly a factor of ten, producing net live-tree gains of 23,544-23,805 Mg C yr^{-1}.

These results are summarized visually in Figure 7, which follows the layout used in FEMC's Pisgah analysis. Sequestration by unharvested areas (bars extending left) overwhelmingly offsets harvest removals and transport emissions (bars extending right), and the two independent growth models bracket nearly identical outcomes. The figure highlights the dominant role of unharvested stands in maintaining NSF as a strong net carbon sink and illustrates the small share of forest-wide carbon represented by harvest removals.

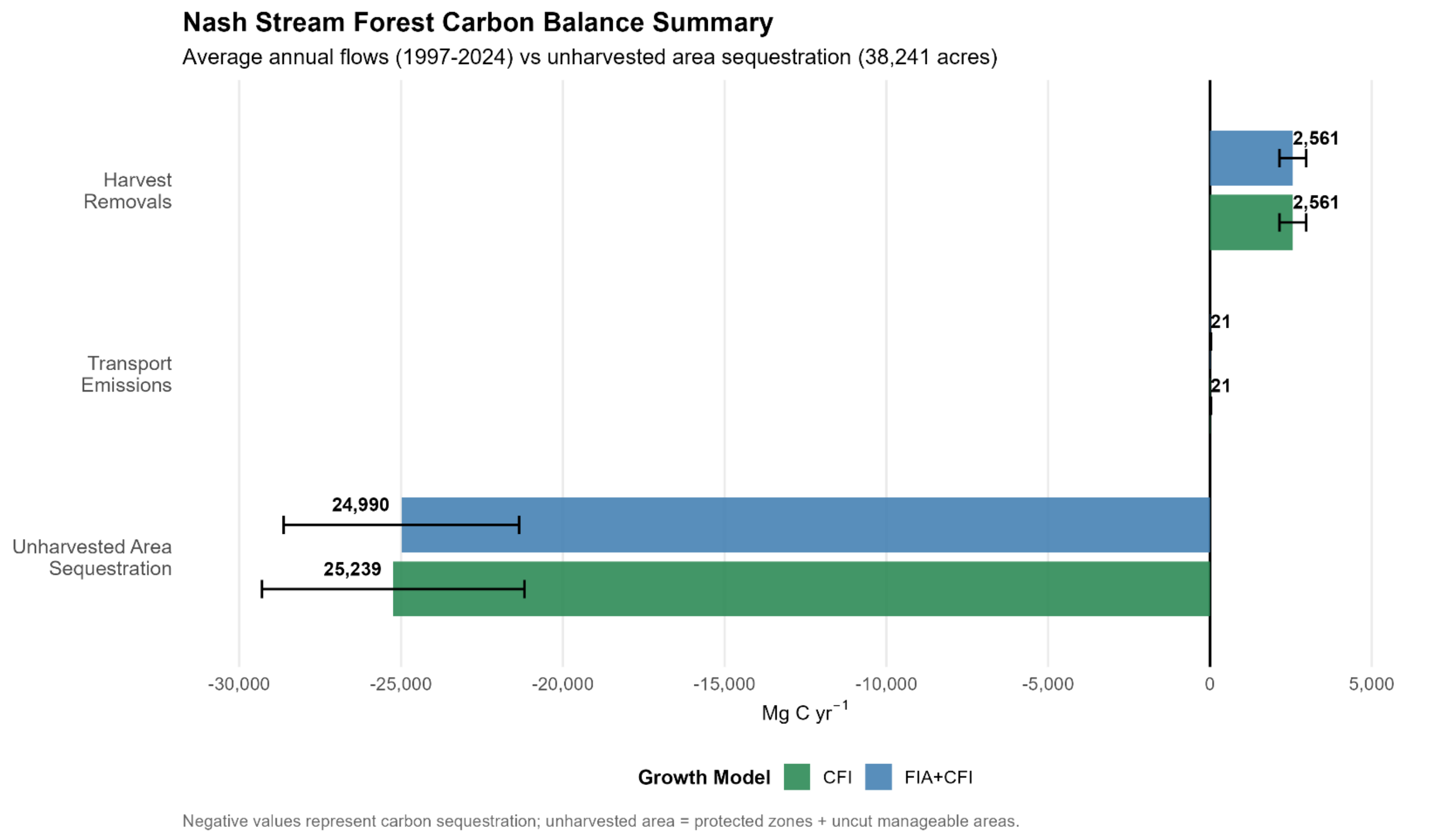


Figure 7 *Nash Stream Forest carbon balance summary (1997-2024), expressed as average annual flows. Negative values represent carbon sequestration in the unharvested areas (protected zones + uncut manageable areas); excludes regeneration credits on harvested acres. Positive values represent carbon removals. This illustrates the aboveground carbon balance for Nash Stream in the same style as Pisgah's Figure 4: sequestration from unharvested areas overwhelms aboveground harvest removals and transport, with the two independent FVS growth models producing nearly identical results.*

Spatial Carbon Analysis

Building on the annual harvest and transport accounting, we evaluated whether unharvested portions of Nash Stream Forest can offset removals under three spatial scenarios that mirror the 2017 Management Plan: (i) all unharvested areas combined (protected zones + uncut manageable stands), (ii) protected natural areas only, and (iii) uncut manageable areas only. In all three scenarios, sequestration exceeds mean annual harvest and transport removals. Even when the analysis is restricted to the 18,300 acres of permanently protected natural areas, sequestration offsets removals by roughly 4.7:1. For the 19,941 acres of unharvested manageable forest, the offset ratio is approximately 5.1:1. When all 38,241 unharvested acres are combined, live-tree sequestration reaches 25,239 ± 4,057 Mg C yr^{-1}, offsetting combined harvest + transport removals (2,582 Mg C yr^{-1}) at roughly 9.9:1 and leaving a net surplus of ~22,700 Mg C yr^{-1} (≈0.57 Mg C ac^{-1} yr^{-1} when averaged over the entire 39,980-acre forest). Using aboveground-only sequestration yields a slightly more conservative offset ratio (~8.2:1), but in all cases the forest remains a strong carbon sink.

Figure 8 is organized to show these same three scenarios first without, and then with, post-harvest regrowth. Panel A ("Scenarios Without Regrowth") plots annual sequestration from unharvested areas only: solid green for all unharvested lands, dashed blue for protected areas only, and dotted purple for unharvested manageable stands, overlaid on annual harvest and transport bars. These curves represent a conservative lower bound because they exclude any carbon uptake on regeneration patches created by past harvests. Panel B ("Scenarios With Chapman-Richards Regrowth") adds a Chapman-Richards regrowth term on the 551 regeneration acres where clearcuts and patch cuts have occurred. Because protected zones do not contain these regeneration harvests, there is no corresponding "protected + regrowth" line, and only two of the three spatial scenarios are shown: all unharvested + regrowth (orange) and unharvested manageable + regrowth (purple). A gray line and band summarize the regrowth component alone, which contributes an additional 319 ± 84 Mg C yr^{-1}. Including regrowth nudges the overall offset ratio from 9.9:1 to about 10.0:1 and does not change the core conclusion that Nash Stream's unharvested and recovering stands robustly offset harvest and transport emissions.

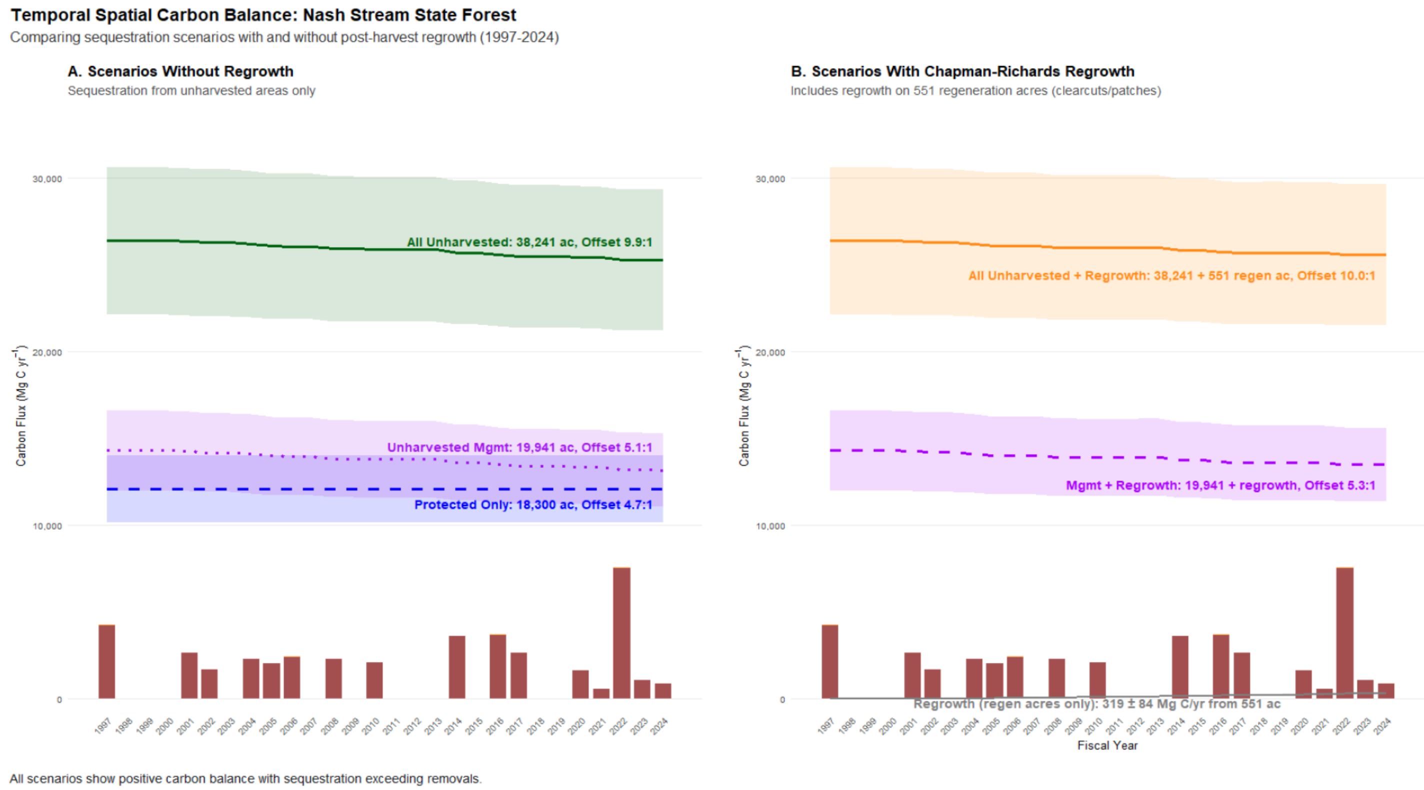


Figure 8 *Annual harvest removals (dark red) and transport emissions (orange stacked on top of red bars) compared against modeled live-tree sequestration in unharvested areas of Nash Stream Forest (lines; CFI-FIA based estimates). Shaded regions reflect Standard Errors of the model which reflect the variability of the estimated carbon over time*

Chapman-Richards regrowth modeling

As referenced above, we implemented a Chapman-Richards recovery model to represent post-harvest regrowth on treated acres (Figure 8B) to complement the static spatial balance. For full methodology see Apendix methods section. Parameters were selected to approximate Nash Stream's dominant northern hardwood systems and the forest's uneven-aged treatment mix: a residual carbon stock immediately after harvest (C_{resid} = 5 Mg C ac^{-1}), an asymptotic live-tree stock (C_{max} = 70 Mg C ac^{-1}), a growth-rate parameter (k = 0.04), a shape parameter (m = 2.4), and a 3-year establishment lag. These settings produce a realistic recovery curve consistent with long-rotation uneven-aged management (Leak & Solomon 1975; Nyland 2002; Keeton et al. 2011).

Regrowth contributions were estimated by convolving annual harvested acreage with a discrete Chapman-Richards increment kernel over a 120-year horizon, such that each cohort contributes increasing carbon uptake for several decades after treatment. A Monte Carlo routine propagated uncertainty in C_{resid}, C_{max}, k, m, and t_{lag} (Appendix: Table 5).

By 2024, after 28 years of harvesting and regrowth on those harvested acres, the regrowth kernel contributes ~1,275 ± 191 Mg C yr^{-1} from approximately 1,700 acres in various stages of recovery. Adding this to the unharvested sequestration total increases the forest-wide live-tree sequestration from 25,239 ± 4,057 Mg C yr^{-1} to 26,514 ± 4,062 Mg C yr^{-1}, raising the live-based offset ratio from ~9.9:1 to ~10.4:1. While modest at the landscape scale, this regrowth contribution reinforces the conclusion that Nash Stream maintains a persistent and robust carbon surplus even under conservative accounting assumptions.

Comparison to Pisgah State Park

FEMC's 2022 analysis of Pisgah State Park (PSP) provides a useful benchmark for interpreting Nash Stream Forest's (NSF) carbon balance. Although the two properties share similar per-acre harvest intensities, they differ in forest type, successional stage, stocking levels, and overall size, factors that strongly influence carbon pools and net carbon balance. Across 1997-2024, NSF removed 2,561 Mg C yr^{-1}, or ~0.06 Mg C ac^{-1} yr^{-1} when averaged over the 39,980-acre forest. Per-acre removal intensity on harvested tracts (~23.6 Mg C ac^{-1}) was nearly identical to Pisgah's (~24 Mg C ac^{-1}), indicating comparable harvest intensity per entry. Because Nash Stream's stands contain less aboveground carbon per acre (26–42 Mg C/ac) than Pisgah (~45 Mg C/ac), removing ~24 Mg C/ac represents a proportionally larger reduction of standing biomass at Nash Stream. This is roughly standard with silvicultural treatment practices and long term regeneration and structural goals.

Aboveground productivity differs between the two forests in ways that reflect both ecological context and management history. Pisgah's FIA-based modeling estimated aboveground sequestration of roughly 0.76 Mg C ac^{-1} yr^{-1}, substantially higher than the ~0.55-0.56 Mg C ac^{-1} yr^{-1} observed at Nash Stream. Although older forests often accumulate carbon more slowly than younger ones, Pisgah's aboveground productivity reflects the behavior of mature HBOP forests, which can retain high annual carbon uptake due to their mixed oak-pine-hemlock composition, deep crowns, and high leaf-area productivity. Its stands contain larger, well-formed trees with expansive crowns, deep rooting zones, and high leaf area, all of which support continued carbon uptake even in later successional stages. These conditions are reinforced by Pisgah's warmer climate, longer growing season, and higher site productivity relative to the cooler, shorter-season environment north of the White Mountains where Nash Stream is situated.

When total live pools are used, the boundary applied in both studies' spatial offsets, NSF exhibits an offset ratio of ~9.9:1, compared to ~7.3:1 at Pisgah. Much of this difference reflects scale: Nash Stream encompasses nearly 40,000 acres, while Pisgah spans ~13,300 acres, giving NSF a substantially larger unharvested land base contributing to steady sequestration. A side-by-side summary (Table 4) places the aboveground carbon dynamics of both forests in direct comparison.

Table 4) Comparative summary of Nash Stream Forest (NSF) and Pisgah State Park (PSP) carbon balance metrics

Metric	Nash Stream Forest (1997-2024)	Pisgah State Park (2008-2020)
Harvest removals	2,561 Mg C yr^{-1} (0.06 Mg C ac^{-1} yr^{-1})	1,320 Mg C yr^{-1} (≈0.05 Mg C ac^{-1} yr^{-1})
Per-acre removal intensity	~23.6 Mg C ac^{-1}	~24 Mg C ac^{-1}
Transport emissions	21 Mg C yr^{-1} (0.8% of removals)	<1% of removals (not reported separately)
Unharvested sequestration *(total live pools)*	25,239 ± 4,057 Mg C yr^{-1}	~9,600 Mg C yr^{-1}
Offset ratio (sequestration : removals)	~9.9 : 1	~7.3 : 1
Net carbon balance	+22,700 Mg C yr^{-1}	+8,300 Mg C yr^{-1}
Silvicultural system	Uneven-aged (single-tree, group selection)	Mixed: shelterwood, patch clearcuts, uneven-aged
Forest types differ: Pisgah State Park is dominated by Hemlock-Beech-Oak-Pine (HBOP), whereas Nash Stream Forest is northern hardwood and spruce-fir. These ecological differences are an intended component of the comparative analysis and influence stocking, growth rates, and carbon densities.		

Overall, the two forests remove similar amounts of carbon per harvested acre, but Pisgah's older age structure and higher stocking support greater per-acre productivity. Nash Stream's larger land base and extensive unharvested acreage allow it to maintain a substantially larger net carbon surplus, positioning it as a strong and stable regional carbon sink under current management.

A critical clarification is that two different carbon pools are used in different parts of this report, following the structure of the Pisgah analysis.

1. Aboveground pools are used for the harvest-versus-growth comparison because removals occur only from aboveground biomass and Pisgah's carbon balance uses this same boundary.
2. Total live pools (above + belowground) are used for the spatial offset scenarios (Figure 8), consistent with Pisgah's spatial modeling framework.

As in Pisgah, these two accounting boundaries produce different but complementary offset ratios.

Caveats In Using Averaged Growth

The growth estimates used in this assessment rely on constant mean annual increments from both the CFI and FIA-CFI calibrated FVS simulations. This necessarily assumes uniform productivity across Nash Stream Forest, even though actual growth varies substantially by forest type and age class. Mid-aged northern hardwood stands accumulate biomass rapidly, while spruce-fir flats, shallow soils, and older hardwood cohorts grow more slowly. At the 40,000-acre scale of Nash Stream, these differences tend to balance out, but they should be considered when interpreting stand-level outcomes (Pacala et al. 2001; Keeton et al. 2011).

FVS growth is also returned in ten-year steps, which smooths over short-term growth dynamics, such as the temporary acceleration following light partial harvests and the gradual slowdown in older cohorts. Although this reduces short-term precision, it is consistent with methods used in long-horizon forest carbon accounting frameworks (IPCC 2019; USDA 2022).

This assessment tracks only live above- and below-ground carbon pools, matching both the Pisgah analysis and regional forest carbon offset protocols (CAL FIRE 2015; Winrock 2020). Dead wood, litter, and soil carbon dynamics, often temporarily elevated following harvest, were excluded to maintain comparability. Likewise, harvested wood products were not credited; accounting for long-lived uses (e.g., dimensional lumber, CLT) would reduce effective removals by an estimated 15-30% (Winchester et al. 2018; Harmon 2022).

Two additional boundary considerations apply. Harvest removals are recorded by fiscal year, while modeled growth represents the 2024-2034 interval. These time windows differ, and the comparison therefore reflects long-term average conditions rather than perfectly aligned annual fluxes and considering landscape scales are negligible. Transport emissions include only direct hauling from landings to mills; secondary transport and return trips are out of scope. Because transport contributes <1% of total removals, this simplification does not materially affect results at this large of a scale.

Management Implications

Despite these limitations, the overall conclusion is robust: Nash Stream Forest remains a strong and stable net carbon sink. Even in the peak harvest year (2022), combined harvest plus transport removals (~7,573 Mg C) offset <29% of modeled growth under both CFI and FIA-enhanced scenarios. Across the full 28-year record, annual removals (~2,582 Mg C yr^{-1}) offset only 8-10% of annual sequestration.

Given modeled sequestration rates of ~0.66 Mg C ac^{-1} yr^{-1} (CFI) and ~0.56 Mg C ac^{-1} yr^{-1} (CFI - aboveground-only), stands are expected to replace removed carbon within 10-12 years, well inside the 15-20-year re-entry cycle specified in the Management Plan (NH DNCR 2017).

Finally, the analytical framework used here, restricting pools to live carbon, applying standardized conversion factors, calibrating two independent plot datasets, and explicitly quantifying transport emissions, follows established principles of transparency, comparability, and conservativeness in forest carbon accounting (IPCC 2019; CAL FIRE 2015). Together, these practices reinforce confidence that Nash Stream's management not only meets the "growth > removal" mandate but positions the property as a dependable contributor to regional carbon and climate goals.

Recommendations

To sustain and improve the precision of Nash Stream's carbon accounting, we recommend the following target actions:

1. Continue, and strengthen, the CFI program: Maintain regular remeasurement intervals and consider modest expansion into under-sampled forest types (spruce-fir, high-elevation, older hardwoods) to further tighten growth and mortality estimates.
2. Collect pre and post-harvest plot data: A small set of treatment-paired both pre and post-harvest measurements in geolocated fixed plots (3-4 plots per sale) would greatly improve estimates of residual carbon, treatment intensity, and early regrowth. These could be staggered year returns to help estimate regrowth on harvested areas
3. Develop a full-forest FVS scenario model: Integrating mapped harvest history with CFI-calibrated FVS projections would allow long-term forecasting of stocking, carbon, and age structure under alternative management strategies.
4. Add harvested-wood-product accounting: Including carbon stored in long-lived wood products would reduce effective removals by ~15-30% and provide a more complete carbon balance aligned with national protocols.

Appendix

Figures

All figures were generated using the reproducible R scripts included in the Supplementary Materials (Donisvitch & FEMC 2025). Supplementary package can be found here: https://www.uvm.edu/femc/data/archive/project/estimation-of-nash-stream-forest-carbon-storage--sequestration--emissions-and-removals/dataset/supplementary-package

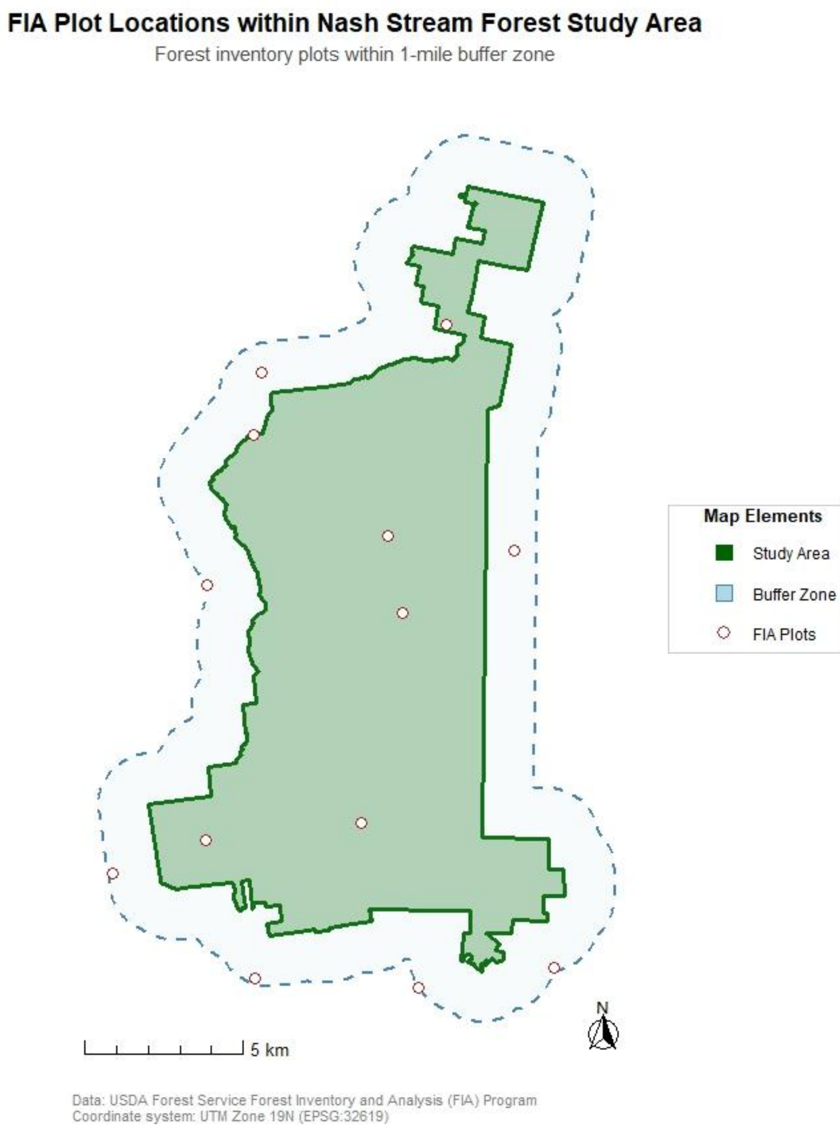


Figure 1 FIA plot locations within one mile of Nash Stream Forest. Points are fuzzed per USFS privacy protocols.

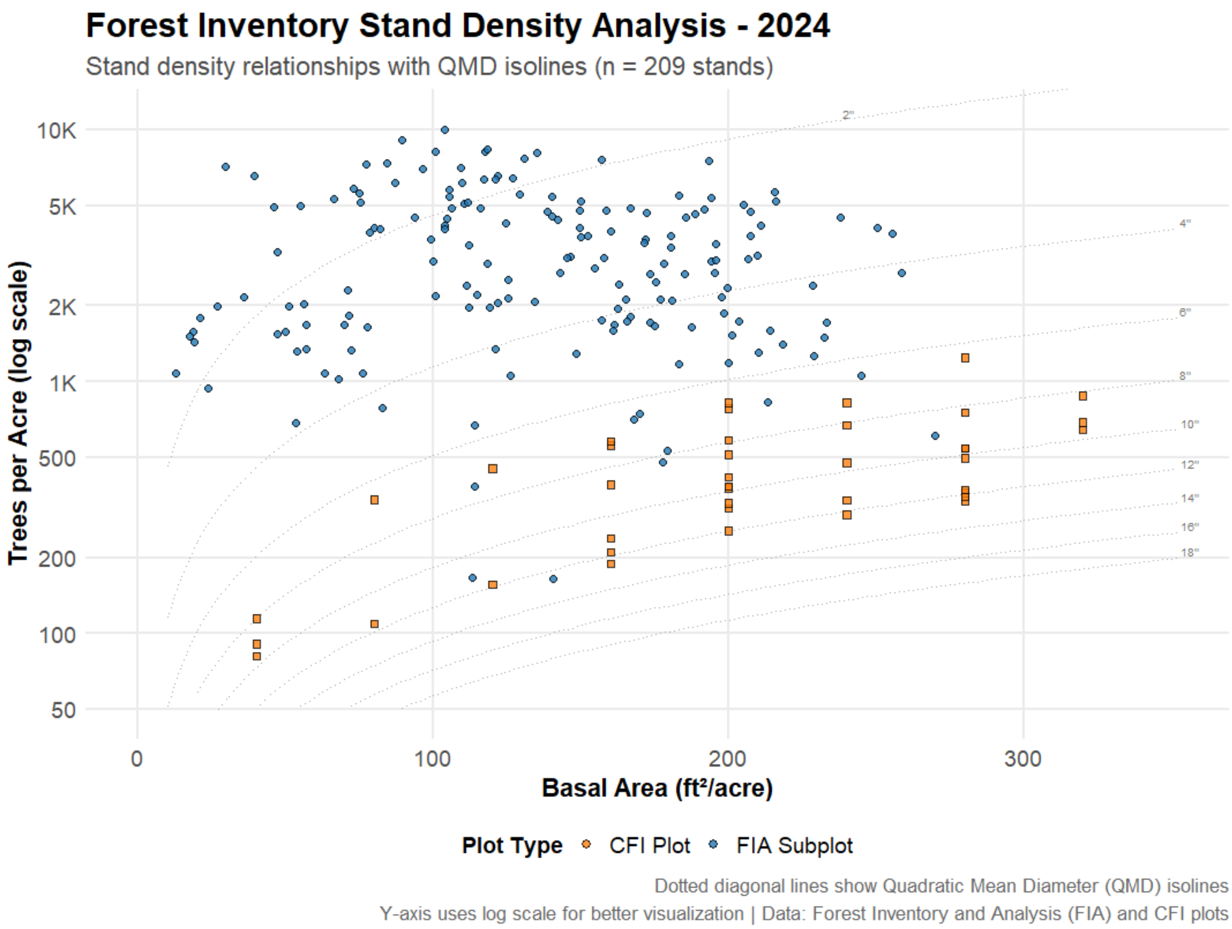


Figure 2 Stand density relationships for 209 plots. Blue points = FIA subplots within 1-mile buffer; orange points = CFI subplots.

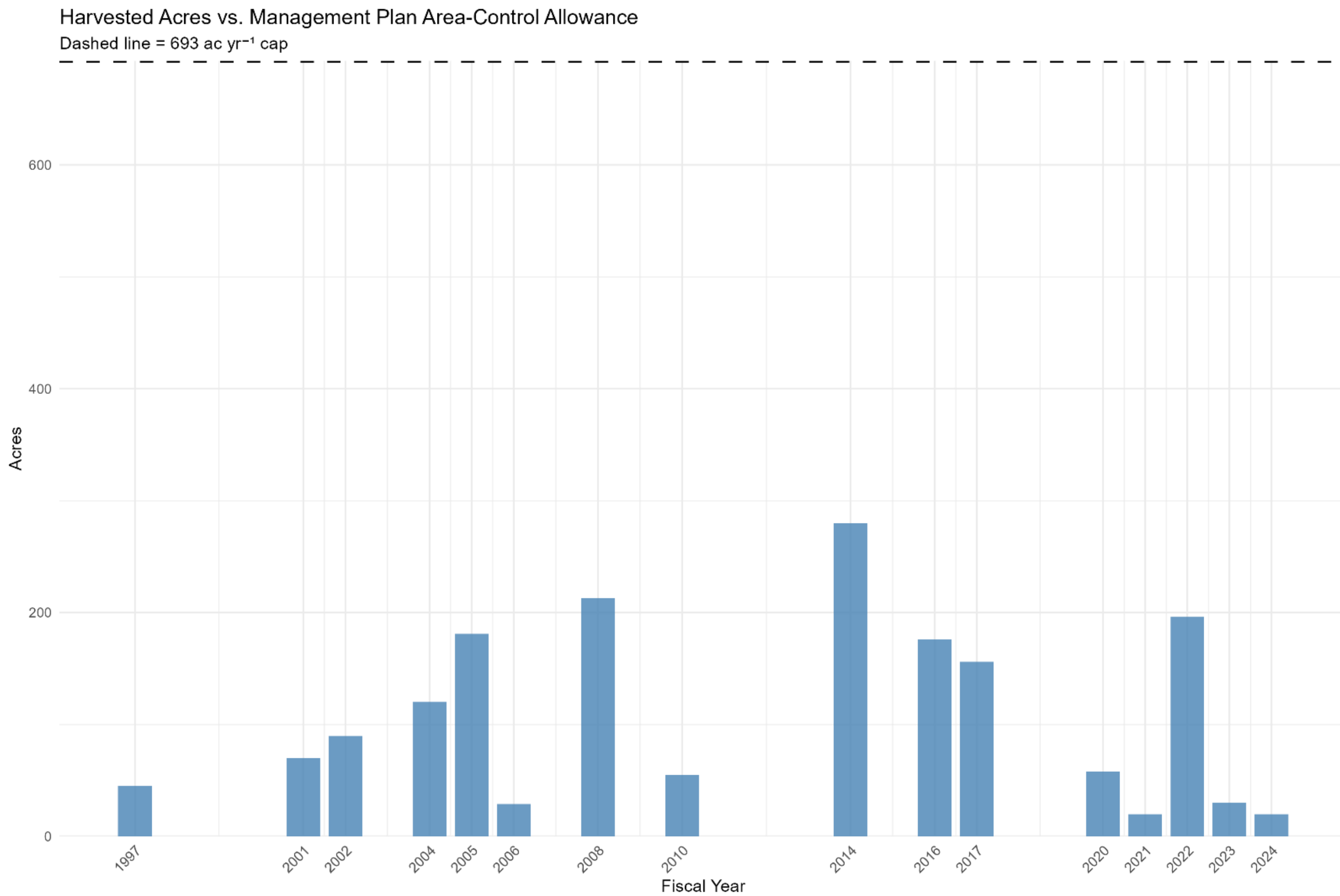


Figure 3 Harvested acres compared to the 693-acre annual cap (dashed line) defined in the 2017 Nash Stream Forest Management Plan. The Management Plan establishes an area-control system in which annual allowable treatment acreage is allocated across two silvicultural categories: 543 acres for tending/partial harvests and 150 acres for regeneration harvests, for a total of 693 acres per year (NH DFL 2017, Table 15). These acreages function as planning guidelines, not as strict annual limits, because multi-year timber sales frequently span fiscal years and treated acres do not map cleanly onto calendar boundaries.

Across the full 1997-2024 record, actual harvest activity falls far below these plan-defined reference levels. Treatment acreage averages only ~66 acres per year, roughly one-quarter of the allowable-cut area. Even in years with multiple projects, completed harvests never approach the 693-acre guideline. Accounting for the fiscal-year timing of sales and the mixture of prescriptions within individual projects does not alter this conclusion: harvest levels at Nash Stream consistently reflect a conservative, low-intensity implementation of the Management Plan relative to the acreage allocations outlined in Table 15 of that management plan.

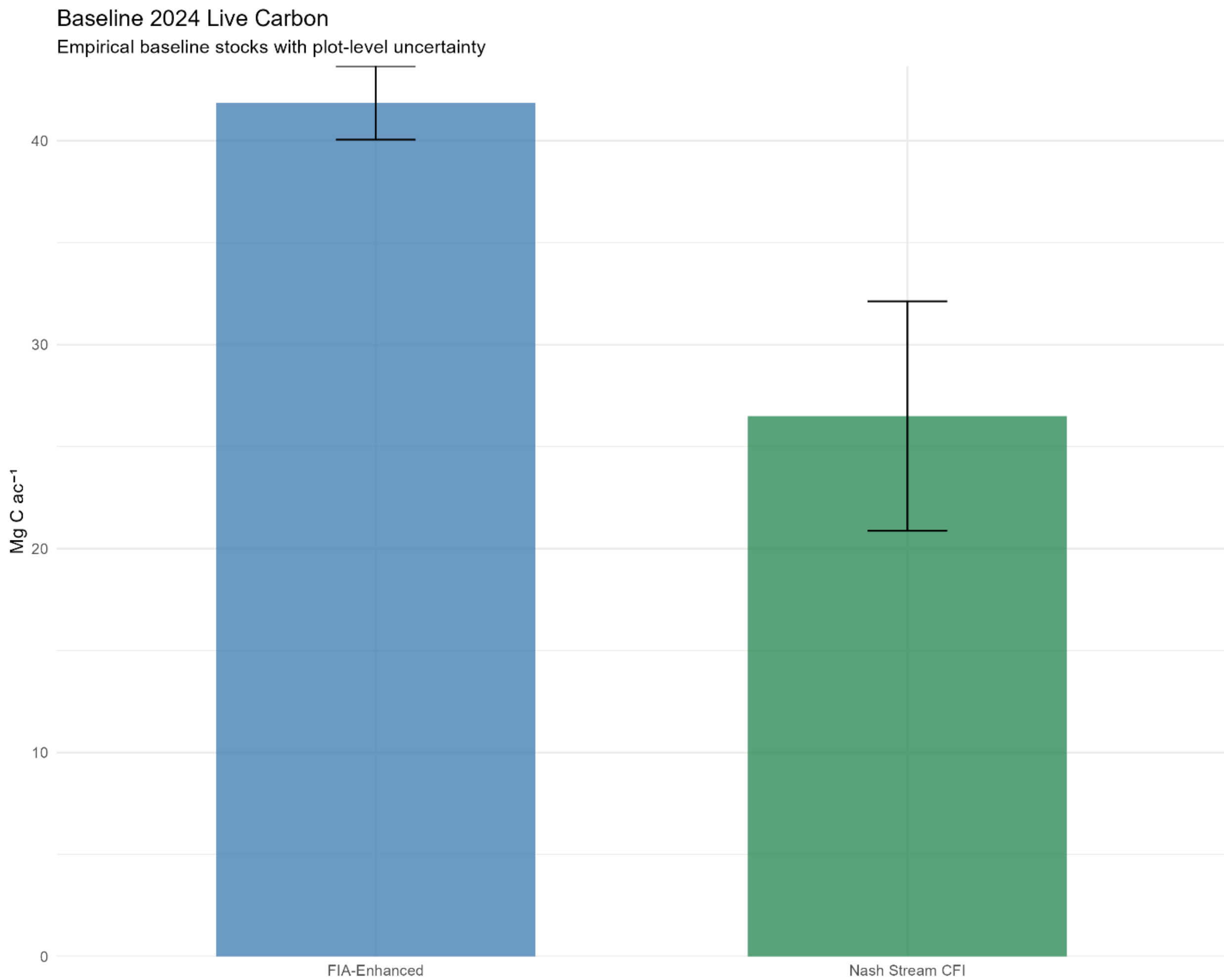


Figure 4 Baseline live carbon stocks for CFI vs FIA-CFI enhanced plots (2024). FIA plots capture denser spruce-fir strata absent in the state CFI grid.

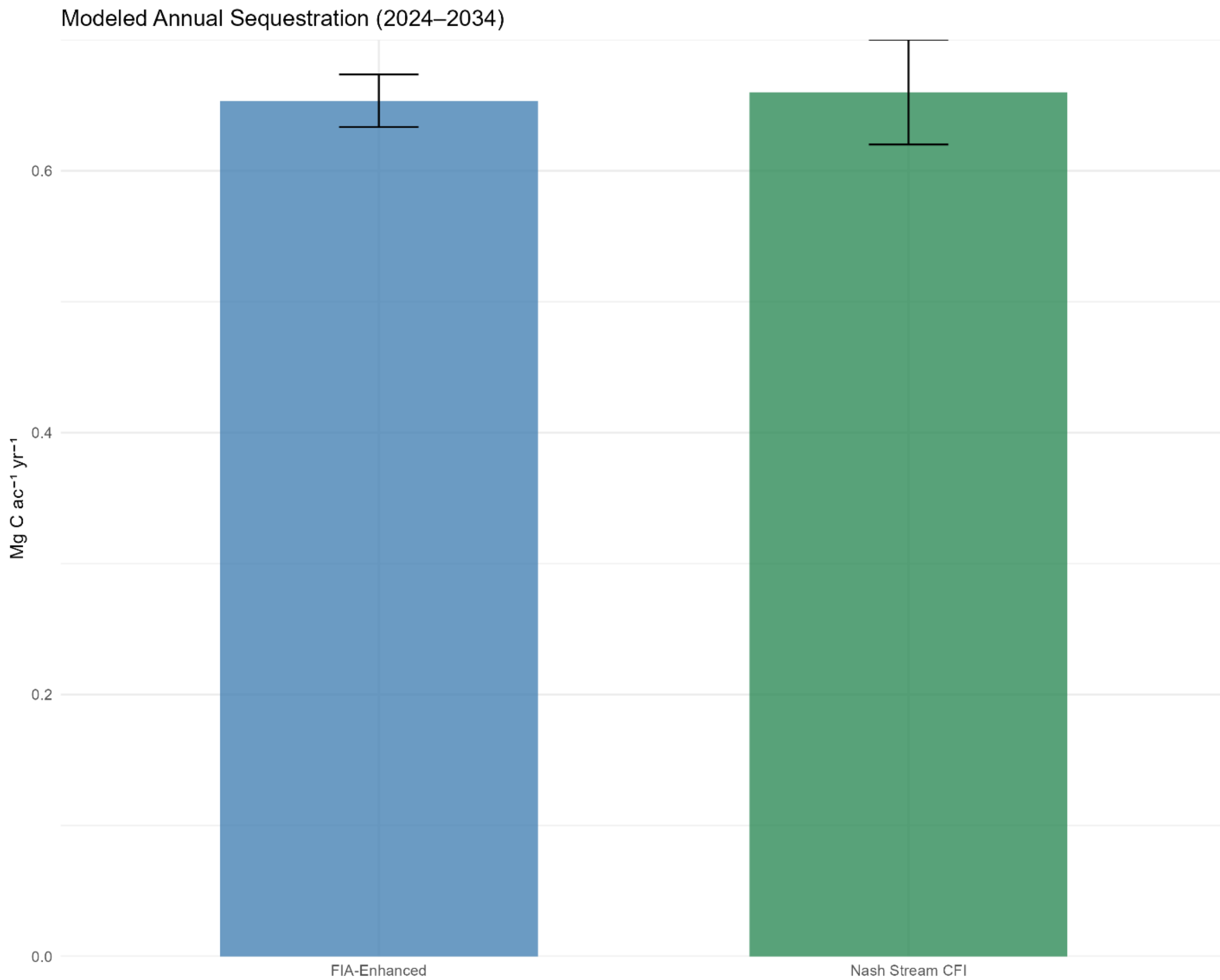


Figure 5 Modeled annual sequestration (2024-2034) showing convergence between CFI-only and FIA+CFI runs (~0.65 Mg C ac^{-1} yr^{-1} for above and below ground live carbon).

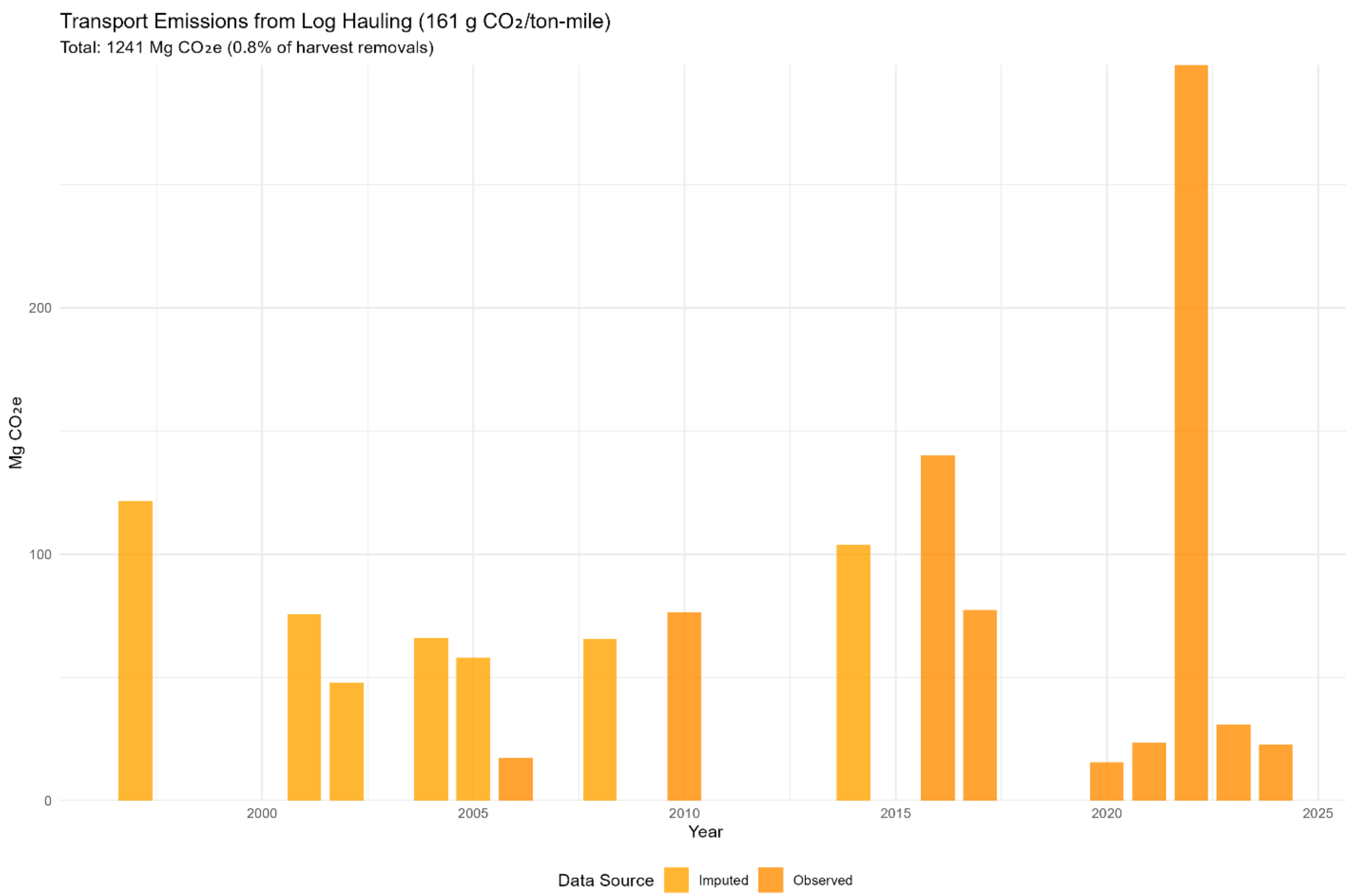


Figure 6 Estimated transport emissions (Mg CO_2) from log hauling, 1997-2024, calculated using a fixed emission factor of 161 g CO_2 ton^{-1} $mile^{-1}$. Bars represent annual totals derived from scale-slip records; darker orange indicates observed hauling distances, while lighter orange shows years for which distances were imputed using mean weighted haul lengths. Total cumulative transport emissions equal 1,241 Mg CO_2 (≈338 Mg C), representing 0.8% of cumulative harvest removals. The spike in 2022 reflects fiscal-year rollover effects that concentrated multi-year harvest operations into a single ledger year.

Carbon Balance Scenarios and Regrowth Modeling Methodology

To evaluate temporal carbon dynamics at Nash Stream Forest, we developed five management and sequestration scenarios that incorporate both static and time-varying forest area conditions. These scenarios quantify net sequestration from unharvested lands and regrowth following harvest disturbance, using a biologically grounded Chapman-Richards (CR) recovery model (Chapman 1961; Richards 1959).

Scenarios Modeled

1. All Unharvested - assumes the entire forest remains unharvested over time, with annual sequestration estimated using Continuous Forest Inventory (CFI) mean sequestration rates (*rate_cfi*).
2. Protected Only - represents sequestration on protected natural areas, held constant across time.
3. Unharvested Manageable - accounts for the shrinking pool of unharvested, non-protected acres as harvesting proceeds through time.
4. All Unharvested + Regrowth - combines scenario 1 sequestration with post-harvest regrowth flux estimated from the CR model.
5. Unharvested Manageable + Regrowth - combines scenario 3 with the CR-modeled regrowth flux, representing realistic management including both unharvested and regenerating stands.

Chapman-Richards Regrowth Model

Post-harvest carbon recovery was simulated using a lagged Chapman-Richards stock function of the form:

$$C(t) = C_{\text{resid}} + (C_{\max} - C_{\text{resid}})(1 - e^{-k(t-t_{\text{lag}})})^m$$

where $C(t)$is live-tree aboveground carbon at time t (Mg C ac^{-1}), $C_{\text{resid}}$is residual carbon immediately after harvest, $C_{\max}$is the asymptotic mature carbon stock, k is the growth constant, m is the shape parameter, and $t_{\text{lag}}$is the establishment lag (years). Annual carbon flux was derived from the discrete increment kernel $I(t) = C(t) - C(t-1)$, yielding time-since-harvest specific regrowth rates (Mg C ac^{-1} yr^{-1}).

Each harvest year's regrowth staggered in time through discrete convolution of all historical cohorts:

$$R_j = \sum_{i \le j} A_i I(j - i + 1)$$

where $R_j$is regrowth flux in year j, $A_i$is acres harvested in year i, and $I(j - i + 1)$is the CR increment corresponding to years since harvest. This approach ensures regrowth is age-structured across the landscape rather than applied to total harvested areas simultaneously.

Parameterization by Treatment Type

Parameter values were calibrated for Nash Stream's dominant forest types and management prescriptions, derived from empirical carbon recovery studies (Birdsey 1992; Smith et al. 2006; Nunery & Keeton 2010; Janowiak et al. 2017; Raymond et al. 2021).
Values used:

Table 5) Regrowth Parameters

Treatment	C_{resid}(Mg C ac^{-1})	$C_{\max}$(Mg C ac^{-1})	*k*	*m*	t_{lag}(y)	Description
Hardwood Patchcut	5	70	0.040	2.40	3	Low residuals, full regeneration lag
Softwood Patchcut	8	60	0.050	2.20	2	Faster early recovery

The dominant treatment from the harvest record determined which parameter set was applied to the landscape-wide model; in this case, group selection/thinning resulted in use of the hardwood selection parameters.

Uncertainty Estimation

Parameter uncertainty was propagated via Monte Carlo simulation (N = 200 draws per parameter set) with coefficients of variation of 10-15% for $C_{\max}, k, m$, and C_{resid}. Annual regrowth uncertainty was combined in quadrature with CFI-based sequestration uncertainty for each scenario's total flux estimate.

Data Integration and Outputs

Harvest records (1997-2024) supplied the annual harvested area and total carbon removals. Unharvested and protected area pools were updated each year as cumulative harvests accrued. The CR model provided annual regrowth flux (Mg C yr^{-1}), which was added to the unharvested sequestration pool for scenarios 4 and 5. This was only conducted on patch cut regeneration acres.

Glossary, Unit Conversions, & Key Metrics

Abbrev. / Term	**Meaning**	**Conversion / Definition**	**Notes for This Report**
Mg (megagram)	1,000 kg = 1 metric ton	1 Mg = 1.102 short tons	Standard metric unit throughout report

t C (short tons carbon)	U.S. customary unit for elemental carbon	1 t C = 0.907 Mg C	Used in legacy scale slips and mill records
Mg C ↔ Mg CO_2	Carbon-CO_2 molecular conversion	1 Mg C × 3.667 = Mg CO_2	Standard IPCC (2006) molecular ratio (44/12)
MBF (thousand board feet)	Sawlog volume measure	≈ 2.4-2.7 green tons (species dependent)	Approximate only; varies with density & log rule
FIA	Forest Inventory & Analysis (USFS)	N/A	Provides regional growth and stocking; used to calibrate FIA-enhanced FVS run
FVS	Forest Vegetation Simulator	N/A	NE Variant used for CFI and FIA-calibrated growth projections
CFI	Continuous Forest Inventory (on-property permanent plots)	N/A	Primary source of growth and mortality inputs; remeasured in 2024
t CO_2	Metric tons of CO_2 equivalent	1 t CO_2 = 0.273 t C	Used in transport emissions figure (converted to Mg C for analysis)
Whole-forest growth/removal ratio	Modeled whole-property live-pool growth ÷ combined removals	≈ 10:1	Uses total live-pool growth (~26,000 Mg C yr^{-1}) vs mean removals (2,582 Mg C yr^{-1})
Aboveground growth/removal ratio	Aboveground sequestration ÷ aboveground removals	≈ 8.2:1	Used to mirror Pisgah's aboveground-only accounting boundary
Scenario offset ratio	Sequestration in unharvested areas ÷ removals	9.9:1 (total live pools)	Follows the spatial modeling framework parallel to Pisgah
Per-entry harvest intensity	Aboveground carbon removed per harvested acre	NSF: 23.6 ± 6.0 Mg C ac^{-1}; Pisgah: ~24 Mg C ac^{-1}	Directly comparable between forests; nearly identical
Whole-property removal rate	Carbon removed averaged across entire ownership	~0.06 Mg C ac^{-1} yr^{-1}	Small because harvests occur on a small fraction of acres annually
Unharvested sequestration	Annual sequestration on all uncut acres	25,239 ± 4,057 Mg C yr^{-1}	Total live pools; used in spatial offset scenarios
Aboveground sequestration	Aboveground-only growth on unharvested land	~22,000-22,400 Mg C yr^{-1}	Used for direct comparison with Pisgah's aboveground-only boundary

Carbon Factors

Wood species recorded in slips	Birdsey forest-type line	MBF Mg C^{-1} (original)	Mg C MBF^{-1} (inverse)	Short-tons C MBF^{-1} [a]	C as % of mass [b]
Paper Birch					
Red Maple	Maple-Beech-Birch	12.48	0.0801	0.0883	0.498
White Ash					

Black Cherry **Black Birch** **Beech**					
Hardwood (generic) **Aspen** **Other Hardwood**	"Hardwood" average	12.32	0.0811	0.0894	0.498
B & W Oak (White/Black)	Oak-Hickory	21.06	0.0822	0.0907	0.498
Sugar Maple **Black & Yellow Birch** **Yellow Birch** **"Y & B" Birch (merged line)**	Northern Hardwood [c]	11.79	0.0848	0.0934	0.498
Red Oak **Black Oak**	Oak-Hickory	21.06	0.0822	0.0907	0.498
White Pine **Red Pine** **Spruce / Fir (all spp.)** [d]	Pine / Spruce-Fir	16.87	0.0593	0.0721	0.521
Hemlock [e]	Softwood (Hemlock)	18.43	0.0543	0.0599	0.521
Mixedwood	Mixedwood	15.37	0.0651	0.0718	0.51

[a] short-tons C MBF^{-1} = Mg C MBF^{-1} × 1.1023

[b] Hardwood = 0.498, Softwood = 0.521, Mixedwood = 0.510 (Birdsey 1992 component-ratio values)

[c] Birdsey lists a separate line "Northern Hardwood (Sugar Maple / Yellow Birch)" at 11.79 MBF Mg C^{-1}.

[d] Birdsey (1996) groups spruce-fir with white pine under the same 16.87 line; no separate spruce-fir factor exists in any Birdsey tables.

[e] 18.43 MBF Mg C^{-1} is the average of maple-beech-birch, oak-hickory and pine softwood factors (Birdsey note c).
Nash Stream Forest - Harvest Carbon Accounting Report

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