Ecological Forest Management

* Franklin et al. 2018. Waveland Press
* Palik et al. 2020. Waveland Press

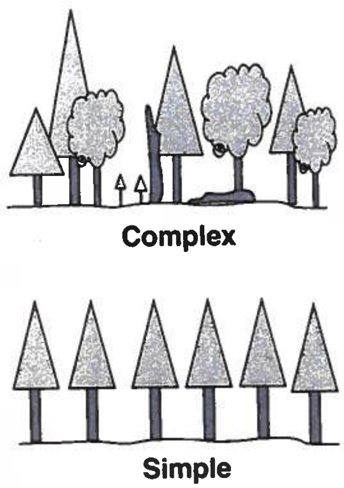

Figure 8.6 *Comparison of two hypothetical forests, one that is structurally complex versus one that is structurally simple.*

Table 3.2 *Attributes associated with complex and simple forest conditions. Promoting and maintaining complex forest conditions is a central principle in the design of ecological silviculture systems.*

Complex	Simple
Multiple tree species in canopy layer	Single species
Multiple age cohorts	Single cohort
Wider size and age ranges	Narrow ranges; young trees
More noncommercial species	Few species
Understory plant populations	Depleted plant populations
Abundant tree-derived structures	Few tree-derived structures
Abundance of coarse, woody material across range of decay states	Low abundance and representation of advanced decay states
Spatial heterogeneity	Spatial homogeneity

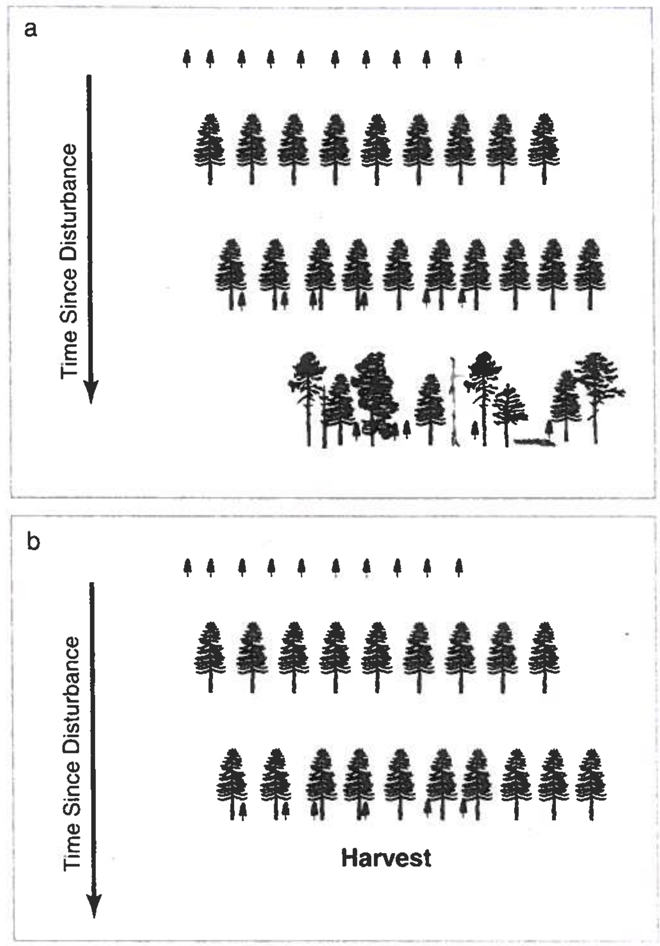

Figure 3.8 *Conceptual representation of the importance of timing for the development of structural complexity. (a) A young post-disturbance forest begins with simplified structure and composition (i.e., no biological legacies) and over time develops significant structural complexity due primarily to tree growth, mortality, and small-scale canopy disturbance. (b) In many classical forestry approaches, the forest is harvested before significant compositional and structural complexity has had time to develop.*

What to Remember about Ecological Forestry

From this chapter, a forester can surmise that ecological forestry is a malleable concept that is adaptable to different settings, but one that can prove invaluable for basing forest management on an ecological foundation of emulating natural disturbance and stand development, as opposed to the agricultural foundation of traditional timber-focused forestry. Also remember, ecological forestry is a conceptual approach to forest management, and not a management prescription; an approach that is built on the assumption that emulating natural developmental processes of forests provides a framework for managing ecosystem for sustainability and adaptability in the face of uncertainty. While ecological forestry by definition puts high value on ecological goals for management, economic and social considerations must still be part of the mix, although as we have suggested, in different ways and with different outcomes than timber-focused forestry. Finally, the ecological forester can consider the similarities and differences between ecological forestry and other ecological forest management approaches. This way they will recognize that ecological forestry is a comprehensive conceptual approach that considers all stages of forest development and readily leads to the formulation of silvicultural prescriptions to achieve objectives, as we will explore later in this book.

Table 2.2 *Ecological implications of ecological forestry and timber-focused forestry. (Adapted from Franklin et al. 2018).*

Ecological Forestry	Timber-Focused Forestry
Results in continuity of structure, function, and biota across forest generations	Results in discontinuity of most structures, functions, and biota across forest generations
Results in stand-level structural complexity and species diversity	Results in stand-level structural simplicity and reduced species diversity
Results in spatial heterogeneity of structure and composition in stands	Results in spatial uniformity in stands
Maintains a more diverse array of successional stages at larger spatial scales, including older trees and forests, as well as early successional ecosystems	Maintains age variants of young and mature stages across a landscape; may not include old trees and stands or extended duration of early successional stages, namely the preforest stage, as management goals

Table 2.1 *Fundamental principles for ecological forestry and timber-focused forestry. (Adapted from Franklin et al. 2018).*

Ecological Forestry	Timber-Focused Forestry
Maintains ecosystems and their array of structures, functions (processes), and biota	Maintains a subset of ecosystem structures, functions, and biota consistent with economic goals
Uses natural stand development models, including effects of disturbances, as the basis for silvicultural prescriptions	Based on agronomic models, e.g., plant spacing, weeding, fertilization, as the bases for silvicultural prescriptions
Values complexity and heterogeneity of ecosystem attributes	Values simplicity and homogeneity of structure and composition
Emphasizes ecosystem diversity and resilience to reduce major disruption risks	Emphasizes optimizing growth of crop species to reduce risks

Table 2.3 *Economic implications of ecological forestry and timber-focused forestry. (Adapted from Franklin et al. 2018).*

Ecological Forestry	Timber-Focused Forestry
Generally seeks financial return from management, especially income over time, but return on capital is not the primary performance measure	Moderate to high return on capital is the primary performance measure
Leaves substantial recoverable values on site at time of harvest; some recoverable values retained have low rates of return	Minimizes recoverable values on sites at time of harvest
Higher cost per unit of output due to complexity of prescriptions and technical expertise needed for management	Lower cost per unit of output due to simplicity of prescriptions and management
May produce significant periodic income from the forest over time, but maintains higher investment level	Producing a periodic income from the forest over time usually a secondary consideration to return on capital, considering all investment opportunities
Lower risk due to emphasis on structural complexity, compositional diversity, and resilience	Higher risk due to its emphasis on structural and compositional simplicity and uniformity

Table 2.4 *Social implications of ecological forestry and timber-focused forestry. (Adapted from Franklin et al. 2018).*

Ecological Forestry	Timber-Focused Forestry
Retaining ecosystem components and processes contributes to effectiveness of collaborative efforts	Simplified forests limit potential effectiveness of collaborative efforts
Retaining ecosystem components and processes makes it easier to respond to changing social goals	Simplified forests limit ability to respond to changing social goals
Tends to increase management options in response to evolving needs and social expectations	Tends to reduce management options, limiting responsiveness to evolving needs and social expectations

Table 7.1 *Biological legacies associated with classical regeneration systems as traditionally applied. (Adapted from Franklin et al. 2007.)*

	Regeneration Method					
	Even-Aged			Two-Aged	Uneven-Aged	
Legacy	Clearcut with site preparation	Seed tree with site preparation	Shelterwood with site preparation	Clearcut, Seed tree, or Shelterwood, *with reserves*, and site preparation	Group selection	Single-tree selection
Live, mature trees	No	No/Maybe[1]	No[2]	Yes	Few/No (in group)	n.a.
Seedling bank	No	No	Yes	Yes	Possible	Possible
Intact understory	No	No	No	Possible	Possible	Possible
Snags	No	No	No	No	No (in group)	Few/No[3]
Logs	Few/No	Few/No	Few/No	Few/No	Few/No (in group)	No
Uproots	No	No	No	No	No	No
Mineral seedbed[4]	Yes	Yes	Yes	Yes	Possible	Possible

[1]As traditionally applied, seed trees are removed, although logistics/economics often prevents this from happening.
[2]Following final removal of overstory.
[3]Declining, poor quality, and dead trees receive priority for removal under single-tree selection resulting in low numbers of snags.
[4]Assuming ground-based harvesting.

Table 2.5 *General silvicultural considerations of ecological forestry and timber-focused forestry. (Adapted from Franklin et al. 2018).*

Ecological Forestry	Timber-Focused Forestry
Focuses on native species and genotypes that provide an array of ecological and other values	Focuses on species with desirable economic characteristics; may include tree improvement
Inclusive of uneven-aged, two-cohort, and single-cohort stands (with older residuals), as reflective of the natural model for a given forest type.	Inclusive of uneven-aged and even-aged stands, with narrowly even-aged stands common in plantation settings
Incorporates biological legacies into regeneration harvests, including in uneven-aged systems	Incorporating biological legacies is not a primary goal
Emphases development of complexity with intermediate treatments, e.g., thinning; intermediate treatments used to modify all structural layers	Emphasizes development of uniformity with intermediate treatments; actions focused on growing stock
Values decadence; retains defective trees and structures as habitat	Eliminates defective trees and structures
Utilizes longer rotations (with stand-replacement forest types) or long cutting cycles (with uneven-aged forest types)	Utilizes economic rotations on high-productivity sites or opportunistic removals on low-productivity sites
Return intervals for management (e.g., rotations, cutting cycles) are keyed to ecological criteria	Return intervals for management interventions (e.g., rotations) are keyed to growth or economic criteria
Landscape context of stand-level treatments focuses on maintenance of ecosystem processes and structures	Landscape context of stand-level treatments focuses on efficiency of harvest patch, road, and logging designs

Table 3.1 *Crosswalk between commonly used terms in ecological silviculture and classical silviculture*

Ecological Term	Definition	Classical analogues	Similarities between terms and their intent	Differences between terms and their intent
Retention tree	Canopy tree retained on site during a regeneration harvest, often to live out its full lifespan, to serve as a source of mature forest structure and associated functions (i.e., seed sources, mycorrhizae)	Reserve trees, standards	All are examples of mature canopy trees retained during regeneration harvests	Classical analogues are typically left as part of a deferred harvest and ultimately may be harvested. When reserved for economically motivated objectives, trees with the greatest potential to increase in financial value are left, as opposed to retention trees which are primarily left for their ecological value and may include "overmature", decadent, and declining trees.
Variable retention harvest	Retention of living and dead trees (retention trees) during regeneration harvest in a range of spatial patterns *(dispersed and aggregated)* to serve as a source of mature forest structure and function in the post-harvest community	Irregular shelterwood	Both contain a range of overstory tree retention patterns following initial regeneration entries	The traditional purpose of these spatial arrangements are to influence the regeneration process of midtolerant and tolerant species. These retained trees are ultimately harvested after successful regeneration is achieved. The primary objective of variable retention harvests is to retain structural legacies to sustain ecological processes and biological diversity from the previous stand when regenerating a new cohort.
Variable density thinning (VDT)	A thinning approach in which the density of tree removals is varied across a stand or management unit to increase heterogeneity in horizontal and vertical structure. With VDT, thinning levels often range from small group removal, to standard thinning with individual tree removals, to patches with no removal. Applications of VDT have been referred to as the "skips and gaps" or "Individuals, Clumps, and Openings" (ICO; Churchill et al., 2013) approach.	(a) Thinning (crown, low, dominant, free, row) (b) Single, group, and patch selection; irregular shelterwood	(a) Both accelerate development of large tree structure (b) All represent multi-age regeneration methods	(a) The term "thinning" in a classical context indicates no attention is being directed toward regenerating a new cohort, whereas VDT explicitly focuses on increasing structural heterogeneity, including recruiting new cohorts in areas containing group removals. In addition, classical thinning strives to create homogeneity in mature tree structure and density across a site, whereas the focus of VDT is to create spatial heterogeneity to influence development of canopy trees, as well as understory and midstory components (b) For selection methods, the primary focus is on the uniform application of these methods across a stand to generate regulated conditions and sustained timber flows. Irregular shelterwoods, another multi-age system, may also generate stand-level heterogeneity in mature tree structure similar to VDT, particularly with continuous cover variants (Raymond et al. 2009); however, permanent reserve patches are not traditionally a component of these systems, as they may be with VDT
Recovery period	Period of time between regeneration harvests of sufficient duration to allow for development of mature forest structure at tree, patch, stand, and management unit scales	Rotation; cutting cycle	All represent intervals of time between regeneration harvests in a forest	The criteria for establishing rotation and cutting cycle length differs from recovery period. With even-aged systems, rotation lengths are based on the age that maximizes economic return on investment or average levels of stand productivity (MAI). For uneven-aged systems, cutting cycle lengths are generally associated with the severity of harvest entries (residual basal area retained) and stand growth rates needed to meet an operable harvest. Both rotation and cutting cycle length are generally fixed for a landscape (even-aged systems) or stand (uneven-aged systems), whereas recovery periods vary to reflect the range in natural disturbance return rates across landscapes and over time and on forest development processes. All of these will vary based on site productivity and associated rates of tree growth and forest development.

Table 3.3 Example outcomes of application of the four principles of ecological silviculture to priority objectives for management.

Principle	Commodity productivity	Biodiversity conservation	Global change resilience/adaptation
1) Continuity	• Opportunities for natural regeneration of a range of species • Larger high-value products	• Life boating of species requiring mature forest conditions • Greater diversity of food/energy sources from canopy species • Large snags/deadwood for saproxylic and cavity nesting species	• Options for regeneration in face of uncertainty • Amelioration of harsh environmental conditions ∘ regeneration safe sites (shaded understory, decomposed wood) • Conservation of genetic diversity

2) Complexity/ Diversity	• Opportunities for multiple entries (outputs)
	• Diverse product mix
	• High-quality products (resulting from natural pruning, training)
	• Multiple opportunities for natural regeneration of desired species
		• Diversity of habitat niches
		  ∘ tree size classes
		  ∘ deadwood decay classes
		  ∘ live-tree spatial conditions
		  ∘ tree, shrub, understory species
			• Reduced vulnerability to disturbance
			  ∘ spatial variability in fuels
			  ∘ heterogeneity in wind risk (diverse heights)
			  ∘ heterogeneity in potential host species (insects/disease)
			  ∘ heterogeneity of tree sizes (host preferences, stress tolerance)
			• Multiple Recovery and developmental pathways
			  ∘ diversity of seed sources
			  ∘ advance regeneration
			• High levels of onsite mitigation potential (carbon storage)

3) Timing	• Higher-value products • Multiple entries (outputs) • Seed source over extended periods • Multiple species and lifespans (diversity of products/harvests over time)	• Opportunity for multiple life cycles for species with slower development • Habitats for large tree specialists (live and dead trees)	• Long-term maintenance of options for adaptation from current overstory species • Long-term amelioration of extremes in understory conditions • Reduced likelihood for compounding influence of harvesting with other stressors/disturbance • Accumulation of large onsite carbon stores
4) Context	• Diverse portfolio of products and potential harvest entries • Lower risk from changing market conditions	• Connectivity across landscapes and habitat gradients (e.g., riparian to upland, travel corridors) • Refugia at multiple scales • Diversity of structures/ composition at landscape-scale	• Reduced risk from landscape-scale stressors (drought) and disturbance (insects, fire, wind) • Greater options for adaptation potential at broad scales • Greater range of regeneration conditions for new species due to localized and landscape-scale heterogeneity in structure

CHAPTER 6

Natural Disturbance Archetypes

In this chapter, we focus our attention on natural disturbance **archetypes.** The definition of an archetype is *the original pattern or model from which all things of the same kind are copied or on which they are based.* Forest archetypes then, as conceptualized in this chapter, are meant to provide the reader with model systems for major types of forest ecosystems, including their disturbance regimes, stand dynamics, structural and compositional features, and, ultimately, appropriate ecological silviculture practices. The archetypes also illustrate how the developmental stages presented in the previous chapter (Chapter 5) play out in different forest types. Note that references to the developmental stages in the different archetypes is based on the developmental model description in Chapter 3 of Franklin et al. (2018).

Many forests will not fit perfectly into the models, but elements of the archetypes will be apparent in almost all forests. Our goal is to help the reader better understand the developmental processes that go on in natural forests, which has rarely been emphasized in the forest management literature because of the historical emphasis on early stages of development. The archetypes that follow should not be viewed as models that must be directly emulated in management, but rather as sources of information to consider when developing ecological silviculture prescriptions. We focus on four archetypes, as distinguished by their natural disturbance regimes:

1. *forests initiated by infrequent severe disturbance;*
2. *forests characterized by frequent low-severity disturbance, primarily fire;*
3. *forests characterized by gap disturbance, notably from wind;*
4. *forests characterized by mixed-severity disturbance regimes*

Archetype 1 is initiated by severe forest- or landscape-scale disturbance at infrequent intervals (one hundred years or more), thereby initiating new developmental sequences. Development progresses through the Preforest Stage (PFS), Young Forest Stage (YFS), and Mature Forest Stage (MFS), and eventually arrives at a quasi-equilibrium Old Forest Stage (OFS). The OFS is sustained by frequent, small-scale (tree- and gap-level) disturbances until a new disturbance begins the sere anew.

Archetype 2 applies to forests that experience low severity disturbance, largely wildfire, which occurs at frequent intervals (e.g., one year to several decades). In this archetype, severe disturbances that eliminate overstory cover over large areas are rare. Tree mortality occurs primarily to individuals, and in small patches, creating openings for regeneration and subsequent stand development. In this archetype, developmental stages are present at small spatial scales as elements of a forest mosaic.

Archetype 3 is one in which gap-scale disturbances, primarily from wind, drive the dynamics of the ecosystem. It has similarities to Archetype 1 in that the *OFS* is also in a quasi-equilibrium of structure and composition defined by a shifting mosaic of gap disturbance. It differs from Archetype 1 in that gap disturbances define the ecosystem at earlier developmental stages and can be indefinite in tenure, with severe disturbance being extremely rare. Archetype 3 also has similarities to Archetype 2 in that a mosaic of development stages, albeit at the gap scale, is present in the forest.

Finally, Archetype 4, is best characterized by a mixed-severity disturbance regime that includes variation in severity among events and variation in the agent of disturbance. Variable amounts of canopy disturbance are an outcome among stands (i.e., sometimes, but not always, stand-replacing). This disturbance regime is not easily pigeonholed into any of the other archetypes, since it includes chronic, low-severity disturbance such as surface fire, disturbances that can be gap-based, and disturbances that infrequently are severe enough to result in stand-replacement. This disturbance archetype also may contain all developmental stages simultaneously as elements of a forest mosaic.

In the following sections, we discuss the archetypes in greater detail, including how our forest development model (Chapter 5) applies to each. We use a case study ecosystem to illustrate our ideas for each archetype, but we note that the generalities are meant to apply to the variety of similar forests in each archetype.