Developing the Visible Habitat Profile for New England Forests

A Pilot Reference-Based Structural Assessment Tool for Land Stewards

Nature's Pharmacy Project

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Abstract

Forest structure shapes the habitat available for important ecological processes such as regeneration, decomposition, and nutrient cycling. Many of the soil conditions and forest-floor processes connected with that structure are difficult for land stewards to assess directly without laboratory analysis. Visible features such as fallen deadwood, native woody species richness, and surface-litter depth are linked to these ecological functions and can be measured with ordinary field equipment. What practitioners lack is a practical basis for judging whether the values they measure are unusual for a New England forest. Drawing on regional forest data, a matched-scale forest census, and peer-reviewed ecological evidence, this project developed a pilot version of the Visible Habitat Profile (VHP), a reference-based structural assessment tool for land stewards.

The VHP establishes reference ranges for three habitat features that are ecologically meaningful, easy to measure, and responsive to forest stewardship. It allows a practitioner to translate raw field measurements into an interpretable comparison: a plot with four native woody species falls below the lower boundary of the Harvard Forest reference for the same 400 m² plot size, indicating that native woody richness may warrant greater management attention. The framework is supported by field instructions, a mobile app, a field datasheet, a workbook, and an interpretation guide, providing a practical way to record, calculate, and interpret results.

The framework places field measurements within explicit reference distributions and shows that ecological comparisons depend on how features are defined and which reference populations are used. The reference ranges are empirically derived but reflect design judgments rather than validated thresholds, and they can be revised as field use reveals areas for refinement in measurement, reference matching, and interpretation.

An independent northeastern dataset was used to explore whether the same measurements were associated with soil microbial biomass; it was not used to set the reference ranges. A four-site pilot field study was designed to test whether independent observers obtain reproducible VHP range classifications using the same standardized field protocol. In the completed pilot, the two observers assigned the same Low, Typical, or High classification on 8 of 8 paired plots for native woody richness and on 7 of 8 paired plots for both coarse woody debris volume and surface-litter depth, which meet the 6-of-8 reproducibility standard.

The Project demonstrates how existing ecological research and datasets can be adapted for practical field assessment. By synthesizing these materials and developing field protocols matched to the reference data, the VHP provides a pilot framework for giving practitioners usable information about visible habitat features, a first step toward bringing soil-related considerations into routine forest stewardship.

1. Introduction

Nature's Pharmacy Project (the "Project") began by considering the connection between forest soils and human health. Soil microbial communities help drive decomposition and nutrient cycling and have historically been an important source of antibiotic compounds. Yet these communities are not visible in routine forest assessment and are expensive to assess directly in the laboratory.

Research increasingly shows that aboveground forest features are linked to belowground microbial communities and forest-floor processes (Lang et al. 2023). This raised a practical question: could visible forest features that are ecologically relevant to those processes form the basis of an assessment framework for land practitioners?

Drawing on peer-reviewed temperate-forest research, forest census data, and regional forest inventory data, the Project evaluated candidate habitat features based on ecological relevance, practicality of field measurement, responsiveness to forest management, and availability of an appropriate basis for comparison. Existing forest monitoring programs contain extensive data, but their measurements are not automatically comparable with those collected by a practitioner. Establishing a useful reference therefore requires matching both the habitat feature and the way it is measured as closely as possible, while also accounting for differences in spatial scale and sampling design.

The Project developed a pilot version of the **Visible Habitat Profile (VHP)**, which establishes standardized field protocols and reference ranges for three visible forest habitat features: native woody richness, coarse woody debris (CWD) volume, and identifiable surface-litter depth. These features were selected because the ecological literature links them, to differing degrees, with microbial biomass, fungal properties, enzyme activity, community composition, decomposition, moisture, and other forest-floor processes. Just as importantly, each can be measured using simple field methods, interpreted against existing forest data, and influenced through forest stewardship, including decisions about native regeneration, deadwood retention, invasive woody vegetation, and forest-floor disturbance.

The Project comprised four linked components that develop and initially test this pilot framework. First, the literature was reviewed to establish ecological relevance and measurement limitations of the three features. Second, comparable forest datasets were used to establish Low, Typical, and High reference ranges for each measurement. Third, an independent northeastern dataset from the National Ecological Observatory Network (NEON) was used to explore whether these habitat measurements were associated with microbial biomass. Fourth, a four-site field study was designed to test whether independent observers obtain reproducible VHP range classifications using the same field protocol.

2. Evidence Basis for the Three Measurements

The literature review screened roughly 245 peer-reviewed sources, of which 93 were retained for detailed annotation in the accompanying bibliography. The review was used to evaluate the ecological relevance of candidate habitat features, the ways those features have been measured in previous research, and the limitations affecting how the measurements can be interpreted. Supportive, null, contradictory, and qualifying findings were retained so that feature selection reflected the balance of the evidence rather than only positive results.

2.1 Native woody richness

Plant diversity influences forest soils through differences in roots, root exudates, litter chemistry, host species, and mycorrhizal associations. A synthesis of 106 studies found that mixed plant communities supported about 12.5% more total soil microbial biomass than monocultures (Chen et al. 2019). In a temperate tree-diversity experiment, Khlifa et al. (2017) found that greater tree richness affected several measures of microbial function. The evidence therefore supports native woody richness as an ecologically relevant habitat feature.

2.2 Coarse woody debris

Downed wood provides substrate for decomposers, retains moisture, and influences local forest-floor conditions. Kim et al. (2017) found greater soil moisture beneath experimental wood pieces, while Perreault et al. (2021) found that downed wood could alter temperature and bacterial community composition. At the plot scale, Rousseau et al. (2025) found that ground-lying deadwood volume explained about 1–3% of variation in microbial community composition. The evidence therefore supports CWD as an ecologically relevant habitat feature.

2.3 Identifiable surface-litter depth

Long-term litter-manipulation experiments show that forest-floor inputs can strongly affect belowground processes. At Harvard Forest, 23 years of litter manipulation produced large differences in fungal biomass (Rousk & Frey 2015), while 20 years of litter addition increased two extracellular enzyme activities by roughly 30% (Lajtha et al. 2014). A global forest synthesis by Jing et al. (2021) found that removing aboveground litter reduced total microbial biomass by 4.9% overall and also altered microbial community composition. The evidence therefore supports surface litter as an ecologically relevant habitat feature.

2.4 Design implication

The literature supports measuring all three features because each is connected to important forest-floor conditions and processes. Native woody richness reflects differences in roots, litter, and tree species; deadwood provides substrate and helps retain moisture; and surface litter supplies organic material and affects forest-floor conditions. However, the research did not identify specific values at which microbial conditions clearly change. The VHP therefore sets its Low, Typical, and High ranges using the distributions found in the reference data, rather than treating any particular value as an ecological cutoff.

3. Methods

3.1 Framework design, interpretation rule, and pilot assumptions

For this pilot version of the VHP, the same rule is used to define the reference ranges for all three measurements. For each reference dataset, the 25th percentile (Q1) and 75th percentile (Q3) are used as the boundaries between Low, Typical, and High. Values below Q1 are classified as Low, values from Q1 through Q3 as Typical, and values above Q3 as High. The three measurements are reported as a habitat profile. Other site conditions may be noted separately when useful for interpretation, but they are not standardized VHP measurements and do not change a measurement's range.

The pilot VHP necessarily incorporates several provisional design assumptions. It assumes that the selected reference populations are useful comparators, that the Low, Typical, and High classes provide a practical way to interpret the measurements, and that the three selected habitat features provide a useful, though incomplete, structural profile. These assumptions are part of the first pilot version and are intended to be tested and revised through field use and subsequent research.

3.2 Native woody richness reference

Native woody richness was derived from the Harvard Forest ForestGEO 35-ha Forest Dynamics Plot. The census was divided into 875 non-overlapping 20 × 20 m quadrats, exactly matching the 400 m^2 plots used in the field protocol. A species was counted when at least one living woody stem reached 1 cm diameter at breast height (DBH), matching the census threshold. Non-native woody species were excluded from the richness count; they are not systematically measured in the core VHP field protocol.

Across the 875 quadrats, the native-woody richness distribution had Q1 = 6, a median of 9, and Q3 = 11 species per 400 m^2 plot. These values produced VHP ranges of <6, 6–11, and >11 species. Because all quadrats come from a single 35-ha forest, this reference represents variation within one mature, protected, long-unharvested second-growth forest rather than across the New England region. The plot also contains a beaver swamp covering 87 quadrats (3.5 ha), so the analysis was repeated after excluding those quadrats. The Low and High boundaries remained 6 and 11 species, while the median shifted only from 9 to 8.

3.3 Coarse woody debris and litter reference

Coarse woody debris and litter depth were derived from the USDA Forest Service Forest Inventory and Analysis (FIA) Down Woody Materials inventory. The final reference set contains 185 single-condition hardwood and mixed-forest plots: 61 in Vermont, 60 in New Hampshire, 35 in Massachusetts, 25 in Connecticut, and 4 in Rhode Island. For each plot, the most recent eligible measurement was retained, spanning 2005–2025. Maine was excluded because its measured forest-floor values were substantially lower than those of the retained states, consistent with its different regional forest composition and environmental setting.

Identifiable surface-litter depth was taken from FIA LITTER_DEPTH and converted from inches to centimetres (×2.54). Coarse woody debris volume was taken from CWD_VOLCF_ADJ and converted from ft^3/acre to m^3/ha (×0.06997). Thirteen plots with no qualifying coarse woody debris were retained as genuine zero-volume observations rather than treated as missing data.

Reference-range stability was assessed by repeating the calculations across alternative FIA subsets based on land reservation status, ownership, measurement year, and forest type. Across these checks, litter boundaries changed by no more than 0.06 cm and coarse woody debris boundaries by no more than about 2.4 m^3/ha. The reference datasets and calculation files were retained so the reported ranges can be traced to their source data.

The FIA deadwood reference values were checked against the individual pieces of wood recorded in the inventory. Piece-level data from Connecticut, Massachusetts, New Hampshire, Rhode Island, and Vermont were matched to the 185 reference plots, producing 999 individual records. Deadwood volume was then recalculated from the diameter of each piece where it crossed the sampling line, using the transect length required by the FIA protocol in effect at the time. Plots measured before the 2012 protocol change used 87.78 m of transect, while later plots used 58.52 m. The 13 plots with no recorded pieces were checked against the original FIA data and confirmed as genuine zero-volume plots before the reference distribution was recalculated.

3.4 Construct matching between reference data and field protocol

Reference datasets were selected based on how closely their measurements corresponded to the VHP field quantities. Native woody richness was matched directly in plot area and inclusion definition: the 400 m² field plot matches the census quadrat area, and both use the same 1 cm minimum stem threshold. FIA CWD and litter data measure the same underlying quantities used by the VHP, but the FIA sampling layouts differ from the simplified practitioner protocols. These comparisons are therefore treated as sufficiently comparable reference measurements rather than identical field methods.

For native woody richness, practitioners count native trees, shrubs, and woody vines in a 20 × 20 m plot when at least one stem reaches 1 cm diameter at breast height (1.37 m). This directly matches the reference census in plot area and stem-size threshold. Using a consistent size threshold matters because counting every species present can produce much higher richness values.

For coarse woody debris, both FIA and the VHP use line-intercept sampling and the same approximate 7.6 cm minimum diameter threshold. FIA uses a more extensive transect layout and includes some shorter pieces, while the VHP uses two 20 m transects crossing the plot centre and counts pieces at least 1 m long. The VHP is therefore somewhat more restrictive than the FIA reference method. Volume is calculated from the diameters of pieces crossing the transects.

For litter, both FIA and the VHP measure identifiable surface-litter depth above the more decomposed organic layer. FIA samples this quantity at more points across its plot (U.S. Department of Agriculture, Forest Service 2025). The VHP measures loose, recognisable plant material at the plot centre and at four points 1 m away in the cardinal directions, then averages the five readings. Measurements are avoided within 48 hours of substantial rainfall where possible; if they cannot be postponed, recent rainfall is recorded.

3.5 Exploratory microbial analysis

The National Ecological Observatory Network (NEON) provided an independent opportunity to examine whether the three structural measurements were associated with soil microbial biomass. NEON measurements of plant composition, coarse downed wood, and litter were matched by plot identifier with soil microbial biomass data across 18 northeastern hardwood plots, nine at Harvard Forest and nine at Bartlett Experimental Forest. The analysis used 2022 organic-horizon microbial biomass as the response, accounted for site, and included seasonal, longer-term, and measurement-sensitivity checks.

The analysis was exploratory and was not used to select or adjust the reference ranges. The reference distributions show where a plot falls structurally, while the NEON analysis examines whether the same simple measurements are also associated with microbial biomass in an independent northeastern dataset.

3.6 Pilot field study design and classification reproducibility check

A four-site pilot field study was designed to see whether independent observers using the same VHP protocol would produce the same Low, Typical, or High classifications. Two of the four sites, Fox Forest and Newbury Logged, are actively managed, while the other two, Newbury Preserved and Sheldrick Preserve, are undisturbed. Two 20 × 20 m plot centres were randomly located within each site using GIS, with at least 50 m between plots, for eight plots in total. Any necessary adjustments made in the field were recorded.

Within each plot, practitioners measure native woody richness, coarse woody debris, and surface litter using the methods described above. Other notable site conditions may be recorded in plot notes when useful for interpretation, but they are not required measurements in the pilot. At every plot, a second observer independently repeats all three measurements without seeing the first observer's results, giving eight paired plots. For each measurement, observer agreement is assessed by comparing the resulting Low, Typical, or High classifications. A classification is considered reproducible if both observers place the measurement in the same range on at least 6 of the 8 paired plots. For every CWD crossing, observers record its position along the transect to the nearest 0.1 m so that the same pieces can be matched between observers.

4. Results

4.1 Reference ranges

Measurement	Low / Typical / High	Reference dataset
Native woody richness (species per 400 m²)	<6 / 6–11 / >11	Harvard Forest ForestGEO census, 875 quadrats within one 35-ha plot
Coarse woody debris (m³/ha)	<8.4 / 8.4–46.7 / >46.7	USDA FIA, 185 plots, New England excluding Maine
Identifiable surface-litter depth (cm)	<2.2 / 2.2–3.5 / >3.5	USDA FIA, same 185 plots

Table 1. Reference ranges for the three field measurements. Each boundary is the first or third quartile of the stated reference distribution.

4.2 Reference range checks and CWD verification

The reference boundaries remained largely unchanged across the sensitivity checks. Removing the beaver-swamp quadrats did not change the native-richness boundaries, and alternative FIA subsets produced only small changes in the litter and CWD boundaries.

The coarse woody debris reference values were also checked against the individual pieces recorded by FIA. Piece records were available for 172 of the 185 reference plots, and the remaining 13 plots were confirmed as genuine zero-volume observations. Recalculating CWD volume from the individual pieces produced nearly the same distribution as the FIA plot-level values, with quartile boundaries of 8.84 and 47.87 m³/ha compared with 8.42 and 46.65 m³/ha in the original data. This supports the CWD reference ranges reported in Table 1.

FIA piece records could not be used to estimate the effect of the VHP's 1 m minimum length. Length was not recorded for pieces measured under the current FIA protocol, while the earlier records did not include pieces shorter than 0.91 m.

4.3 Exploratory microbial analysis

In the 18 NEON plots, no clear relationship was evident between microbial biomass and either native woody richness or coarse woody debris. Surface-litter depth showed a possible positive relationship, but this pattern was not consistent across additional analyses.

4.4 Field study: classification reproducibility

Eight 20 × 20 m plots were established across the four sites (two per site), and the two observers independently measured all three features on every plot, giving the eight paired plots used for the reproducibility check (Table 2; Figure 1).

For native woody richness, the two observers assigned the same classification on 8 of 8 paired plots. Observer counts never differed by more than one species (median absolute difference, 1 species), and no paired difference moved a plot across a range boundary.

For coarse woody debris volume, classifications agreed on 7 of 8 paired plots, with a median absolute between-observer difference of 2.4 m^3/ha (range 0.9–9.6 m^3/ha). The disagreement was a boundary-straddling case at plot 1F, where volumes of 7.3 m^3/ha (Observer 1) and 9.0 m^3/ha (Observer 2) fell on opposite sides of the 8.4 m^3/ha lower boundary. Matching individual crossings by their recorded transect positions showed that both observers detected the same three pieces at this plot, so the disagreement arose from differences in the measured crossing diameters rather than from missed pieces. At one other plot (2F), Observer 2 did not record an 8.0 cm crossing recorded by Observer 1; both observers nonetheless classified that plot as Low.

For identifiable surface-litter depth, classifications agreed on 7 of 8 paired plots, with a median absolute difference of 0.2 cm in five-point mean depth (maximum 0.3 cm). The disagreement was again boundary-straddling: at plot 1P, mean depths of 3.7 cm (Observer 1) and 3.4 cm (Observer 2) fell on opposite sides of the 3.5 cm upper boundary. Within-plot variation among the five replicate litter readings was modest, with the range of the five readings spanning 0.5–1.0 cm across all sixteen plot visits.

All three measurements therefore met the 6-of-8 reproducibility criterion, with both classification disagreements occurring where raw values close to a quartile boundary fell on opposite sides of it.

Plot	Site	Native woody richness (spp / 400 m^2)	CWD volume (m^3/ha)	Litter depth, mean of 5 (cm)
1F	Fox Forest	5 / 5 Low / Low	7.3 / 9.0 Low / Typical	1.2 / 1.4 Low / Low
2F	Fox Forest	6 / 6 Typical / Typical	6.8 / 5.8 Low / Low	0.8 / 1.0 Low / Low
3L	Newbury Logged	7 / 6 Typical / Typical	21.9 / 24.4 Typical / Typical	3.0 / 2.8 Typical / Typical
4L	Newbury Logged	6 / 7 Typical / Typical	29.5 / 27.3 Typical / Typical	3.2 / 3.0 Typical / Typical
1P	Newbury Preserved	9 / 8 Typical / Typical	54.1 / 59.0 High / High	3.7 / 3.4 High / Typical
4P	Newbury Preserved	8 / 9 Typical / Typical	60.8 / 51.2 High / High	3.8 / 3.9 High / High

Plot	Site	Native woody richness (spp / 400 m²)	CWD volume (m³/ha)	Litter depth, mean of 5 (cm)
1S	Sheldrick Preserve	8 / 8 Typical / Typical	49.0 / 51.7 High / High	3.2 / 3.4 Typical / Typical
2S	Sheldrick Preserve	7 / 8 Typical / Typical	37.8 / 35.9 Typical / Typical	3.0 / 3.1 Typical / Typical

Table 2. Paired observer measurements and range classifications for the eight pilot plots. Values and classifications are shown as Observer 1 / Observer 2; classifications follow the Table 1 reference ranges.

4.5 Field measurements

Across the eight plots (Observer 1 values), native woody richness ranged from 5 to 9 species per 400 m² (mean 7.0), coarse woody debris volume from 6.8 to 60.8 m³/ha (mean 33.4), and mean surface-litter depth from 0.8 to 3.8 cm (mean 2.7). Against the reference ranges, richness was Typical on seven plots and Low on one; CWD volume was Low on two plots, Typical on three, and High on three; and litter depth was Low on two plots, Typical on four, and High on two.

The plot-level pattern was consistent across measurements. The two Fox Forest plots produced the lowest values for all three measurements and account for every Low placement, while the two Newbury Preserved plots and one Sheldrick Preserve plot exceeded the upper CWD boundary, and the Newbury Preserved plots also carried the deepest litter. Figure 1 shows the paired measurements for each plot against the reference ranges, and Table 2 lists the plot-level values and classifications.

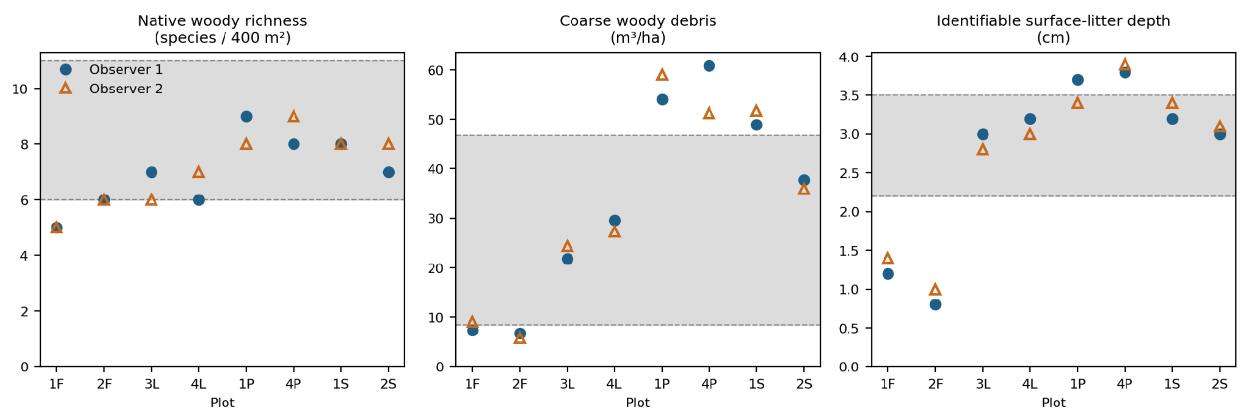

Figure 1. Paired observer measurements for the eight pilot plots. Shaded bands show the Typical range for each measurement; dashed lines mark the Q1 and Q3 reference boundaries from Table 1.

5. Discussion

5.1 What the ranges show

The main value of the VHP is that it gives individual field measurements meaning by comparing them with forest reference data. The meaning of each comparison depends on the reference population. For native woody richness, the ranges describe variation within one mature, protected forest at Harvard Forest. For coarse woody debris and litter, they describe variation across a regional FIA inventory that includes managed and unmanaged forests across New England, excluding Maine.

Although the pilot was designed to test reproducibility, Values also differed between preserved and managed sites in the direction you might expect: preserved plots generally scored higher on all three measurements, most clearly for CWD volume.

5.2 Measurement definition is central to comparability

A reference range is only useful when the field and reference measurements are sufficiently comparable. Small changes in measurement definitions can produce very different values. Counting woody species regardless of stem size roughly doubled richness, while including the deeper decomposed organic layer produced much greater depth values than measuring surface litter alone. Deadwood estimates also change with the minimum piece size included. The NEON analysis showed the same problem for litter: the possible relationship with microbial biomass found using surface-litter depth disappeared when the deeper organic layer was included. For that reason, the VHP field instructions define exactly what is included in each measurement and at what scale it is measured.

5.3 What the pilot framework delivers to a practitioner

In its current pilot form, the VHP produces a standardized three-part habitat profile. In each 20 × 20 m plot, native woody richness, CWD volume, and identifiable surface-litter depth are recorded using definitions designed to remain comparable with the reference data. The workbook keeps the raw measurement and shows whether it is Low, Typical, or High compared with the forest data used to create the range. Non-native woody species and other notable contextual conditions may be recorded in plot notes where useful for interpretation, but do not affect the classification.

A Low, Typical, or High result is a starting point for identifying which habitat features may need attention. For example, a low deadwood value might prompt a closer look at how fallen wood is being managed. A low native-richness value might prompt a closer look at invasive woody vegetation. A low litter-depth value might reflect rapid decomposition or recent disturbance.

The pilot VHP is supported by a set of practitioner materials. These include field measurement instructions, the Field Tracker app and field datasheet for recording measurements at the plot, an interpretation guide, and a workbook for compiling and reviewing results. These materials allow practitioners to use the framework without consulting the underlying datasets or scientific literature and without performing their own conversions.

5.4 Limitations and future work

The VHP is a pilot framework, and further field use and testing will be needed to determine which parts work as intended, which need to be changed, and whether the overall approach is useful in practice.

Several central design choices still need to be tested. This study does not establish that Harvard Forest and the five-state FIA dataset are the best reference populations, that the 25th and 75th percentiles are the most useful boundaries for Low, Typical, and High, or that the three measurements provide a complete picture of forest habitat condition. The pilot makes these choices explicit so they can be evaluated and changed if needed.

In particular, the native-richness range is based on 875 20 × 20 m sampling areas within a single forest at Harvard Forest, so it is not yet known how well the same range applies elsewhere in New England. The VHP and FIA also use slightly different minimum-length rules for coarse woody debris. The VHP counts pieces at least 1 m long, while the FIA reference can include shorter pieces. The available FIA data do not show how much this difference affects CWD volume or reference-range placement, so this will need to be tested through additional field work. The reproducibility check is also limited to eight paired plots across four sites, so broader testing will be important.

Ultimately, future work will need to directly test the relationship between the three habitat measurements and soil microbial conditions by collecting habitat and soil data at the same locations across a wider range of forest conditions. This is necessary to determine whether the VHP's visible habitat measurements can reliably tell practitioners something about the belowground conditions that remain at the core of this Project.

6. Conclusion

This Project developed the Visible Habitat Profile as a practical way for land stewards to measure three forest habitat features, interpret those measurements against explicit reference data, and use that information to inform management decisions. Measurements of native woody richness, coarse woody debris volume, and identifiable surface-litter depth can each be collected with simple field tools in a 400 m^2 plot, without requiring laboratory analysis or specialized equipment. The pilot also provided an initial test of whether the protocol could be applied consistently by different observers. Although limited in scope, all three measurements met the Project's reproducibility criterion across the pilot's eight paired plots. The Project demonstrates how existing ecological research and datasets can be used to create practical tools for practitioners, a first step toward making soil-related considerations part of routine forest stewardship.

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