

UNIVERSAL DECLARATION OF TREE RIGHTS

GLOBAL FOREST ATLAS

Scientific Protocol

Framework for Identification, Classification, Evidence, Validation, and Temporal Monitoring of Forest Ecosystems

DOCUMENT STATUS

Version 0.1.4 - succession, biological legacies, and post-disturbance interpretation consolidation revision. Prepared for structured external scientific review. This document operationalizes the Global Forest Atlas doctrine as revised on 25 August 2026 and preserves the Version 0.1.3 integrity / degradation framework while adding a targeted distinction between characteristic natural post-disturbance succession / seral state and reference-dependent recovery. The revision is informed by further critical scientific exchange with Dominick A. DellaSala and examination of additional published materials, including DellaSala et al. (2014), DellaSala (2020) on fire-mediated biological legacies, and DellaSala (2020), Forest Biome: Trees of Life. Inclusion of comments or publications does not imply endorsement by the scientists or institutions cited.

VERSION 0.1.4

25 August 2026

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Project initiated by Ricardo Rey within the work of La Compagnie des Papillons Bleus, the official steward organization of the Universal Declaration of Tree Rights. The Global Forest Atlas is conceived as an independent international scientific instrument whose scientific, methodological, and institutional governance must remain autonomous.

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Document Control

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Status	Succession, biological-legacies and post-disturbance interpretation consolidation revision for external scientific review
Origin and preparation framework	Project initiated by Ricardo Rey within the work of La Compagnie des Papillons Bleus.
Institutional status of the Atlas	Independent international scientific instrument in development; autonomous scientific, methodological, and institutional governance.
Primary language	English
Intended use	Methodological foundation for progressive development of the Global Forest Atlas and associated scientific annex; capable of use by the Declaration, Convention, or other instruments without institutional subordination.
Legal effect	None by itself; ecological, scientific, interpretive, informational, and programmatic. Outputs may constitute relevant scientific evidence for competent authorities.
Supersession rule	Version 0.1.4 supersedes Version 0.1.3 for current use. Earlier versions remain archived; later versions must state what they supersede and preserve public change history.

Version History

Version	Date	Status	Principal change
0.1	12 Aug 2026	Foundational protocol	Initial evidence architecture, provisional confidence system, and pilot criteria.
0.1.1	14 Aug 2026	Alignment revision	Doctrine / Convention alignment; strengthened primary-forest definition; precaution; governance autonomy; legal-effect separation.
0.1.2	18 Aug 2026	Restoration alignment	SER-aligned restoration / recovery terminology; native ecosystem; reference model / site; rehabilitation; natural / assisted regeneration; six-attribute crosswalk.
0.1.3	24 Aug 2026	Integrity / degradation consolidation	Degradation definition and reference hierarchy; degradation PCIV; disturbance-regime rule; recovery provenance; gross loss; roads; risk / vulnerability; recovery / carbon debt; non-forest safeguards.
0.1.4	25 Aug 2026	Succession / legacies consolidation	Separates characteristic natural post-disturbance succession / seral state from reference-dependent recovery; strengthens biological-legacies interpretation, dynamic seral reference models, recovery-debt safeguard, seral-state recording, and pilot tests; adds DellaSala 2014/2020 sources.
0.2	To be determined	Planned review version	Structured external scientific comments, pilot-testing results, and methodological corrections.
1.0	To be determined	Future consolidated protocol	After scientific review, pilot testing, and formal methodological approval under autonomous governance.

INTERPRETIVE RULE

Version 0.1.4 remains intentionally conservative. It preserves the safeguards of Version 0.1.3 and adds a limited succession / seral-state consolidation following further critical scientific exchange with Dominick A. DellaSala and examination of additional published materials. It does not treat natural disturbance or an early-seral condition as degradation or recovery by default, and it still imposes no universal numerical thresholds.

Executive Summary

The Global Forest Atlas is conceived as an evolving, spatially explicit, temporal, and evidentiary system. Its purpose is not merely to show where tree cover occurs. It must distinguish the ecological identity of forest and tree-based systems, their present condition, integrity, historical continuity, management, disturbances, trajectory, carbon characteristics, landscape and governance context, uncertainty, and decision needs.

The Atlas is conceived as an independent international scientific instrument. Its scientific, methodological, and institutional governance must remain autonomous from the bodies of the Declaration, the International Convention on Tree Rights, States, funders, and data providers. Recognition or use of the Atlas by any such actor confers no authority to direct its classifications, assessments, or publication decisions.

Its primary function is scientific knowledge, ecological qualification, longitudinal assessment, and transparent documentation of forest ecosystems and their trajectories. It is not a police service, an administrative authorization system, or a compliance body. Detection of logging, conversion, degradation, or another pressure may be one output of its scientific work without defining its institutional purpose.

This Protocol translates that ambition into operational rules. It establishes a common architecture for spatial units, classification dimensions, evidence types, metadata, reference models and reference sites, uncertainty, confidence, review, contestability, versioning, scientific governance, and data governance. It also sets boundaries on what the Atlas may infer from incomplete evidence, what remote sensing may and may not establish, and what classifications require field validation or independent expertise.

CORE COMMITMENT

Map what is known. State what is uncertain. Preserve what cannot be replaced. Follow ecological trajectories through time.

Version 0.1.4 retains the primary-forest safeguards introduced in Version 0.1.1, the restoration-methodology alignment introduced in Version 0.1.2, and the integrity / degradation consolidation introduced in Version 0.1.3. Ecological restoration remains the process of assisting recovery of a native ecosystem; recovery remains an outcome that must be demonstrated against an explicit reference; reference models remain distinct from reference sites; and the SER six-attribute crosswalk remains interoperable rather than controlling.

The 24 August 2026 consolidation remains in force: forest degradation is treated as immediate or long-term anthropogenic deterioration of ecosystem integrity relative to an ecologically appropriate reference condition; natural disturbance within a characteristic regime is not automatically degradation; severity alone is insufficient; gross integrity losses remain visible; disturbance origin remains separate from degradation causality; and risk / vulnerability remain autonomous prospective dimensions.

The 25 August 2026 revision adds a succession-before-recovery rule. A natural disturbance operating within the characteristic regime may initiate functional post-disturbance succession or an early-seral state rich in biological legacies and biodiversity, without implying that the forest is degraded or 'recovering'. Recovery terminology is reserved for cases in which a material ecological loss or deficit relative to an appropriate reference has been established. The Protocol therefore records seral state explicitly, strengthens biological-legacies interpretation, treats reference models as dynamic across characteristic seral phases, and prohibits assigning recovery debt merely because a natural post-disturbance state differs from the preceding mature state.

The Protocol complements, rather than displaces, statistical definitions, national inventories, ecosystem typologies, restoration standards, biodiversity datasets, remote-sensing products, tenure systems, and protected-area frameworks. Original source categories remain identifiable. Version 0.1.4 retains the provisional confidence scale, review and correction process, and pilot-testing strategy across contrasting forest systems before global operational deployment.

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1. Purpose, Scope, and Status

1.1 Purpose. This Protocol establishes the minimum methodological conditions under which ecological information may be incorporated, interpreted, classified, displayed, reviewed, and revised within the Global Forest Atlas. It is intended to create a transparent chain between a mapped statement and the evidence that supports it.

1.2 Scope. The Protocol applies to forest ecosystems, forest recovery areas, production-oriented tree plantations, agroforestry systems, and other tree-based systems where those categories are relevant to distinguishing forest ecological identity. It also applies to associated landscape, hydrological, carbon, disturbance, risk, vulnerability, governance, and rights information insofar as those dimensions are necessary to interpret forest condition and trajectory. Where necessary to prevent ecological misclassification or inappropriate afforestation, the Atlas may also record adjacent, historical, or potential non-forest natural ecosystems and their sensitivity to tree establishment.

1.3 Status. This document is a scientific and methodological working protocol. It does not create a new category of binding international law; amend FAO terminology; alter national forest codes; change ownership or tenure; establish protected areas; confer legal personality; create causes of action; determine compensation; or replace environmental assessment, site-specific expertise, or a decision by a competent authority. Its outputs may nevertheless constitute relevant scientific evidence and, where applicable law so provides, trigger assessment, prevention, precaution, enhanced monitoring, or review.

1.4 Intended users. The Protocol is designed for scientists, forest ecologists, remote-sensing specialists, field teams, data managers, public institutions, Indigenous and community partners, reviewers, and technical teams responsible for Atlas development. Public-facing Atlas interfaces should simplify presentation without weakening the underlying evidentiary record.

1.5 Independence and institutional purpose. The Global Forest Atlas is conceived as an independent international scientific instrument. Its scientific, methodological, and institutional governance must remain autonomous. The Universal Declaration of Tree Rights, the International Convention on Tree Rights, States, funders, data providers, and cooperation partners acquire no authority, merely by virtue of their relationship with the Atlas, to direct, alter, delay, or suppress a classification, assessment, method, or publication decision. The primary function of the Atlas is scientific; it is not a police or authorization body.

BOUNDARY CONDITION

The absence of a classification is not a finding of ecological absence. A site that has not yet been assessed must not be treated as unimportant, degraded, legally available for conversion, or free of rights. Where credible evidence indicates possible primary status, uncertainty must remain visible and independent assessment must be required before any high-consequence conclusion.

2. Relationship to the Forest Doctrine

The Protocol operationalizes the forest doctrine advanced under the Universal Declaration of Tree Rights in its revised and consolidated version of 25 August 2026. The doctrine provides the interpretive principles: a forest is more than tree cover; ecological origin, condition, integrity, stability, disturbance and causal attribution, seral state and trajectory, risk and vulnerability, management, rights, and landscape context remain distinct; primary forests are subject to non-substitution and strict permanent protection; and characteristic natural post-disturbance succession must not be labelled as recovery by default. Recovery remains reference-dependent and is used only where a material loss or deficit has been established. For restoration-related assessments, the Protocol continues to use the reference-model and recovery terminology stated in Gann et al. (2026), without implying institutional endorsement.

The 25 August 2026 doctrinal revision also preserves the scientific limits surrounding Articles I and II of the Declaration. The Protocol does not operationalize "sentient living being" as an Atlas variable and does not test a global counterfactual involving disappearance of all trees. Its operational scope is limited to documented biological and ecological properties, functions, processes, dependencies, interactions, conditions, pressures, disturbance regimes, seral states, and trajectories that can be assessed through appropriate evidence.

The Protocol does not rewrite the doctrine. Where a doctrinal definition is required - for example primary forest, natural forest, degraded natural forest, ecological naturalness, non-substitution, ecological restoration, recovery, rehabilitation, natural regeneration, or reference-model terminology - the doctrinal version explicitly recorded for the assessment remains the interpretive source. The Protocol specifies how evidence should be assembled and how uncertainty should be handled when those concepts are applied operationally.

The International Convention on Tree Rights, consolidated review edition of 14 August 2026, is a distinct legal framework capable of recognizing the Atlas, using its outputs, and attaching duties of assessment, prevention, or precaution to certain evidence. This relationship does not place either the Protocol or the Atlas under the authority of Convention bodies.

The Atlas must preserve the distinction between source terminology and Atlas interpretation. If a national inventory labels an area as "forest," that label remains part of the source record. The Atlas may add an ecological interpretation only where the additional evidence required by this Protocol is available. The source category itself must never be overwritten or misrepresented.

3. Guiding Principles

Principle	Operational consequence
P1 - Ecological non-reduction	Tree cover, biomass, or area alone cannot establish forest ecological identity or integrity.
P2 - Multi-dimensionality	Origin, condition, integrity, stability, disturbance, causal attribution, seral state, trajectory, risk, vulnerability, carbon, governance, and decision needs remain analytically distinguishable.
P3 - Traceability	Every material Atlas statement must be traceable to sources, methods, dates, resolution, assumptions, and uncertainty.
P4 - Explicit uncertainty	Unknown, insufficient, conflicting, and contested evidence must remain visible rather than silently resolved by assumption.
P5 - Scale awareness	A valid conclusion at pixel, stand, landscape, ecoregion, or national scale must not be transferred automatically to another scale.
P6 - Non-compensability	A high value in one ecological dimension does not automatically compensate for severe loss in another.
P7 - Rights-based governance	Ecological assessment must not erase ownership, tenure, Indigenous rights, customary rights, or legitimate community governance.
P8 - Source integrity	Imported data retain original terminology, licence conditions, version, resolution, and limitations.
P9 - Contestability	No Atlas classification is permanently immune from evidence-based challenge and correction.
P10 - Progressive completeness	The Atlas may expand incrementally; it must never simulate global certainty by filling gaps with unjustified classifications.
P11 - Scientific and institutional independence	Classifications, assessments, methods, data-governance rules, and publication decisions fall within autonomous governance; cooperation confers no scientific direction.
P12 - Precaution where primary status is possible	Credible possible-primary evidence with insufficient proof remains visible and requires independent assessment; uncertainty is not evidence of absence.
P13 - Disturbance-regime interpretation	Severity alone does not establish degradation. Interpret disturbance through origin, characteristic regime, frequency, interval, extent, biological legacies, interacting pressures, and subsequent trajectory.
P14 - Gross-loss accounting	Losses of ecological integrity are recorded where and when they occur and are not netted against restoration, regeneration, plantation establishment, or gains elsewhere.
P15 - Succession before recovery	Characteristic natural post-disturbance succession, seral transition, or ecological reorganization is not recovery by default. Record seral state, biological legacies, continuity, and regime compatibility before applying recovery terminology.
P16 - Recovery provenance	Where recovery is applicable, identify the material loss or deficit, what the ecosystem is recovering from, the origin and timing of the continuity break or degradation, the reference condition, and supporting evidence.
P17 - Risk / vulnerability separation	Risk and vulnerability are prospective dimensions and remain separate from present condition, integrity, degradation, and confidence.
P18 - Non-forest ecosystem safeguard	Natural non-forest ecosystems are not empty land for tree establishment; identity and afforestation sensitivity remain visible where tree establishment could cause harm.

4. Spatial Units and Scale

The Atlas must operate through nested spatial units. No single unit is sufficient for all variables. Ecological identity may be expressed at biome or ecosystem-type scale; disturbance and management may be stand-specific; connectivity requires landscape analysis; hydrological processes may require watershed units; governance may follow legal or customary territories; and satellite variables may exist as pixels whose resolution differs from ecological boundaries.

Level	Primary function	Typical questions
Biome / broad climatic domain	Global comparison and broad ecological context	What climatic and disturbance regime frames the system?
Ecoregion / ecosystem group	Reference condition and biogeographic calibration	What composition, structure, and dynamics are ecologically plausible here?
Landscape / watershed	Connectivity, cumulative pressures, hydrology, fire, infrastructure	How do patches interact, and what processes cross property boundaries?
Forest complex / ecosystem	Ecological identity and integrated condition	What living forest system exists here and what is its trajectory?
Stand / patch / site	Management, field verification, local condition	What structures, interventions, or disturbances are directly present?
Pixel / observation footprint	Sensor or sampling support; observation scale	What precisely was observed by a sensor or sampling method?

Every Atlas record must include a spatial-unit field and an assessment-scale field. Where information is downscaled or upscaled, the method and limitations must be explicit. Administrative boundaries may be useful for reporting but must not be treated as ecological boundaries unless independently justified.

SCALE RULE

A 10 m land-cover pixel does not imply that ecological integrity, microbial condition, historical continuity, tenure, or governance is known at 10 m resolution.

5. Classification Architecture

Classification is multidimensional. The Atlas should avoid forcing every location into a single mutually exclusive label when several descriptors answer different questions. A record may therefore combine an ecosystem type, an origin class, present condition, integrity, stability, disturbance and causal attribution, trajectory, risk and vulnerability, management, spatial context, governance, and confidence information.

Dimension	Minimum question	Examples of outputs
Identity	What kind of system is this, and how was it established?	Biome; ecoregion; ecosystem type; natural / planted / mixed origin; primary continuity; secondary recovery.
Condition	What is present now?	Composition; structure; soils; water; regeneration; biodiversity; present functions.
Integrity	How coherent is the system relative to an appropriate reference?	Structural, biological, ecological, landscape, and biocultural integrity descriptors.
Stability	How does the system behave through time?	Resistance; resilience; variability; persistence; ecological reorganization; recovery where applicable.
Disturbances and pressures	What has affected or is affecting it?	Fire; harvesting; drought; drainage; roads; mining; hunting; pollution; invasive species; origin; frequency; duration; recurrence; cumulative interactions.
Trajectory	In what direction is it moving?	Post-disturbance succession; seral transition; maturation; recovery where applicable; stability; regression; conversion; regeneration failure; other transition; recovery provenance.
Risk and vulnerability	What future pressures, thresholds, or losses could affect the system, and how susceptible is it?	Exposure; sensitivity; adaptive capacity; threshold / tipping-point risk; reversibility; likely recovery time; climate and disturbance vulnerability.
Carbon	What stocks, flows, capacities, and risks are relevant?	Current stock; carrying capacity; gross emissions / removals; foregone sequestration; permanence risk.
Governance and rights	Who holds rights and how is the area governed?	Ownership; tenure; customary rights; Indigenous / community territory; protection and effectiveness.
Decision needs	What evidence-based action is indicated?	Protect; investigate; restore; reconnect; monitor; reduce risk; compatible production only where category and law permit.

"Compatible production" is available only in categories where a productive purpose is ecologically and legally compatible. For a primary forest, admissible decision needs concern strict permanent protection, monitoring, non-destructive research, maintenance of compatible uses, pressure reduction, and, where necessary, restoration; no commercial or industrial timber or biomass production is compatible.

5.1 Operational Ecological Categories

Version 0.1.4 uses the doctrinal categories below as operational descriptors. They must not be assigned through tree-cover appearance alone and require body of evidence appropriate to their defining characteristics.

Category	Minimum evidentiary logic
Primary forest	Evidence must support a naturally regenerated forest ecosystem dominated by native species, in which natural ecological and evolutionary processes, biological legacies, characteristic disturbance regimes, and ecological continuity remain predominant, and whose composition, structure, functions, ecological relationships, and trajectory have not been fundamentally reorganized by industrial intervention or other intensive human intervention. Human presence and compatible Indigenous, traditional, cultural, or subsistence uses do not exclude primary status. No single criterion is sufficient.
Forest of very high ecological naturalness	Evidence supports near-primary ecological attributes, but history includes ancient, limited, or uncertain intervention. Historical continuity, present naturalness, and present integrity must be separated.
Second-growth / secondary forest	Evidence must support natural regeneration after a substantial break in ecological continuity resulting, in particular, from significant anthropogenic disturbance, harvesting, or land-use conversion. A natural disturbance within the characteristic regime of a primary forest does not, by itself, establish secondary origin where primary continuity persists.
Degraded natural forest	Natural origin remains relevant, but immediate or long-term anthropogenic deterioration of ecosystem integrity relative to an appropriate reference condition is documented or strongly supported across composition, structure, processes, biological communities, soils, hydrology, connectivity, regenerative capacity, or landscape configuration. Degradation may occur without deforestation or canopy loss. Natural disturbance within the characteristic regime is not, by itself, degradation.
Forest under ecological restoration	Documented restoration activities or interventions are recorded as processes. Recovery is assessed separately relative to an appropriate reference model of a native ecosystem, using measurable attributes, monitoring, and adaptive management; project designation alone is insufficient.
Planted establishment within restoration / rehabilitation	Planting is recorded as an intervention or mode of establishment, not as a final ecological class. In ecological restoration, recovery is evaluated separately; in rehabilitation, improved physical conditions, functioning, or services do not by themselves establish substantive recovery of a native ecosystem.
Production-oriented tree plantation	A predominant planned production objective and recurrent management constrain ecological autonomy, structural diversity, natural regeneration, or characteristic forest dynamics.
Agroforest / agroforestry system	Intentional combination of trees with crops, pasture, or livestock; reported separately because production, livelihood, and ecological functions differ from forest ecosystems.
Other tree-based system	Orchards, parks, hedgerows, urban tree cover, windbreaks, and other systems are identified accurately rather than forced into a forest category.

5.2 Orthogonal Descriptors of Origin, Continuity, Development, Integrity, and Landscape Context

The descriptors below are neither synonymous nor necessarily mutually exclusive. They must be recorded in separate fields so that an old-growth forest is not automatically treated as primary, and a young primary forest after natural disturbance is not automatically downgraded.

Orthogonal descriptor	Minimum evidentiary logic
High-integrity forest	High present condition relative to an appropriate reference model; composition, structure, processes, connectivity, stability, adaptive capacity, autonomy, and, where relevant, biocultural integrity. Does not by itself establish historical origin.
Long-continuity forest	Persistence of forest land use and ecological functions over a long period without durable conversion; distinct from tree age and primary status.
Seral / developmental state	Biome-appropriate early-seral, intermediate, mature, late-successional, multi-seral mosaic, or other characteristic state; does not by itself establish degradation, recovery, or historical origin.

Orthogonal descriptor	Minimum evidentiary logic
Old-growth / old forest in the structural sense	Substantial presence of old and large trees, deadwood, cavities, vertical layering, microhabitats, and other late structures; does not by itself prove primary continuity.
Intact forest landscape	Large continuous complex of natural ecosystems, dominated by primary forests, with little fragmentation from industrial infrastructure or land use and retaining large-scale ecological processes.

6. Principle-Criteria-Indicator-Verifier Chain

The core evidence architecture follows a Principle-Criteria-Indicator-Verifier (PCIV) logic. This prevents a doctrinal principle from becoming an unsupported label. Each classification must be linked to criteria, indicators, and concrete verifiers whose relevance and limitations are documented.

Level	Function	Example - ecological integrity
Principle	States the higher condition or requirement.	Maintain the coherence and regenerative capacity of the living forest system.
Criteria	Identify the dimensions necessary to satisfy the principle.	Structure, composition, processes, connectivity, hydrology, biological communities, biocultural relations.
Indicators	Describe observable conditions, changes, or distance from reference.	Large trees, deadwood, regeneration, fauna, microbial communities, water-table condition, connectivity, resistance, trajectory.
Verifiers	Identify the data and methods used to establish the evidence.	Field plots, lidar, satellite time series, soil measurements, biodiversity surveys, archival records, legitimate Indigenous and local knowledge.

A verifier is not considered valid merely because it exists. Its spatial support, temporal relevance, quality, licence, method, uncertainty, and fitness for the criterion must be assessed. An indicator derived from a regional model should not be presented as a direct site observation.

For forest-degradation assessment, Version 0.1.4 applies the PCIV logic directly to losses of ecological integrity relative to appropriate reference conditions, informed in particular by DellaSala et al. (2025). The listed indicators are candidate evidentiary families, not universal thresholds; actual verifiers must be calibrated to biome, ecoregion, ecosystem type, scale, data quality, and decision context.

SCIENTIFIC INTEROPERABILITY

For ecological-restoration assessments, Atlas indicators may be cross-walked to the six key ecosystem attributes used in Gann et al. (2026): absence of threats; physical conditions; species composition; structural diversity; ecosystem function; and external exchanges. This crosswalk supports interoperability but does not replace Atlas-specific dimensions such as origin, continuity, naturalness, biocultural integrity, governance, risk, or trajectory.

6.1 Degradation-Oriented PCIV Module

Criteria family	Candidate indicators	Illustrative verifiers / evidence
Structural quality	Age and diameter structure; large and old trees; snags; coarse woody debris; canopy layering; height; biomass; carbon stocks.	Field plots; forest inventories; lidar; structural remote sensing; carbon estimates.
Ecosystem processes	Degree of altered fire or disturbance regime; nutrient cycling; soil compaction and productivity; mycorrhizal function; hydro-ecology; runoff; evapotranspiration.	Fire and disturbance history; soil measurements; hydrological data; field studies; remote-sensing time series.
Ecological composition and adaptive potential	Native / exotic composition; rare, threatened or focal species; plant and animal richness; genetic adaptation signals; biological legacies; micro- and macrorefugia.	Biodiversity surveys; species records; genetic or trait data; field evidence; refugia mapping.
Functionality, complexity and climate buffering	Vegetation density; topographic heterogeneity; carbon storage; vascular-plant richness; tree height; functional richness; forest temperature / microclimate.	Field and remote-sensing metrics; thermal data; terrain models; ecological-function studies.
Landscape characteristics	High-conservation-value areas; seral stages; patch sizes; roadless core area; barriers to movement; road density; intra-patch connectivity / fragmentation.	Landscape metrics; road datasets; GuidosToolbox / FRAGSTATS-type analyses; habitat and connectivity data.
Temporal cumulative impacts	Degree of cumulative impacts from roads, logging, extraction, repeated fire or other disturbances; interval between events; chronicity.	Time-series remote sensing; harvest and road histories; disturbance archives; repeated field assessments.

NO UNIVERSAL THRESHOLD

The PCIV module is a transparent chain of evidence, not a single global cutoff. Degradation is a continuum of integrity loss; threshold or tipping-point interpretation must be ecosystem-specific and supported by regional evidence.

7. Evidence Types and Verifiers

The Atlas should distinguish evidence by how it is produced. A public user must be able to tell whether a statement is based on direct measurement, remote sensing, modelling, historical reconstruction, expert interpretation, community-defined evidence, or a synthesis of several sources.

Evidence type	Examples	Principal strengths	Principal limitations
Direct field observation	Forest plots, soil cores, hydrological measurements, species surveys	High ecological specificity; supports site diagnosis	Spatial coverage may be limited; costly; temporal frequency variable
Remote sensing	Optical, radar, lidar, thermal, time series	Large-area repeatability; disturbance detection; structural indicators	Cannot directly establish all ecological, historical, microbial, governance, or rights dimensions
Modelled / inferred	Biomass models, climate risk models, habitat suitability	Extends information beyond measured sites; scenario analysis	Dependent on assumptions, training data, transferability, uncertainty
Historical / archival	Historical maps, aerial imagery, management records, land-use archives	Supports continuity, land-use history, disturbance reconstruction	Coverage and interpretation may be incomplete or biased
Administrative / legal	Protected-area status, tenure records, permits	Essential for legal and governance context	Formal status may diverge from effective protection or customary reality
Indigenous and local knowledge	Community-defined observations, oral history, territorial knowledge	May provide long temporal depth and locally specific ecological knowledge	Requires authority, consent, confidentiality, contextual interpretation
Expert synthesis	Peer-reviewed assessment of converging evidence	Integrates heterogeneous sources and uncertainty	Must disclose reviewer identity, conflicts, reasoning, and evidentiary basis

8. Reference Models, Reference Sites, and Regional Calibration

A reference model is required whenever condition, integrity, degradation, recovery, or naturalness is assessed relative to an expected ecological condition. For ecological restoration, the object of recovery is a native ecosystem. The reference model describes the expected state, in its high-integrity condition, that the restoration site would exhibit in the absence of degradation, including biota, abiotic elements, functions, processes, and successional states, while accounting for background and predicted environmental change.

Reference sites are extant sites - ideally undegraded or nearly undegraded - whose attributes and successional phases can inform development of the reference model. A reference site is an evidentiary source, not the model itself. Where feasible, an appropriate number of reference sites should be combined with historical evidence, field data, scientific literature, Indigenous and local knowledge, palaeoecological information, and projected environmental change.

Reference hierarchy for degradation assessment. Where ecologically appropriate, primary or old-growth forests of the relevant type remain principal reference anchors. Reference models are dynamic, however, and may include multiple characteristic seral states and disturbance phases. A natural early-seral state created by a within-regime disturbance must not be diagnosed as degraded merely because it differs from the preceding mature state. Where primary or old-growth reference sites no longer exist, reconstruction may combine historical evidence, mature or late states, structurally complex natural regeneration, and other characteristic seral states. Any departure must be explained and uncertainty recorded; a degraded baseline or the most common current condition must not silently become the reference.

- State the reference model explicitly and identify the native ecosystem to which recovery or integrity is compared.
- Identify the spatial and temporal scale variability and evidence used to build the model, including reference sites where available.
- Distinguish the reference model from a degraded baseline or the most common current condition.
- Distinguish the reference model from a degraded baseline or from the most common current condition.
- For degradation assessment, state the reference anchor and the characteristic seral / disturbance phase against which the observed state is interpreted.
- Document known departures caused by climate change, land-use legacies, irreversible transformation, and any regional thresholds.
- For degradation assessments, state whether the reference is primary / old-growth, historically reconstructed natural forest, mature advanced succession, structurally complex natural regeneration, or another justified condition.

CALIBRATION PRINCIPLE

Natural monodominance, open-canopy structure, frequent fire, low biomass, or slow regeneration may be normal in one ecosystem and evidence of degradation in another. Indicators and SER-attribute crosswalks require ecological context.

9. Confidence Levels and Evidentiary Status

The provisional confidence scale introduced in Version 0.1 remains unchanged in Version 0.1.4. The scale expresses confidence in a particular Atlas statement; it does not express ecological value. A low-confidence record is not a low-value forest. Confidence must be assigned separately for each material classification or variable.

Code	Working label	Minimum interpretation
CL0	Not determined	Evidence is absent, insufficient, inaccessible, or too contradictory to support a classification.
CL1	Indicative	One or more relevant signals exist, but material gaps, scale limitations, or unresolved uncertainty remain.
CL2	Substantially supported	Multiple relevant sources or a strong source support the statement, but important verification or calibration remains incomplete.
CL3	Strongly supported	Independent or complementary evidence converges; methods are appropriate; principal uncertainties are bounded and documented.
CL4	Validated for current protocol use	Evidence and method have passed the applicable technical / expert validation procedure and are fit for the stated scale and decision context.

A separate status flag should identify whether a record is current, provisional, contested, under review, superseded, or withdrawn. Confidence and review status must not be collapsed into one code.

Status flag	Meaning
CURRENT	Current Atlas interpretation under the stated protocol version.
PROVISIONAL	Published for transparency but awaiting defined validation steps.
CONTESTED	A documented evidence-based challenge is pending or unresolved.
UNDER REVIEW	Reassessment has been formally opened.
SUPERSEDED	A later version exists; retained for audit history.
WITHDRAWN	The prior classification is no longer considered fit for use; reason must be recorded.

IMPORTANT

Confidence applies to the evidence supporting a statement. It is not a rank of ecological importance and must never be used as such.

9.1 Precautionary Scientific Status for Possible Primary Forest

Confidence level and review status remain distinct from precautionary scientific status. Where credible evidence indicates that an area may be primary forest but the evidence is insufficient for a final classification, the record must carry the status **POSSIBLE PRIMARY FOREST - INDEPENDENT ASSESSMENT REQUIRED**. This status is neither confirmation of primary status nor authorization for conversion; it signals that lack of certainty cannot be treated as evidence of absence.

Precautionary status	Minimum interpretation
POSSIBLE PRIMARY FOREST - INDEPENDENT ASSESSMENT REQUIRED	Credible indicators of primary status exist; the record remains incomplete or contradictory; independent expertise is required before any high-consequence conclusion. Any legal effects arise from applicable law, not from the Protocol.

10. Missing Data, Uncertainty, and Indeterminacy

Unknown must be treated as a legitimate scientific outcome. The Atlas must not use algorithmic completeness as a substitute for evidence. If a classification cannot be supported, the correct output is "not determined," together with the reason and the evidence needed to improve the assessment.

- Missing data must not be treated as zero.
- Absence of a recorded species is not evidence of true absence unless detectability and survey design justify that conclusion.
- Absence of mapped rights is not evidence that no customary or Indigenous rights exist.
- Cloud cover, sensor limitations, inaccessible terrain, or inconsistent national reporting must be identified explicitly.
- Conflicting high-quality sources should trigger a conflict note or review, not automatic averaging.
- Uncertainty should be quantified where possible and described qualitatively where quantitative estimation is not meaningful.

Where a model provides a probability or confidence interval, that numerical uncertainty should remain visible. Where expert interpretation is used, uncertainty should include both evidentiary limitations and interpretive disagreement. The Atlas should preserve uncertainty rather than compressing it into a categorical label that appears more certain than the source data.

The absence of a forest from an inventory, statistical category, or national or international map is not evidence that it is not primary. Conversely, the absence of a documented harvesting history does not by itself prove primary status; both propositions require positive evidentiary analysis.

Where a proposed decision could cause conversion, extraction, or irreversible harm and credible evidence indicates possible primary status, the Atlas must record a precautionary signal, identify missing evidence, and recommend independent scientific assessment. The Protocol does not itself order legal suspension; it makes available the scientific evidence to which the Convention or applicable law may attach interim protection.

EVIDENTIARY PRECAUTION RULE

Unknown does not mean absent. Credible uncertainty about primary status must remain visible and cannot be converted into implied availability for irreversible activity.

11. Remote Sensing and Geospatial Evidence

Remote sensing is indispensable to a global Atlas because it provides repeatable, spatially extensive evidence. It is particularly well suited to detecting cover change, canopy structure, fire, flooding, drought signals, roads, linear infrastructure, fragmentation, some aspects of biomass, and temporal stability. It is not, by itself, sufficient to establish every aspect of ecological integrity or forest history.

- Record sensor, product, acquisition period, processing level, native resolution, classification method, and version.
- Do not resample a coarse product to a finer grid and present the result as new fine-resolution knowledge.
- Retain the distinction between observation and model-derived layers.
- For change detection, document baseline date, comparison date, temporal compositing, and disturbance-detection rules.
- Use field or independent reference data for calibration and validation where the variable requires it.
- Document omission and commission errors for categorical products when available.
- Avoid inferring primary status, customary rights, microbial integrity, effective governance, or complete degradation status from spectral appearance alone.
- Where road and infrastructure pressure is assessed, retain original network data and derive road density, roadless core area, road-stream intersections, edge penetration, and fragmentation only at scales where those metrics are valid.

Where multiple remote-sensing products disagree, the Atlas should preserve the disagreement at the evidence layer and define how the final interpretation was reached. A fused product must identify the fusion method and must not conceal contradictions that materially affect classification.

12. Field Evidence and Site-Specific Diagnosis

Field evidence is required when the question cannot be answered reliably from remotely sensed or documentary evidence. Site-specific diagnosis may be necessary for forest structure, regeneration, soils, hydrology, fauna, fungi, microbial communities, management effects, restoration activity, degradation diagnosis, biological legacies, and recovery progress.

Field protocols should be indicator-specific rather than universally identical. Plot size, sampling intensity, seasonal timing, taxonomic method, soil depth, hydrological instrumentation, and detection procedures should be calibrated to the ecosystem and question. The Protocol therefore defines minimum metadata and quality requirements while leaving detailed sub-protocols to specialist modules and biome-specific calibration.

Field domain	Minimum metadata
Vegetation / structure	Plot geometry, sampling method, date, observer, DBH / height methods, regeneration method, deadwood protocol, taxonomic standard.
Soils	Sampling depth, horizon, method, laboratory method, bulk density / carbon basis where relevant, moisture state, QA controls.
Hydrology	Variable measured, instrument, location, datum, frequency, period, calibration, upstream / downstream context.
Fauna / biodiversity	Taxonomic group, survey method, effort, detectability assumptions, season, replication, reference taxonomy.
Fungi / microbiota	Sampling substrate, laboratory or sequencing method, contamination controls, taxonomic / functional interpretation limits.
Management effects	Intervention type, date, intensity, spatial footprint, stated objective, pre/post evidence where available.
Degradation / disturbance diagnosis	Reference condition; causal attribution; intensity, frequency, duration, extent, recurrence, interval between events; interacting pressures; biological legacies; recovery evidence.

13. Historical Evidence and Ecological Continuity

Historical continuity is central to distinguishing primary continuity, long-continuity forests, secondary recovery, and planted establishment. It cannot always be reconstructed from one source. The Atlas should use converging evidence and record the earliest reliable date to which a conclusion applies.

- Historical maps and cadastral records;
- aerial photography and declassified imagery;
- satellite archives;
- forest management records and harvest histories;
- land-use records, agricultural abandonment records, or fire history;
- palaeoecological or dendroecological evidence where appropriate;
- legitimate Indigenous and local historical knowledge.

The absence of documented industrial use does not prove that no use occurred. Conversely, evidence of compatible Indigenous, traditional, cultural, or subsistence use does not automatically negate primary status. The relevant question is whether industrial intervention or other intensive human intervention fundamentally reorganized the system's composition, structure, functions, ecological relationships, or trajectory.

A natural disturbance - fire, storm, flooding, insect outbreak, or windthrow - does not by itself create secondary forest where it belongs to the ecosystem's characteristic disturbance regime and primary continuity persists. Assessment must document disturbance origin, compatibility with the natural regime, retained biological legacies, and subsequent trajectory.

Version 0.1.4 preserves the disturbance-regime rule: severity alone does not establish degradation. Natural pulse disturbances, including severe events, may remain compatible with ecological integrity when they operate within characteristic bounds and retain biological legacies and regenerative pathways. Degradation diagnosis must instead examine whether frequency, intensity, extent, recurrence, intervals, chronicity, interacting anthropogenic pressures, or climate amplification shift the system away from its characteristic range and trajectory.

Disturbance origin and degradation causality remain separate. A disturbance may be natural, anthropogenic, mixed, or indeterminate. A purely natural disturbance operating within the characteristic regime is not itself entered as a degradation cause. New degradation changes recorded condition, integrity, and trajectory but does not erase origin, continuity, or prior primary status.

Succession before recovery. A natural within-regime disturbance may initiate a functional post-disturbance succession or early-seral state without implying degradation or recovery. The Atlas first records seral state, biological legacies, primary continuity, regime compatibility, and subsequent trajectory.

Recovery provenance. "Recovering" is used only where a material loss or ecological deficit relative to an appropriate reference is established. When recovery applies, the record identifies what the ecosystem is recovering from, the timing and cause of the continuity break or degradation, the reference condition, and the evidence supporting the trajectory. A characteristic natural seral transition is recorded as succession / seral state rather than automatically as recovery.

HISTORICAL TRUTHFULNESS

A restored or mature secondary forest may attain very high ecological value without being relabelled as historically primary. Conversely, a degraded primary forest remains historically primary: the Atlas must preserve present ecological achievement, historical trajectory, and subsequent harm.

14. Indigenous and Local Knowledge; Sensitive Information

The Atlas must not treat Indigenous and local knowledge as a free data layer available for extraction. Knowledge supplied by peoples or communities must be governed by legitimate authority, consent, agreed purpose, attribution rules, confidentiality conditions, and any community-defined restrictions on use or publication.

The Atlas should support several publication classes: public, restricted scientific access, and confidential / non-disclosable. The most restrictive applicable condition governs publication when disclosure could expose sacred places, culturally sensitive information, threatened species, traditional knowledge, or territories to exploitation, persecution, collection, or other harm.

Data class	Default publication approach
Public	May be displayed with provenance and licence / attribution conditions.
Restricted scientific	Available only to authorized users for defined purposes; no public precise coordinates where restriction is justified.
Confidential / non-disclosable	Not published; existence of withheld information may be indicated only if authorized and safe.

Community-defined indicators may be incorporated as their own evidence type rather than translated automatically into external scientific categories. Where scientific and community interpretations differ, the Atlas should be capable of displaying the difference rather than forcing one to erase the other.

15. Carbon Evidence

Carbon information must be disaggregated so that existing ecological stocks are not obscured by future removals. At minimum, the Atlas should distinguish current carbon stock, ecological carbon-carrying capacity where scientifically assessable, gross emissions, gross removals, avoided emissions where a defensible counterfactual exists, foregone sequestration, permanence risk, and the ecological category in which carbon is stored.

The Atlas must not use a carbon score as a proxy for ecological integrity. High carbon density may coexist with biological degradation, and low biomass may be natural in some forest systems. Likewise, rapid carbon accumulation in a plantation or young regrowth forest does not establish ecological equivalence with an old or primary forest.

- Record carbon pool(s) included: aboveground biomass, belowground biomass, deadwood, litter, soil organic carbon, or other pools.
- Record the estimation method and allometric or remote-sensing model used.
- Report units, reference area, date, uncertainty, and spatial support.
- Separate stock from flux.
- State counterfactual assumptions for avoided emissions or foregone sequestration.
- Record permanence and reversal risks separately from current stock.
- Where a defensible counterfactual and temporal model exist, record carbon debt as the cumulative carbon-stock or atmospheric burden difference through time following a loss event; disclose assumptions and do not treat carbon debt as an offset unit.

Case-study evidence from the Tongass reinforces the methodological reason for this separation: loss of an existing old-growth stock and future carbon uptake in young growth are different temporal quantities. Version 0.1.4 uses that evidence to support stock / flow separation and non-netting; it does not convert a site-specific young-growth transition into a universal silvicultural rule.

Carbon debt. Where scientifically assessable, the Atlas may report the cumulative carbon deficit or additional atmospheric burden through time relative to a defensible protection or no-loss counterfactual following harvesting, conversion, or another carbon-loss event. Carbon debt is a temporal diagnostic, not an ecological equivalence or a credit that can retrospectively neutralize the loss of an existing forest stock.

16. Governance, Rights, Tenure, and Effective Protection

Governance and rights information must be treated as distinct from ecological condition, while recognizing that governance can materially affect forest trajectory. A legally protected polygon does not, by itself, establish effective protection. Conversely, a territory without a formal protected-area designation may be effectively conserved under Indigenous, community, private, or shared governance.

Dimension	Minimum information
Ownership / tenure	Legal or customary basis; holder / community where disclosure is legitimate; source and date.
Land-use and customary rights	Access, use, management, exclusion, harvesting, cultural or other recognized rights.
Indigenous / community territory	Recognition status, governance institutions, disclosure constraints, consent requirements.
Formal protection	Designation, category, date, legal basis, permitted / prohibited activities.
Effective protection	Resources, personnel, enforcement, violations, authorized pressures, management effectiveness, ecological outcomes.
Conflict / uncertainty	Competing claims, unresolved boundaries, litigation, contested records, missing recognition.

LEGAL SAFEGUARD

Atlas inclusion does not alter ownership, tenure, rights, jurisdiction, legal personality, protected status, or the legality of activities. Binding consequences arise only from competent legal authorities and applicable law.

A classification, assessment, map, alert, or other scientific output of the Atlas does not, by itself, create or extinguish ownership, tenure, or use rights; confer legal personality; constitute an administrative authorization; establish criminal or civil liability; determine compensation; create a protected area; or replace environmental assessment or a site-specific legal decision.

Such outputs may nevertheless constitute relevant scientific evidence. Where they provide credible evidence of serious risk to a primary forest or another protected ecosystem, they may trigger, under the Convention or applicable law, timely assessment, prevention or precaution, enhanced monitoring, or review by a competent authority.

LEGAL SAFEGUARD AND EVIDENTIARY VALUE

No automatic legal effect; no scientific neutralization. The Atlas does not decide the law, but its outputs may require competent authorities to examine, assess, and act where the applicable legal framework so provides.

17. Non-Compensability and Multi-Dimensional Interpretation

The Atlas should resist a universal composite score because ecological dimensions are not fully interchangeable. Where synthetic indicators are useful, their construction must be transparent, and dimensions that cannot be compensated must be governed by minimum conditions or veto rules rather than simple averaging.

Examples of non-compensability include: high biomass does not compensate for hydrological collapse; legal protection does not compensate for ineffective enforcement; canopy stability does not compensate for loss of fauna or regeneration; a plantation elsewhere does not compensate ecologically for destruction of a primary forest; and future carbon removals do not erase an immediate loss of an existing forest stock.

Situation	Required interpretation
High carbon, low biodiversity	Display both dimensions; do not call the ecosystem "high integrity" solely because carbon is high.
High canopy stability, severe simplification	Stability remains a temporal observation; integrity requires independent evidence.
Protected in law, continued degradation	Formal protection and effective protection must be shown separately.
Restoration project, no demonstrated recovery	Record restoration activity / project and recovery status separately; do not infer recovery from project designation.
New plantation after natural forest loss	Report natural forest loss and plantation gain separately; no ecological netting.
Loss of integrity at one site, gain elsewhere	Record the gross integrity loss at the location and time at which it occurred and report gains elsewhere separately; no offsetting or netting.
Primary forest after natural disturbance	Display prior primary status, disturbance, biological legacies, current condition, and trajectory separately; salvage logging or post-disturbance extraction does not transform the forest into a compatible production resource.

Situation	Required interpretation
Repeated disturbance with persistent canopy	Assess cumulative integrity loss and causal interactions; persistent tree cover or biomass does not establish absence of degradation.

GROSS INTEGRITY LOSS RULE

Losses of ecological integrity are recorded as gross losses at the location and time of occurrence. Recovery, restoration, plantation establishment, natural expansion, or gains elsewhere are recorded separately and cannot erase the historical loss.

Recovery debt. Where relevant and methodologically supportable, the Atlas may quantify or qualitatively describe cumulative deficits in selected ecosystem attributes, functions, biodiversity, or services relative to a reference model during degradation and subsequent recovery. Recovery debt is applied only after a material loss or deficit has been established. It must not be assigned merely because a characteristic natural post-disturbance or early-seral state differs from the preceding mature state. Recovery debt documents losses through time; it is not a conversion factor, offset, or justification for avoidable destruction.

SER ALIGNMENT AND DOCTRINAL NON-SUBSTITUTION

SER 2026: restoration potential must not justify destruction of native ecosystems; offsets may be considered only after prior mitigation steps. The Atlas's absolute non-substitution rule is doctrinal and is not attributed to SER.

18. Automated and Model-Assisted Classification

Automated classification can support global screening, but it must not silently become the final authority for categories that require historical, ecological, legal, or community interpretation. The Protocol distinguishes automated observation, model-assisted inference, and validated ecological classification.

Class of output	Permitted use	Minimum safeguard
Automated observation	Detect measurable signals such as cover change, fire, canopy height, water extent, roads, or fragmentation.	Product validation and metadata; no unsupported ecological relabelling.
Model-assisted inference	Estimate probability or likely class using multiple variables.	Training data disclosure, uncertainty, transferability testing, independent validation where possible.
Ecological classification requiring expert review	Primary status, possible primary status, high naturalness, degradation diagnosis, reference-condition selection, restoration activity / recovery trajectory, effective protection, and exclusion of primary status in complex cases.	Independent human / expert review, synthesis of converging evidence, and conflict-of-interest record; no automatic exclusion based on inventory absence or a single remote-sensing product.
Rights / sensitive knowledge classification	Tenure, customary rights, community territories, confidential knowledge.	No automated determination without authoritative legal / community evidence and governance safeguards.

Any machine-learning model used in the Atlas must have a model card or equivalent record documenting purpose, training data, spatial and temporal domain, performance metrics, known biases, limitations, version, and conditions under which predictions should not be used.

No automated model may definitively conclude that a forest is not primary solely from an incomplete inventory, canopy appearance, age threshold, small area, or a signal of natural disturbance. No automated model may infer absence of degradation solely from stable canopy cover or biomass.

19. Scientific Review and Validation

Validation must be proportionate to the consequence of the classification. Low-stakes display of a raw satellite measurement requires a different review pathway from a public Atlas statement that an area is primary forest, severely degraded, or under ineffective protection.

Review level	Typical use	Review requirement
Technical QA	Raw or derived data layer	Check data integrity, metadata, processing reproducibility, spatial reference, version.
Methodological review	Indicator or model layer	Check fitness for purpose, calibration, uncertainty, transferability.
Ecological expert review	Material ecological classification	Review converging evidence, reference model, scale, degradation logic, and alternative explanations.
Pluralistic review	Classification involving rights, governance, contested evidence, or major public consequence	Include relevant scientific, legal, governance, and rights-holder expertise; document dissent.
Enhanced high-consequence review	Exclusion of possible primary status; decision capable of supporting conversion, extraction, or irreversible harm	Independent and transparent assessment; plural evidence; ecological and, as relevant, legal and rights-holder review; commissioning entity, funding, conflicts, and decision context documented.

Reviewers must disclose relevant conflicts of interest and funding relationships. A reviewer's participation does not imply endorsement of the Universal Declaration of Tree Rights, the entire forest doctrine, the Protocol, or unrelated Atlas classifications.

An assessment intended to exclude possible primary status or support irreversible activity may not rely solely on inventory absence, satellite appearance, a proponent-commissioned study, a single source, or lack of documented known logging. The record must identify the commissioning entity, funding sources, conflicts of interest, decision context, and degree of independence of assessors and reviewers.

20. Contestation, Correction, and Scientific Versioning

The Atlas must provide a documented mechanism for evidence-based challenges. A request for review may be submitted by researchers, public institutions, Indigenous Peoples, local communities, rights-holders, civil-society organizations, land managers, or other persons able to provide relevant evidence.

- 1 Submission of the challenged record and the specific issue.
- 2 Submission of supporting evidence, source, date, and relevance.
- 3 Initial admissibility check: is the challenge evidence-based and within Atlas scope?
- 4 Assignment to an appropriate review pathway.
- 5 Temporary "under review" or "contested" flag where warranted.
- 6 Reasoned decision: confirm, revise, narrow, suspend, or withdraw.
- 7 Versioned publication of the outcome and preservation of the prior record for audit purposes.

SCIENTIFIC VERSIONING

Previous classification -> evidence submitted -> review -> decision -> revised classification. Changes must be versioned rather than silently overwritten.

Where high-quality evidence remains genuinely conflicting, the Atlas should state that disagreement persists and identify the competing interpretations. Scientific disagreement is preferable to false certainty.

Where a forest previously classified as primary is disturbed or degraded, the new observation changes condition, integrity, disturbance, and trajectory fields but does not silently delete primary-status history. Any reclassification must explain what changed, what new evidence emerged, and why origin or continuity are being reinterpreted.

SCIENTIFIC RECORD CONTINUITY

Prior status -> disturbance or new evidence -> review -> reasoned decision -> revised classification. Primary-status history remains accessible even where present condition has degraded.

21. Metadata, Quality Assurance, and Auditability

Every material Atlas record must carry sufficient metadata to permit an independent reviewer to understand what was measured, how it was interpreted, and why a classification was assigned. Metadata are part of the scientific evidence, not an administrative afterthought.

- Unique Atlas record identifier
- Geographic geometry / footprint and coordinate reference system
- Spatial scale of assessment
- Observation date / period
- Data producer and source
- Source version and licence
- Acquisition method
- Processing / analytical method
- Reference model and supporting reference sites / evidence
- Doctrine version used
- Material ecological classification, restoration activity, recovery status, and orthogonal descriptors
- Primary status and primary-status history
- Historical / reconstructed / ecologically potential ecosystem distribution where relevant
- Compatibility of disturbance with characteristic regime
- Disturbance origin
- Biological legacies
- Degradation diagnosis and, where calibrated, degradation intensity
- Degradation reference condition
- Degradation causality and specific anthropogenic driver(s)
- Cumulative impacts and disturbance intervals
- Risk and vulnerability assessment where relevant

- Recovery-from condition / provenance
- Recovery debt where relevant and assessable
- Road and linear-infrastructure metrics where relevant
- Gross integrity loss record where applicable
- Post-disturbance extraction / salvage logging record where applicable
- Protected natural-succession status where applicable
- Non-forest ecosystem context and afforestation sensitivity where relevant
- Management purpose and compatibility with category
- Essential human needs and compatible uses where relevant
- Carbon debt where relevant and assessable
- Decision context
- Precautionary alert
- Commissioning entity
- Funding source
- Conflicts of interest
- Applicable legal framework and legal-effect note
- Assumptions
- Known limitations
- Quantitative or qualitative uncertainty
- Confidence level
- Review status
- Atlas assessment date
- Protocol version
- Reviewer / validating body where applicable
- Links to superseded or related records

Quality assurance must include automated checks where appropriate - missing fields, geometry validity, impossible dates, inconsistent units, duplicate identifiers - and scientific checks for plausibility, scale, method, source appropriateness, reference-condition fitness, and causal interpretation. Critical changes should be reproducible from stored processing records or documented decision notes.

22. Monitoring Frequency and Update Rules

Monitoring frequency must be indicator-specific. The long-horizon milestones of approximately 15, 25, 50, 100, and 500 years relate to long-term recovery of naturalness; they are not universal measurement intervals for every variable.

Information type	Indicative update logic for v0.1.4
Rapid disturbances / alerts	Near-real-time to monthly where reliable data and operational need justify it.
Cover, fragmentation, fire, drought, infrastructure pressure	Annual or multi-annual depending on product, change rate, and decision context.
Roads / linear infrastructure	Annual or event-driven where data permit; record new access, road density, roadless core area, road-stream intersections, and fragmentation effects at valid scales.
Canopy structure / biomass	Product-dependent; update when new validated acquisitions or models materially improve the record.
Field structure / regeneration / seral state / recovery Periodic remeasurement based on ecosystem dynamics and the objectives of succession tracking, management, restoration, degradation, and recovery monitoring.	
Risk / vulnerability	Update when exposure, climate projections, disturbance regimes, threshold evidence, adaptive capacity, or reversibility assumptions materially change.
Fauna / microbiota	Seasonal / periodic survey design appropriate to detectability and ecological question.
Governance / legal status	Update when authoritative changes occur; periodic verification of effective outcomes.
Long-term trajectory	Multi-decadal synthesis with explicit comparison to prior baselines and the stated reference model.
Primary status / status history	Update upon material new evidence or disturbance; the prior record remains retained and linked.
Gross integrity-loss event	Update when a material degradation event or newly documented cumulative loss is established; retain the event record even if later recovery occurs.
? Biological legacies ? Seral / developmental state and post-disturbance succession status	
	separate from program or legal designation.

Information type	Indicative update logic for v0.1.4
Non-forest afforestation sensitivity	Update when ecosystem mapping, vegetation trajectory, land-use pressure, climate projections, or afforestation proposals materially change the risk assessment.

Every update must preserve the date of the prior assessment. A new observation should not erase historical evidence; it should extend the temporal record. The Atlas is intended to show ecological history, not merely the latest snapshot.

23. Pilot Phase and Calibration

Global deployment should not begin with an assumption that one protocol performs equally well everywhere. Version 0.1.4 retains the requirement for pilot testing across ecologically contrasted systems. Pilot regions are methodological test beds, not representative "showcase" sites.

Pilot forest context	Primary methodological stress test
Tropical humid forest	Primary / secondary distinction, degradation under intact canopy, high biodiversity, rapid land-use pressure, road penetration.
Boreal forest	Large natural disturbance regimes, fire and insects, age mosaics, industrial cumulative impacts, permafrost / peat contexts.
Temperate forest	Long land-use history, management intensity, historical continuity, fragmentation, mixed ownership, old-growth reference scarcity.
Mediterranean / seasonally dry forest	Drought, fire, open structures, land abandonment, grazing, climate transition.
Flooded / peat-forming / coastal / mangrove forest	Hydrology dependence, carbon-rich soils, tidal / flood dynamics, land-water boundary change.

- classification reproducibility and agreement among independent reviewers;
- the primary / secondary distinction after fire or another natural disturbance;
- whether severity can be separated from degradation through disturbance-regime analysis;
- young seral mosaics, naturally open canopies, and small primary-forest fragments;
- compatibility of Indigenous, traditional, cultural, or subsistence uses;
- preservation of primary-status history after degradation, illegal logging, or salvage logging;
- operation of the "possible primary forest - independent assessment required" signal;
- the rule that missing data or inventory absence cannot become absence of primary status;
- whether degradation-oriented PCIV indicators distinguish focal from reference conditions without imposing universal thresholds;

? whether the protocol first distinguishes characteristic post-disturbance succession / seral state from recovery and, where recovery applies, answers "recovering from what?" with explicit causal provenance;

- whether degradation diagnosis / intensity remain separate from confidence and review status;
- whether disturbance origin remains separate from degradation causality;
- whether risk and vulnerability remain analytically separate from present condition, integrity, degradation, and confidence;
- whether recovery debt and carbon debt, where used, are transparently defined and never treated as compensation units;
- whether protected natural succession is recorded separately from ecological classification and legal protection;
- whether natural non-forest ecosystems at risk of inappropriate afforestation remain identifiable and are not forced into forest classes;
- whether road density, roadless core area, road-stream intersections, and fragmentation metrics add valid explanatory value at the chosen scale;
- separation between an Atlas scientific output and the legal consequence determined by a competent authority;
- classification independence where major economic or political interests are involved;
- scale transfer; field / remote-sensing integration; rights and governance data handling; contestation procedures; metadata burden; user-facing clarity; reference-model construction; separation of restoration activity from recovery status; SER six-attribute interoperability; and missing specialist sub-protocols.

PILOT RULE

A method that fails in a pilot is not a failed Atlas. It is useful evidence that the protocol must be revised before wider deployment.

24. Scientific Governance and Institutional Independence

The scientific governance of the Atlas must be institutionally distinct from the bodies of the Universal Declaration of Tree Rights, the International Convention on Tree Rights, Parties, funders, data providers, and any administrative operator. Foundational or administrative stewardship may provide coordination, secretariat, and technical resources without unilateral authority over classifications, methods, or publication decisions.

Governance requirement	Minimum safeguard
Composition	Disciplinary, geographic, and knowledge-system plurality; appropriate participation of forest, data, legal, social-science, and Indigenous and local knowledge specialists.

Governance requirement	Minimum safeguard
Appointment and terms	Public procedure, competence and independence criteria, fixed terms, controlled renewal, and reasoned removal for breach.
Conflicts of interest	Public declarations, recusal rules, traceability of funding, and prohibition on participating in a decision where an unmanaged material interest exists.
Scientific and editorial independence	No external actor may direct, alter, delay, or suppress a method, classification, assessment, alert, or scientific publication.
Separation of functions	Administrative stewardship, technical maintenance, scientific validation, challenge handling, and publication decisions are distinguished.
Review and appeal	Documented challenge, revision, appeal, or reconsideration procedures, with reasoned decisions, versioning, and preservation of dissent.
Cooperation	Arrangements may organize interoperability, review, and information exchange with the Convention, States, or other systems without conferring scientific supervision.
Transparency	Governance rules, composition, terms, funding, methodological decisions, and protocol changes are public, subject to legitimately confidential information.

TRANSITIONAL PHASE

Until autonomous governance is formally constituted, the project may be prepared and administered by its initiator and La Compagnie des Papillons Bleus. This transitional phase must not be presented as conferring final scientific authority or as allowing classifications to escape independent review.

25. Data Governance, Licensing, and Publication

The Atlas should maintain a source register for every dataset used. For each source, the register should state producer, title, version, spatial and temporal coverage, licence, attribution requirements, permitted transformations, redistribution restrictions, access conditions, and any sensitivity or confidentiality limitations.

Open data are preferred where scientifically appropriate, but openness cannot override legal restrictions, Indigenous or community authority, confidentiality, threatened-species protection, or contractual obligations. Some datasets may be referenced or queried without being redistributed.

Governance field	Minimum record
Licence	Exact licence or terms-of-use reference; version / date where available.
Attribution	Required citation, producer name, acknowledgement text.
Transformation	Whether derivatives are permitted; conditions on modification.
Redistribution	Whether source or derivative data may be redistributed.
Access class	Public, restricted, confidential / non-disclosable.
Retention	Whether source copies may be stored and for how long.
Withdrawal / update	How a superseded or withdrawn source is handled.

26. Atlas Outputs and User-Facing Classification

The public interface should simplify access without flattening scientific nuance. Every displayed classification should support a "why this classification?" path leading to provenance, date, method, confidence, limitations, and review status.

- Show ecological category separately from confidence.
- Show current condition separately from trajectory.
- Show risk and vulnerability separately from present condition, integrity, degradation, and confidence.
- Show legal protection separately from effective protection.
- Show natural forest loss separately from plantation gain.
- Show gross integrity loss separately from later recovery or gains elsewhere.
- Provide time-series views where data permit.
- Use "not determined" rather than visually forcing every area into a class.
- Display contested status clearly without implying that contestation itself proves the classification false.
- Protect sensitive coordinates and confidential knowledge.
- Show current primary status separately from primary-status history.
- Display the precautionary "possible primary forest - independent assessment required" signal separately.
- Show whether a management purpose is compatible or incompatible with the ecological category.
- Where recovery is displayed, identify the recovery-from condition and reference model.

- Where recovery debt or carbon debt is displayed, show the reference / counterfactual, time horizon, assumptions, and uncertainty and state that the metric is not an offset.
- Show protected natural succession separately from ecological class, formal legal protection, and effective protection.
- Where relevant, identify natural non-forest ecosystems and afforestation sensitivity so that open ecosystems are not visually treated as forest-restoration gaps.
- Provide a clear note on the absence of automatic legal effect and, where relevant, the legal framework that may be triggered.

The default world view should avoid implying pixel-level certainty for coarse or modelled variables. Resolution and scale should be communicated in legends and information panels. Where several sources disagree, users should be able to inspect the underlying evidence rather than seeing only an unexplained final colour.

The public interface must not reduce the Atlas to logging surveillance. Cover change, harvesting, roads, fire, conversion, degradation, recovery, and other pressures or trajectories are possible layers or outputs within a broader system of knowledge, qualification, and longitudinal monitoring.

27. Implementation Roadmap

Stage	Output	Decision gate
0.1 - Foundational protocol	Initial evidence architecture; provisional confidence system; pilot criteria.	External scientific review opens.
0.1.1 - Alignment revision	Doctrine / Convention alignment; governance autonomy; strengthened primary-forest definition; precaution.	Published as then-current version for external review.
0.1.2 - Restoration alignment	Restoration / recovery terminology, native ecosystem, reference-model logic, SER interoperability.	Then-current working version; no SER endorsement claim.
0.1.3 - Integrity / degradation consolidation	24 Aug: degradation definition; reference hierarchy; PCIV; disturbance-regime rule; recovery provenance; gross loss; roads; risk / vulnerability; debts; non-forest safeguards.	Then-current working version; DellaSala inputs used without endorsement.
0.1.4 - Succession / legacies consolidation	25 Aug: succession-before-recovery; seral state; strengthened biological legacies; dynamic seral reference models; recovery-debt safeguard; updated fields, pilots, and references.	Current working version for external scientific review; further DellaSala publications treated as scientific input without endorsement.
0.2 - Reviewed protocol	Structured reviewer comments and major methodological objections resolved.	Autonomous scientific-governance framework adopted; proceed to pilots.
Pilot implementation	Contrasted pilot sites; reproducibility tests; data catalogue; technical and governance tests.	Test categories, succession / recovery logic, degradation, reference conditions, gross-loss rules, and precaution.
0.3 / 0.4 - Pilot revisions	Method corrections; calibration rules; specialist sub-protocols.	Independent review of pilot evidence.
1.0 - Consolidated protocol	Approved methodological baseline for wider operational deployment.	Progressive regional / global expansion.
Atlas Alpha / Beta	Public-facing spatial implementation with versioned records and review mechanisms.	Ongoing audit, correction, and protocol revision.

Technical implementation - databases, cloud storage, APIs, map libraries, and processing infrastructure - must remain subordinate to the methodological architecture and autonomous scientific governance. Technology may change without changing scientific meaning. Any system design must preserve provenance, versioning, uncertainty, analytical separation of Atlas dimensions, and independence of publication decisions.

Annex A. Minimum Atlas Record

The following fields constitute the minimum conceptual record for a material Atlas classification. Specialist layers may require additional metadata.

Field	Minimum meaning
record_id	Persistent unique identifier.
geometry	Polygon, point, raster footprint, or referenced spatial unit.
assessment_scale	Pixel, site, stand, forest complex, landscape, watershed, ecoregion, etc.
ecosystem_context	Biome, ecoregion, ecosystem / forest type; include non-forest natural ecosystem type where relevant to landscape interpretation or afforestation sensitivity.
historical_potential_distribution	Historical, reconstructed, or ecologically potential distribution of the ecosystem where relevant; method, date, and reconstruction limits.
doctrine_version	Exact doctrine version used for assessment.
ecological_origin	Natural, planted, mixed, unknown; supporting evidence.
ecological_classification	Material ecological category assigned or not determined.
primary_status	Confirmed primary / possible primary / not primary / not determined. Evidentiary confidence and review status are recorded separately.
primary_status_history	Prior primary classifications, dates, evidence, reviews, and links.
historical_continuity	Primary continuity, long continuity, secondary recovery, uncertain; earliest supported date.
ecological_naturalness	Present naturalness and supporting evidence.

Field	Minimum meaning
integrity_status	Structural, biological, ecological, landscape, and biocultural dimensions.
degradation_diagnosis	Not assessed / no degradation detected under assessed dimensions / degradation detected / indeterminate. Evidentiary confidence is recorded only in confidence_level.
degradation_intensity	Optional calibrated ecological intensity: low / moderate / high / severe / threshold-approaching / indeterminate, only where biome- or ecosystem-specific criteria justify grading; never a confidence code.
degradation_reference	Reference condition or model used to assess loss of integrity and rationale for its selection.
disturbance_origin	Natural / anthropogenic / mixed / indeterminate; source and basis.
degradation_causality	Direct anthropogenic / anthropogenically amplified natural process / mixed anthropogenic / indeterminate / not applicable; specific drivers where supported. A purely natural disturbance within the characteristic regime is not coded as a degradation cause.
cumulative_impacts	Repeated or interacting pressures, chronology, intervals, extent, and evidence of chronicity or compounding effects.
risk_vulnerability	Prospective exposure, sensitivity, adaptive capacity, threshold / tipping-point risk, reversibility, and likely recovery time where relevant; evidence and scale stated.
seral_state Early-seral / intermediate / mature / late-successional / multi-seral / other biome-appropriate state / indeterminate; evidence and scale stated.	
old_growth_structure	Presence and evidence of old / late structural attributes.
intact_landscape_context	Intact forest landscape context or degree of fragmentation.
condition_summary	Current composition, structure, soils, water, regeneration, biodiversity.
management	Objective, intensity, interventions, recurrence.
management_compatibility	Compatibility of management purpose with ecological category and applicable law.
disturbance_history	Type, origin, date, intensity, frequency, duration, spatial extent, recurrence, interval between events.
disturbance_regime_compatibility	Compatibility of disturbance with the ecosystem's characteristic regime.
biological_legacies	Living or dead trees, seed, propagules, soils, microorganisms, fungi, refugia, retained structures.
road_linear_infrastructure	Road density, roadless core area, road-stream intersections, barriers, access changes, and fragmentation metrics where relevant and scale-valid.
post_disturbance_extraction	Salvage logging or other extraction after natural disturbance; date, footprint, authorization, ecological effects.
trajectory Post-disturbance succession / seral transition / maturation / recovery where applicable / stable / declining / conversion / failure / other transition / indeterminate.	
recovery_from_condition Used only where recovery is applicable: material loss / ecological deficit and condition or anthropogenic continuity break from which recovery occurs; cause, date, reference, and evidence stated.	
restoration_activity	Restoration intervention / process, date, objective, methods, intensity; not a recovery outcome.
rehabilitation_activity	Actions reinstating physical conditions, functioning, or services without implying substantive native-ecosystem recovery.
recovery_status Not applicable / none / initiating / progressing / partial / full / indeterminate; date and evidentiary basis.	
recovery_evidence	Evidence supporting recovery relative to the reference model.
recovery_debt Optional cumulative deficit relative to a defensible reference during degradation and recovery; method, horizon, uncertainty; never an offset and never assigned solely because a characteristic natural seral state differs from the preceding state.	
self_organization_status	Evidence that ecosystem attributes continue developing toward the reference model; remaining management dependence disclosed.
ser_attribute_assessment	Where restoration is assessed, optional crosswalk across SER's six key ecosystem attributes; does not replace Atlas-specific dimensions.
reference_model	Expected high-integrity condition of the native ecosystem, rationale, variability, and environmental-change assumptions.
reference_sites	Reference-site identifiers and other evidentiary sources used to construct the reference model.
gross_integrity_loss_record	Material integrity losses recorded at location and time of occurrence; later recovery or gains linked but not netted.
protected_succession_status	None / proposed / designated or secured / under monitoring / other, with legal or governance basis where applicable; kept separate from ecological classification and protection effectiveness.
non_forest_ecosystem_context	Identity and ecological condition of relevant naturally open or other non-forest ecosystems; do not force into a forest class.
afforestation_sensitivity	Evidence that tree establishment may be compatible, neutral, uncertain, or ecologically harmful to the non-forest system; reference condition, scale, and uncertainty.
carbon	Relevant stock, flow, capacity, foregone-sequestration, permanence, and risk fields.
carbon_debt	Optional cumulative carbon deficit or additional atmospheric burden through time relative to a defensible counterfactual after a carbon-loss event; method, horizon, assumptions, uncertainty; never an offset unit.
rights_governance	Tenure, rights, territory, protection, governance, disclosure class.
essential_human_needs_compatible_uses	Essential human needs and uses compatible with the ecological category, rights, and applicable governance where relevant.
decision_need	Protect, restore, investigate, reconnect, monitor, reduce risk; compatible production only where category and law permit.
decision_context	Decision, policy, project, or use for which the assessment is intended.
precautionary_alert	Possible primary status or other precautionary signal; evidence and recommended scientific action.
commissioning_entity	Commissioning entity for the assessment or study.
funding_source	Funding source and relevant material relationship.
conflict_of_interest	Conflicts declared by producers, assessors, and reviewers.

Field	Minimum meaning
applicable_legal_framework	Law or legal instrument capable of using the output.
legal_effect_note	No automatic legal effect; record any assessment or precaution mechanism.
source_list	Primary and secondary evidence sources.
method	Acquisition and analytical method.
uncertainty	Quantitative / qualitative uncertainty.
confidence_level	CL0-CL4 provisional scale.
status_flag	CURRENT / PROVISIONAL / CONTESTED / UNDER REVIEW / SUPERSEDED / WITHDRAWN.
assessment_date	Date of Atlas interpretation.
protocol_version	Protocol version used.
review_record	Reviewer / body, date, conflicts, decision.
version_links	Predecessor / successor records.

Annex B. Provisional Confidence Matrix

This matrix is deliberately generic in Version 0.1.4. Biome-specific protocols may raise minimum requirements for particular classifications. The matrix must be tested during external review and pilot implementation.

Criterion	CL0	CL1	CL2	CL3	CL4
Evidence quantity	None / unusable	Single / sparse	One strong or several moderate	Multiple complementary	Multiple + validation record
Method fitness	Unknown / unsuitable	Partly relevant	Generally appropriate	Appropriate and calibrated	Validated for stated use
Spatial scale	Mismatch unresolved	Potential mismatch	Acceptable with limitation	Good match	Verified match
Temporal relevance	Unknown / obsolete	Weak	Generally relevant	Current / reconstructed appropriately	Current + reviewed
Independent convergence	None	Limited	Some	Strong	Strong + formal review
Uncertainty	Unbounded	High / poorly bounded	Material but described	Bounded and documented	Bounded + validation confirms fitness

A classification may not be promoted to a higher confidence level merely because one data source is high resolution. Confidence depends on fitness to the ecological question, not only technical precision.

Normalization rule. Confidence level expresses evidentiary support only. It must never be used as an ecological state, degradation intensity, primary-status category, risk class, or review status. PROVISIONAL and CONTESTED belong to status_flag, not to primary_status.

Version 0.1.4 sets no universal threshold for excluding possible primary status or diagnosing severe degradation in a high-consequence decision. Such a conclusion requires enhanced review, converging evidence, an explicit reference condition, and fitness for the decision context.

Annex C. Category Evidence Matrix

Category / descriptor	Evidence generally required	Evidence that is insufficient by itself
Primary forest	Natural regeneration; native species; natural ecological and evolutionary processes; biological legacies; characteristic disturbance regime; ecological continuity; intervention and land-use history; current ecological evidence; landscape context; compatible human uses.	Old canopy appearance; height; biomass; age; canopy openness; area; legal status; management plan; human presence; natural disturbance; inventory absence; absence of known logging.
Very high naturalness	Present naturalness; autonomous processes; historical evidence of limited, ancient, or uncertain intervention; appropriate reference model.	Low management intensity alone; high species richness alone; visual similarity to primary forest.
Secondary forest	Substantial continuity break linked to significant anthropogenic disturbance, harvesting, or conversion; natural regeneration; present forest processes; recovery trajectory where applicable.	Age threshold; tree-cover gain; natural fire or storm without disturbance-regime analysis.
High-integrity forest	Appropriate reference model; composition, structure, processes, connectivity, stability, autonomy, adaptive capacity and, where relevant, biocultural dimension.	High carbon, legal protection, or stable canopy taken alone.
Risk / vulnerability	Prospective exposure and pressure pathways; sensitivity; adaptive capacity; threshold or tipping-point evidence; reversibility; likely recovery time; scale-appropriate climate and disturbance information.	Present degradation alone; a single hazard map; present condition or confidence score used as a proxy for future vulnerability.
Long-continuity forest	Converging historical sources demonstrating forest persistence and absence of durable conversion.	Tree age or present old-growth structure alone.
Seral / developmental state	Biome-appropriate early-seral, intermediate, mature, late-successional or multi-seral state; biological legacies; disturbance context; trajectory and regime compatibility.	A single universal age, canopy condition, or difference from the prior mature state alone.
Old-growth / old forest structure	Old and large trees, deadwood, cavities, layering, microhabitats, and other late structures.	Old-looking canopy or legal protection alone.
Intact forest landscape	Large continuity, low industrial fragmentation, natural cores, large-scale processes, and landscape context.	Large area or high cover without infrastructure and land-use analysis.
Degraded natural forest	Natural origin plus documented or strongly supported anthropogenic deterioration of integrity relative to an appropriate reference; structure, function, biota, soils, hydrology, connectivity, regeneration, landscape configuration or cumulative impacts; primary-status history retained where applicable.	Canopy thinning alone; low biomass alone; severe natural disturbance alone; stable canopy alone.
Recovery trajectory	Demonstrated applicability of recovery; material prior loss or ecological deficit; recovery-from condition; reference model / condition; time-series evidence of relevant attributes.	Tree-cover gain, canopy closure, project designation, age alone, or characteristic natural post-disturbance succession without demonstrated deficit.
Forest under restoration	Documented restoration activity + explicit native-ecosystem reference model + measurable recovery evidence / status + monitoring and adaptive management.	Project name, budget, planting event, or canopy establishment alone.
Production plantation	Planted establishment; predominant production objective; recurrent management or harvest; constrained autonomy and structure.	Regular rows alone, especially in young restoration plantings.
Agroforest	Intentional tree-crop, pasture, or livestock association; management and livelihood context.	Scattered trees in agricultural land without management context.

Annex D. Pilot Evaluation Checklist

- Are spatial units ecologically meaningful and reproducible?
- Do doctrinal categories and orthogonal descriptors remain distinguishable with available evidence?
- Which variables can be supported from remote sensing and which require field evidence?
- Do confidence levels produce consistent results among independent reviewers?
- Does "not determined" occur where evidence is genuinely insufficient?
- Does the "possible primary forest - independent assessment required" signal occur in appropriate cases?
- Does the primary / secondary distinction withstand natural fire, storms, young seral mosaics, and open canopies?
- Can the protocol distinguish natural disturbance from degradation without using severity alone?
- Are small primary-forest fragments assessed without exclusionary administrative thresholds?
- Are compatible Indigenous, traditional, cultural, or subsistence uses distinguished from intensive transformation?
- Does primary-status history remain visible after degradation, illegal logging, or salvage logging?
- Is inventory or data absence prevented from becoming evidence of absence of primary status?
- Are reference models defensible, transparent, and calibrated to the ecosystem, with supporting reference sites / evidence identified where appropriate?
- Does the degradation reference follow the reference-condition hierarchy or explain any justified departure?
- Do degradation-oriented PCIV indicators behave differently across biomes in ways requiring regional thresholds?
- Does every recovery classification answer "recovering from what?" and preserve the relevant causal history?
- Are primary_status, confidence_level, and status_flag normalized as separate concepts?
- Are degradation diagnosis, calibrated degradation intensity, and confidence kept separate?
- Are disturbance origin and degradation causality kept separate, with purely natural within-regime disturbance excluded as a degradation cause?

- Are risk and vulnerability represented as prospective dimensions distinct from current condition and integrity?
- Are protected natural-succession records distinct from ecological classification, legal protection, and effective protection?
- Are non-forest ecosystems and afforestation sensitivity represented where inappropriate tree establishment could cause harm?
- Where recovery debt or carbon debt is used, is the metric transparent, time-bounded, non-compensatory, and supported by a defensible reference or counterfactual?
- Are gross integrity losses kept separate from later recovery, restoration, plantation gains, or gains elsewhere?
- Do road density, roadless core area, road-stream intersections, and fragmentation metrics operate at appropriate spatial scales?
- Can rights and governance information be handled without exposing sensitive or contested data?
- Can source licences be respected without undermining transparency?
- Are classification changes fully versioned and auditable?
- Can a stakeholder submit a challenge and receive a reasoned, traceable review outcome?
- Is the separation between scientific output and legal effect understood by users?
- Do independence safeguards function where major economic or political interests are involved?
- Does the public interface communicate uncertainty without overwhelming users?
- Are non-compensability and gross-loss rules clear enough to prevent misleading composite or net scores?
- Are field and remote-sensing datasets temporally aligned?
- What specialist sub-protocols are still missing?
- Are restoration activity and recovery status recorded and communicated as separate variables?
- Do restoration assessments document the native ecosystem, reference model, recovery evidence, and self-organization status where applicable?
- Does the SER six-attribute crosswalk improve interoperability without replacing Atlas-specific dimensions?

Annex E. Change and Review Record

Field	Required entry
Record / protocol version	Version being reviewed.
Doctrine version	Doctrine version used in the challenged assessment.
Issue raised	Specific classification, method, threshold, source, or interpretation challenged.
Submitted by	Name / institution / community or confidential reference as appropriate.
Commissioning / funding	Entity commissioning the assessment and relevant funding sources.
Evidence submitted	Citation / dataset / field record / legal record / community evidence.
Conflict of interest	Declarations from reviewers and materially involved parties.
Decision / legal context	Proposed decision, applicable legal framework, and possible consequences.
Effect on primary-status history	State whether review affects a prior primary classification and how history is preserved.
Effect on degradation / gross-loss record	State whether review changes a degradation diagnosis, reference condition, causal attribution, or prior gross-loss record, and how history is preserved.
Review pathway	Technical, methodological, ecological expert, enhanced high-consequence, or pluralistic.
Decision	Confirm / revise / narrow / suspend / withdraw / unresolved.
Reasoning	Concise evidence-based explanation.
Effective date	Date revised status takes effect.
Superseded record	Identifier and retained archive location.

Principal References

The references below form part of the methodological and scientific context from which Version 0.1.4 has been developed. The 18 August 2026 revision uses Gann et al. (2026) for restoration terminology and interoperability; the 24 August revision consolidates integrity and degradation; and the 25 August revision adds a targeted succession / seral-state and biological-legacies consolidation following further critical scientific exchange with Dominick A. DellaSala and examination of additional published materials. Inclusion does not imply endorsement of this Protocol by the authors or institutions cited.

1. FAO. *Global Forest Resources Assessment 2025; FRA 2025 Terms and Definitions*.

2. Chazdon, R. L., Brancalion, P. H. S., Laestadius, L., et al. (2016). "When Is a Forest a Forest? Forest Concepts and Definitions in the Era of Forest and Landscape Restoration." *Ambio* 45, 538-550. <https://doi.org/10.1007/s13280-016-0772-y>

3. Kormos, C. F., Mackey, B., DellaSala, D. A., et al. (2017). "Primary Forests: Definition, Status and Future Prospects for Global Conservation." *Encyclopedia of the Anthropocene*.

4. Brancalion, P. H. S., and Chazdon, R. L. (2017). "Beyond Hectares: Four Principles to Guide Reforestation in the Context of Tropical Forest and Landscape Restoration." *Restoration Ecology* 25(4), 491-496. <https://doi.org/10.1111/rec.12519>
5. DellaSala, D. A., and Furnish, J. (2020). "Can Young-Growth Forests Save the Tongass Rainforest in Southeast Alaska?" *Encyclopedia of the World's Biomes*, Vol. 3, 218-225. <https://doi.org/10.1016/B978-0-12-409548-9.11685-9>
6. Grantham, H. S., Duncan, A., Evans, T. D., et al. (2020). "Anthropogenic Modification of Forests Means Only 40% of Remaining Forests Have High Ecosystem Integrity." *Nature Communications* 11, 5978. <https://www.nature.com/articles/s41467-020-19493-3>
7. Rogers, B. M., Mackey, B., Shestakova, T. A., et al. (2022). "Using Ecosystem Integrity to Maximize Climate Mitigation and Minimize Risk in International Forest Policy." *Frontiers in Forests and Global Change* 5, 929281. <https://doi.org/10.3389/ffgc.2022.929281>
8. Mackey, B., Morgan, E., and Keith, H. (2024). "Evaluating Forest Landscape Management for Ecosystem Integrity." *Landscape Research* 49(2), 246-267. <https://doi.org/10.1080/01426397.2023.2284938>
9. Mackey, B., Hugh, S., Norman, P., Rogers, B. M., and DellaSala, D. (2024). "Insights into Boreal Forest Disturbance from Canopy Stability Index." *Land* 13, 1644. <https://doi.org/10.3390/land13101644>
10. Keith, H., et al. (2024). "Carbon Carrying Capacity in Primary Forests Shows Potential for Mitigation Achieving the European Green Deal 2030 Target." *Communications Earth & Environment* 5, 256. <https://doi.org/10.1038/s43247-024-01416-5>
11. DellaSala, D. A., Mackey, B., Kormos, C. F., Young, V., Boan, J. J., Skene, J. L., Lindenmayer, D. B., Kun, Z., Selva, N., Malcolm, J. R., and Laurance, W. F. (2025). "Measuring Forest Degradation via Ecological-Integrity Indicators at Multiple Spatial Scales." *Biological Conservation* 302, 110939. <https://doi.org/10.1016/j.biocon.2024.110939>
12. Gann, G. D., McDonald, T., Walder, B., et al. (2026). "International Principles and Standards for the Practice of Ecological Restoration. Third Edition." *Restoration Ecology* 34, e70441. <https://doi.org/10.1111/rec.70441>
13. Maron, M., Ward, M., Simmonds, J. S., et al. (2026). "Ecological Irreplaceability in the Era of Nature Positive." *Conservation Letters* 19(4), e70073. <https://doi.org/10.1111/con4.70073>
14. IUCN. *Global Ecosystem Typology*.
15. United Nations. *United Nations Declaration on the Rights of Indigenous Peoples*.
16. Convention on Biological Diversity. *Kunming-Montreal Global Biodiversity Framework*, including Targets 2, 3, and 22.
18. Universal Declaration of Tree Rights. What a Forest Is - and What It Is Not - in Light of the Declaration: A Global Classification of Forest Ecosystems, Protection of Primary Forests, and a Program for the Recovery of Naturalness. Revised and consolidated version of 25 August 2026.
19. International Convention on Tree Rights. Consolidated review edition of 14 August 2026.
20. DellaSala, D. A., Bond, M. L., Hanson, C. T., Hutto, R. L., and Odion, D. C. (2014). "Complex Early Seral Forests of the Sierra Nevada: What are They and How Can They Be Managed for Ecological Integrity?" *Natural Areas Journal* 34(3), 310-324. <https://doi.org/10.3375/043.034.0317>
21. DellaSala, D. A. (2020). "Fire-mediated Biological Legacies in Dry Forested Ecosystems of the Pacific Northwest, USA." In *Disturbance Ecology and Biological Diversity*, Chapter 3, 63-78.
22. DellaSala, D. A. (2020). "Forest Biome: Trees of Life." *Encyclopedia of the World's Biomes*, Vol. 3, 1-15. <https://doi.org/10.1016/B978-0-12-409548-9.12007-X>

END OF VERSION 0.1.4

This working protocol is intended to be revised following structured external scientific review and pilot testing. The public version history must preserve all material changes, unresolved disagreements, and reasons for revision.