9 Silviculture and Habitat Management
Uneven-Aged Systems

Even-aged management is the most common approach to managing forests for commodity production, but on many of the privately owned forests where a single forest owner might manage 2–4 ha, uneven-aged systems are more consistent with owner goals (Gagnon and Jokela 2010). Where certain characteristics of forest structure and composition are desired while still managing a forest for commodities, uneven-aged management represents a useful and practical approach, regardless of landowner. Although uneven-aged systems may not maximize financial income, this system does have ecological and sociocultural benefits (Axelsson and Angelstam 2011).

CHARACTERISTICS OF UNEVEN-AGED STANDS

Uneven-aged stands consist of three or more age classes represented in the same stand. Managing a variety of tree ages in the same stand can be challenging because of the potential for large trees to outcompete smaller trees for growing space. Further, in mixed species stands each tree species varies in its tolerance to shade, water, or nutrients so management becomes even more challenging. The advantage to managing stands using an uneven-aged system is that there are trees of various ages and sizes in the same stand at all times. So from the standpoint of providing homogeneity over a large area, or for a small private landowner to always have trees on her property, uneven-aged stands can be an attractive alternative to even-aged stands. Because there should be a variety of tree sizes represented in the same stand, vertical and horizontal complexity and tree size diversity can be high and can provide a diverse set of food and cover resources for many, but not all, species in a region. Further, many old-growth stands have structural characteristics typical of uneven-aged stands, but uneven-aged stands should not be considered a substitute for old-growth. Old-growth stands often have much higher stocking levels than managed uneven-aged stands, and most trees in a managed stand are not allowed to get very old. Old trees, regardless of their size, support some habitat elements, such as tree hollows, lichen communities, and large dead limbs, that can only develop over a long period of time.

In order to maintain an uneven-aged stands, the manager must be sure that there are always enough small, young trees to replace larger trees that are harvested or die over time. Consequently, there are three primary factors defining an uneven-aged stand and the habitat elements therein:

1. Basal area—how much growing space is occupied?
2. Tree density in each diameter class—are there enough small diameter trees to replace the larger ones that are cut?
3. Target tree size—what diameter class represents the largest harvestable trees in the stand?

First it is important to understand when cutting occurs. Uneven-aged management is based on a *cutting cycle* or a period of time between harvests when some trees of all tree diameters are cut. A typical cutting cycle is once every 15–30 years in most North American managed forests.

The following example is for a fully regulated balanced uneven-aged stand—something that rarely exists. But it provides the conceptual basis for approaching uneven-aged management. It may be easiest to understand how uneven-aged management operates by working backward from the target tree size. Let us assume that the forest manager wants at least 1 tree/ha (1/2.5 acres) that is 76 cm (30 in) in dbh (diameter at breast height) in the stand at all times and that she is using a 15-year cutting cycle. When the manager decides to cut these 76-cm trees, there must be at least 1 tree/ha that is 71 cm (28 in) dbh to grow to be 76 cm during the next 15 years. And there must be at least 1/ha that is 66 cm (26 in) to grow to be 71 cm, and so on. This means that you need at least 1 tree/ha of all size classes down to the smallest size class that is the regeneration you want to establish (Table 9.1). But that would be a perfect world, and we know that unpredictable things happen in forests so we always try to have more trees in each smaller size class. In our example, let us say you want twice as many trees in each successively smaller diameter class, so you may want to have 1 tree/ha that is 76 cm dbh, but 2 that are 71 cm, and 4 that are 66 cm, and so on.

But if you calculate the number of trees that you would need in the smallest diameter class, then you would need to have over 16,000 5-cm (2-in) trees per ha (Table 9.1)! If you could get that many seedlings started per hectare in a stand, their growth would probably be very slow because the stocking would be impossibly high. It simply is impossible to maintain a stand like this. But if we wished to maintain a reasonable stocking level where there is enough room for all trees to grow, then we would want to have 1.5 trees/ha in each successively smaller diameter class in this example.

Note that under ideal circumstances there is a negative exponential distribution of tree diameters in an uneven-aged stand (Figure 9.1). Also that the shape of the curve is a function of the factor by which you multiply the number of trees in one diameter class to get the number in the next smallest diameter class. This is known as the *Q factor*. The higher the Q the steeper the curve (more small trees). The larger the target tree size, the longer or more protracted the curve. But because growing space is limited, setting a large target tree size automatically means that there have to be many fewer small trees to allow space for all trees to grow. Consequently, managers will estimate basal area for a stand and see if the stand is overstocked (trees dying from competition), fully stocked (growing without imminent tree mortality), or understocked (not all growing space is being used). In our previous example, let us assume that 25 m^2/ha (110 ft^2/acre) of basal area is a fully stocked stand.

TABLE 9.1
Examples of Tree Densities by Diameter Classes for Three Diameter Distributions with a Target Tree Size of 76 cm (30 in)

dbh (cm)	Trees per ha *Q* = 2.0	Trees per ha *Q* = 1.5	Trees per ha *Q* = 1
76	1.0	1.0	1.0
71	2.0	1.5	1.0
66	4.0	2.3	1.0
61	8.0	3.4	1.0
56	16.0	5.1	1.0
51	32.0	7.6	1.0
46	64.0	11.4	1.0
41	128.0	17.1	1.0
36	256.0	25.6	1.0
31	512.0	38.4	1.0
25	1024.0	57.7	1.0
20	2048.0	86.5	1.0
15	4096.0	129.7	1.0
10	8192.0	194.6	1.0
5	16384.0	291.9	1.0
Basal area (m^2/ha)	407	25	2.5
	Impossible!	Fully stocked	Understocked

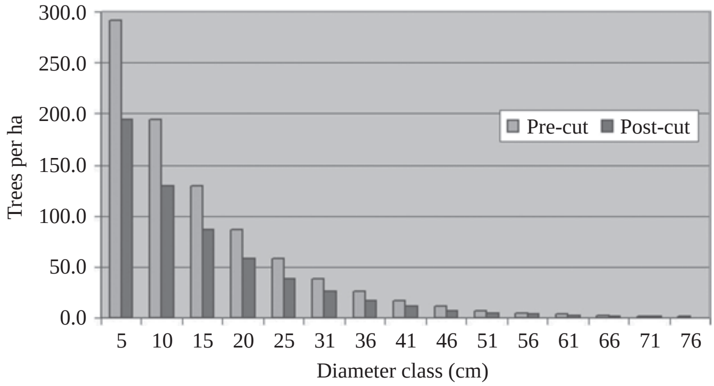

FIGURE 9.1 Idealized distribution of tree sizes in an uneven-aged stand. Note that trees of all tree size classes are harvested during each cutting cycle.

When this point is reached at the end of a cutting cycle, we may want to reduce the basal area to 16 m^2/ha (70 ft^2/acre) to provide more growing space for the remaining trees and allow the remaining trees to grow faster. But we want all trees to grow in diameter, not just the big ones, so we have to provide growing space for all tree size classes. Therefore, a harvest that would reduce the basal area to 16 m^2/ha would remove some trees from each size class.

After harvesting, the remaining trees will grow into the larger size classes and replace those that were cut. In addition, there is a new influx of regeneration established by creating a *seedbed* or growing site for seedlings and sprouts that will replace the trees in the 5-cm (2-in) dbh class that grew larger. It is important to realize, though, that if the minimum marketable tree size is 31 cm (12 in) dbh, then only those trees 31 cm dbh or larger that are cut can be sold for a profit (Table 9.2).

TABLE 9.2
Example of Trees Harvested (Bold = Merchantable) by Diameter Class in an Idealized Uneven-Aged Stand at the End of a Cutting Cycle

dbh cm (in)	Trees Cut/ha	Trees Cut/acre
5(2)	97.3	39
10(4)	64.9	26
15(6)	43.2	17
20(8)	28.8	12
25(10)	19.2	8
31(12)	12.8	5
36(14)	8.5	3
41(16)	5.7	2
46(18)	3.8	1.5
51(20)	2.5	1.0
56(22)	1.7	0.7
61(24)	1.1	0.4
66(26)	0.8	0.3
71(28)	0.5	0.2
76(30)	1.0	0.4

Note: See Figure 9.1.

Trees <31 cm dbh are cut to provide growing space at a cost to the landowner and effectively represent a precommercial thin. In addition, the stand is harvested more frequently than an even-aged stand might be harvested, increasing harvesting costs and impacting the site more often. Finally, less timber volume is removed during each harvest than in an even-aged stand so the net short-term profit to the landowner may be less, but she will generate a more regular income from the property, which will come at the end of every cutting cycle instead of at the end of a rotation.

The above is an idealized example. Managers can never control tree densities by size classes as accurately as described in this example so there is considerable art involved in managing uneven-aged stands to ensure that the resulting diameter distribution after a harvest approximates a negative exponential distribution. For tree species that are intolerant of shade as they regenerate and grow, the ability to maintain the shape of the diameter distribution (and hence the foliage height profile) becomes even more complicated and dictates the type of regeneration harvest that will be used.

CONSIDERING THE SITE POTENTIAL

The choice of which regeneration approach to use, what the target tree size should be, and what stocking level to maintain are influenced by many factors. The ability to manage an area using uneven-aged regeneration methods is often constrained by topography. Due to the high cost of harvesting per income from volume harvested using this system, typically ground-based harvesting equipment, such as horses, skidders, and feller-bunchers, is used. Cable, skyline, and helicopter logging often costs more than the value of the timber to be removed and so are cost prohibitive except in very high value stands.

The site index for the tree species being grown will influence the cutting cycle length. Low site index locations grow trees more slowly and extend cutting cycles. As mentioned earlier, the tree species that you wish to manage influences the basal area removed depending on the shade or moisture tolerance of these species. In addition, the presence of competing vegetation such as shrubs or herbs may represent excellent forage resources, but inhibit establishment of regeneration. Consequently, careful consideration must be given to the restrictions that the characteristics of the site place on your ability to use uneven-aged systems to achieve habitat structure and/or timber goals.

UNEVEN-AGED REGENERATION METHODS

Uneven-aged management usually involves *group selection* or *individual tree selection*. Individual tree selection is usually used with tree species that are moderately to very shade tolerant because it requires the removal of one or a few trees from a location in the stand to create a canopy gap to allow tree regeneration to occur. For many tree species, there is simply not enough light entering the forest floor to allow the regeneration to survive and grow if only one tree crown is removed. For these less shade-tolerant species, a group selection system may be used that involves creating small openings in the stand to allow more light and somewhat larger patches of regeneration to become established. These groups are usually less than one tree height in width but may necessarily exceed that width for very shade-intolerant species. The point at which a large group becomes a small clearcut is somewhat semantic, as is the point at which a small group selection becomes individual tree selection. These uneven-aged regeneration systems cause a fine-scale disturbance so within-stand vertical structure and fine-scale horizontal patchiness are usually high compared with even-aged systems (Figure 9.2).

NATURAL REGENERATION AND PLANTING OPTIONS

Site preparation in uneven-aged systems may range from none to mechanical scarification or prescribed burning. If advance regeneration is already established in the existing litter layer, then no site preparation is needed. But if the regeneration needs to be established and the plant species requires bare mineral soil for seed germination, then litter layer disturbance may be done during

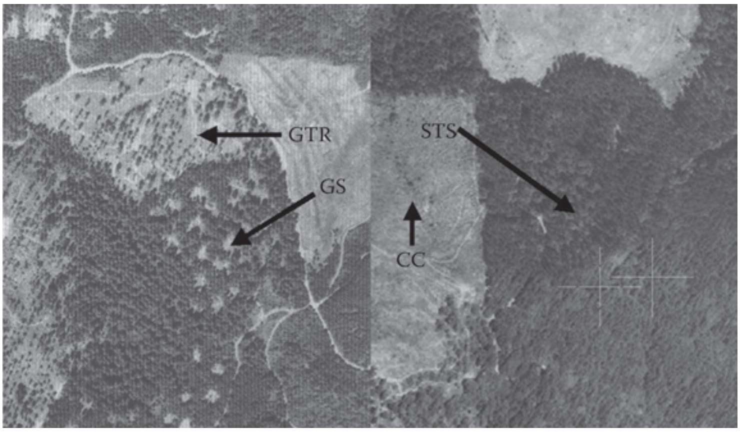

FIGURE 9.2 Single-tree selection (STS) and group selection (GS) stands, compared with green-tree retention (GTR) and clearcut (CC) stands, McDonald Forest, Benton County, Oregon. Note the fine scale patchiness in the single-tree selection stand and the coarser level of patchiness in the group selection stand.

harvesting by using the blade on the skidder to expose soil. Alternatively if the remaining trees are reasonably tolerant of fire, a cool burn may be used to expose an ash layer as a seedbed (Salverson et al. 2011). Mechanical scarification of the harvest groups and compaction of the soils along designated skid trails can significantly affect below-ground habitat by reducing the availability of burrow systems to many animal species and restricting the ability of animals to burrow in the compacted soil. Careful harvest planning and use of designated skid trails is essential on many soil types (Kellogg et al. 1996). Alternatively, fires and litter layer disruption can lead to increased sprouting of a wide variety of plant species as potential forage and allow seeds in the soil seedbank to germinate and proliferate. Chemical site preparation is also an option but can be expensive and time consuming because herbicides often must be applied using backpack sprayers.

Artificial regeneration may be established if advance regeneration is not present. Tree species that are somewhat shade intolerant can be regenerated more easily with a group selection than with a single-tree selection. Small patch, group-selection systems or single-tree selection systems that rely on existing advance regeneration or large planting stock may eliminate or significantly reduce the duration of grass-forb-shrub patches in the stand.

UNEVEN-AGED STAND DEVELOPMENT

During management of uneven-aged stands, the structure is in a continual state of flux. Trees grow until the growing space leads to a fully stocked condition at the end of a cutting cycle, then some trees of all size classes are harvested to produce the growing space needed for regeneration and continued growth of residual trees. In unmanaged uneven-aged forests, growing space occurs from competition mortality or disturbances such as insects, disease, fire, or wind. When competition causes mortality and creates growing space, usually shade-tolerant tree species fill the gap unless the gap is large and disturbs the soil. For instance, in an old-growth forest in Great Smoky Mountains National Park, Tennessee, when large (dbh > 70 cm) shade-tolerant trees die and fall, they are usually replaced by less shade-tolerant species such as yellow birch, yellow poplar, and Fraser magnolia (Barden 1979). Uneven-aged management simply imitates this process and selects certain species to favor during the harvesting process, causing the desired species to dominate the stand.

One uneven-aged approach taken by some forest managers is *diameter-limit cutting*, or cutting all the trees above some minimum diameter, usually the merchantable tree diameter. Although widely used, this approach is often criticized by silviculturists because the harvest leaves small trees (usually with small crowns) and diseased, damaged, or shade-tolerant trees to regenerate the next stand.

So from a timber production standpoint, diameter-limit cutting may not produce consistent long-term yields of products in some forest types. Effects on habitat elements and vertebrates are less clear, however. A study in the eastern United States demonstrated only minor effects on abundances of various bird species using this system (Weakland et al. 2002). Abundances of most songbird species present prior to harvest changed little after the timber removal (Weakland et al. 2002). Two species, the Canada warbler and dark-eyed junco, were more abundant in harvested areas than in an unharvested forest. Stands that were harvested differed from unharvested stands in only a few structural characteristics. Harvested stands had more snags, more trees (8–14.9 cm [3–6 in] dbh), and more down wood (Weakland et al. 2002). Canopy cover over 24 m (80 ft), density of saplings, and the amount of leaf litter decreased after harvesting. Another study modeled three stand management options in southern Indiana. The "do-nothing" management provided the best gray squirrel habitat but the worst economic return; the diameter-limit alternative produced a poorer squirrel habitat but a better short-term financial return; and intensive management provided the highest long-term economic return but produced the poorest squirrel habitat (Brand et al. 1986). Although the impacts of diameter-limit harvesting may be well accepted from a timber management perspective, the effects on habitat elements and vertebrates are highly variable and may not be problematic at low levels of volume removals.

HABITAT ELEMENTS IN UNEVEN-AGED STANDS

Several factors influence the development of an uneven-aged stand and the resulting habitat elements. Clearly, the tree species composition and the ability of the desired species to regenerate in the stand have the greatest effects on stand development. Mixed species stands can be difficult to manage because of the varying growth rates of the different species, but also can provide the manager with the opportunity to favor some species over others during management. The desired range of basal area can also influence stand development. If a manager wishes to provide growing space for regeneration, browse, soft mast, and hard mast production, then the stocking level must be kept quite low from one cutting cycle to the next, much lower than would be expected under most natural disturbance processes unless disturbances are frequent. Nonetheless, uneven-aged stands seem to support more species of birds typical of unmanaged forests than even-aged stands, at least early in stand development. Chambers et al. (1999) reported that many bird species found in clearcut and green-tree retention stands did not occur in stands managed using small group selection (Figure 9.2). Many of the species using the group selection system were also found in uncut mature forest stands (Chambers and McComb 1997, Chambers et al. 1999, Gram et al. 2001). These patterns likely reflect the distribution of habitat elements in uneven-aged stands. High vertical structural diversity and fine-scale horizontal patchiness tend to be associated with the single-tree selection system (Kenefic and Nyland 2000) (Figure 9.2). Although single-tree selection systems decrease total canopy closure, they maintain high vertical structural diversity and an even distribution of foliage among canopy strata. Single-tree selection regeneration systems can reduce the number of cavity-bearing trees and dead wood but increase browse (McComb and Noble 1980, Kenefic and Nyland 2000). Cutting cycle length, target tree size, and stocking all affect the structure and composition of uneven-aged stands.

Vertical Structure

Probably the most obvious effect of using uneven-aged approaches is that the vertical structure of the stand is more complex than would typically be found in even-aged systems, particularly in single-species stands. Indeed, Lei et al. (2009) recommended uneven-aged stand management to maintain high structural diversity in spruce-dominated forests. However, the shape of the diameter distribution can have a significant effect on the distribution of foliage in the stand. A stand with a high Q will have more foliage represented among the smaller trees and less in the larger trees (steeper diameter distribution). A stand with a low Q (flatter diameter distribution) will have proportionally more foliage in the larger trees. Consequently, depending on the species of animals that you wish to manage and with which foliage layers they are associated, you may wish to use different diameter distributions to meet the needs of those species.

The plant species composition of the various foliage layers can also have an effect on the responses of vertebrates to this vertical structure. If the lower foliage layers are manipulated to remove shrubs and allow tree regeneration to become established, then those species of birds and mammals that rely on shrubs more heavily than tree seedlings could be adversely affected. Removal of understory vegetation in uneven-aged management could decrease populations of some ground- and shrub-nesting forest interior species of birds (Rodewald and Smith 1998). Liang et al. (2009) suggested that a combination of cutting cycle (10 years), target basal area (14 m^2/ha), and q ratio (1.2) in Douglas-fir–western hemlock stands would maximize the percentage of veneer logs (for timber product value) while also maximizing tree-size diversity and tree-species diversity. Holmes and Pitt (2007) found that a residual stocking of 20 m^2/ha in northern hardwoods allowed mature forest associated bird species to persist while also providing habitat for some early successional associates. Clearly, specific guidelines to achieve specific goals will vary by forest type and the habitat elements that you may wish to produce.

Horizontal Diversity

Horizontal diversity or patchiness is high at a small spatial scale especially using group selection approaches. If the groups are sufficiently large then early successional species might colonize them, though they may be too small to be of value to some early seral bird species. King et al. (2001) found gaps served as sinks, not sources for many of these bird species. Chambers et al. (1999) found that small gaps of 0.2 ha (0.5 acres) were not colonized by early successional bird species in western Oregon. As you would expect, the responses of various species to these small gaps varies from one species to the next. Small gaps and single-tree selection systems tend to support a species assemblage more similar to that of a mid- to late-successional forest, especially if snags, logs, hardwoods, and shrubs are allowed to persist. Large gaps (small clearcuts) allow the colonization of some early seral associates.

Forage and Browse

Group selection systems can also provide patches of browse and forage adjacent to cover for ungulates, hares, and other herbivores. The interspersion of forage and cover can be an excellent management strategy for these species if the openings are large enough to produce browse of the correct species and quality. Creating small gaps often leads to increased levels of shade in the gaps and reduces the production of browse, but this apparently is a problem only with very small gaps (80–100 m^2) in northern hardwood stands (Webster and Lorimer 2002). But quantity may not be as important as quality for many herbivores. Gap sizes of 100 m^2 or larger were needed to allow dominance of more palatable browse species (Webster and Lorimer 2002). This may be particularly important were edges of gaps decrease plant growth (York et al. 2004). On the other hand, plants may allocate more energy to growth than to defense under low light conditions, allowing the plants growing in partial shade to be higher quality browse than plants grown in full sunlight (Dudt and Shure 1994). Following selection system harvests to various densities in loblolly-shortleaf pine stands, herbage and browse production were generally related to residual pine basal area and site quality (Wolters et al. 1977). Browse made up about one-fourth of the forage under stands having high residual pine basal area but represented considerably lower proportions in clearings (Wolters et al. 1977). Stands with lower basal areas tend to have higher browse production, denser and higher vertical structure, more woody vine and fern biomass, and higher plant species diversity and richness (Miller et al. 1999).

In addition, Hanley and Barnard (1998) suggested that patches of hardwoods, specifically red alder in conifer forests of southeast Alaska, offer significant food resources to herbivores beyond simply browse. These patches allow more sunlight to the forest floor and provide a diversity of forage species for Sitka black-tailed deer in this region.

Dead and Dying Trees

Maintaining stands at low stocking levels means that competition mortality is kept to a minimum. Snag and fallen log availability in uneven-aged stands is often lower than in unmanaged old-growth stands (Goodburn and Lorimer 1998). If competition mortality is occurring in a stand, then the trees most likely to die are the smaller ones in the stand, and in an uneven-aged system these trees are the regeneration and browse resources. Gronewold et al. (2010) reported that northern hardwood stands maintained at a 11.5 m^2/ha of basal area had significantly lower amounts of down dead wood, snags, and large overstory trees compared with the stands maintained at 20.7 m^2/ha. So providing dead wood in uneven-aged stands often requires either managing at high stocking levels or active management through killing trees or retaining patches of forest that are allowed to remain dense while giving up the opportunity to recruit regeneration and browse in those patches. In addition, legacy trees can be retained from one cutting cycle to another to ensure that some of the elements of old trees are present in the managed stand. But remember that these legacy trees often will grow to a size larger than the target tree size and take up growing space that could be occupied by regeneration if they were not retained.

Mast

Soft mast production in shelterwood stands and clearcuts is often greater than in single-tree selection, group selections, and unharvested stands (Perry et al. 1999), and we would expect that soft mast production increases as gap sizes increase to allow more full sunlight to strike the shrubs. Hard mast production is generally associated with crown size and tree age, and consequently can respond to silvicultural treatments that provide more sunlight to the crowns of mast-producing trees (Perry and Thill 2003). Mast production in many oak species is highly variable from year to year and seems to be heavily influenced by weather and time since the last heavy mast crop. Nonetheless, trees with large crowns should periodically produce an abundant crop of mast. Generally, open crowns are capable of producing many more fruits than closed crowns (Johnson 1994). Larger stem diameters (and consequently larger crowns) also produce greater crops of acorns than smaller diameter stems, so uneven-aged management methods that use large target tree sizes and keep stocking levels near or below crown closure should produce more abundant mast during years of high mast production (Desmarais 1998). Low stocking and widely spaced trees may increase mast production but decrease production of large snags and fallen logs.

As a rule of thumb, the shape of the diameter distribution and the target tree size will influence the ability to provide vertical and horizontal complexity, forage, and mast. If the diameter distribution is steep with very many small trees and only a few large ones, then it will probably function similar to an early to mid-successional even-aged stand for most species; browse availability may be greater in these stands. If the diameter distribution is somewhat flat or if the target tree size is large, with very few small trees and more large trees, then it may function more similarly to a late-successional even-aged stand; hard mast production may be better in these stands. In both cases, uneven-aged regeneration methods cause a more fine-scale of disturbance than even-aged systems, so within-stand vertical structure and fine-scale horizontal patchiness are usually high compared with even-aged systems.

CHALLENGES TO USING UNEVEN-AGED METHODS

Achieving timber and habitat goals using uneven-aged methods presents a few challenges that should be understood before accepting this technique as a way of meeting these goals. First, if stocking levels are not kept low enough, many species of shade-intolerant plants will likely decline in abundance in the stand. These may be important plant species as food resources for herbivores or valuable timber species. Hence, cutting cycles may need to be more frequent on highly productive sites, or volume removals heavier than one might wish to achieve goals related to vegetative cover.

In addition, each entry will require that trees of a wide range of tree diameters (and often tree species) be harvested. These various tree sizes and species have different market values. So it is quite likely that sawtimber, pulpwood, firewood, and perhaps veneer logs could all be removed in one harvest. Ensuring that logs are sorted and that markets are available for each tree size and species can present challenges to the manager. Harvesting these various-sized trees can also be a challenge especially where advance regeneration occurs. Felling large trees onto existing regeneration can damage the smaller trees and reduce the ability to maintain the desired diameter distribution. Use of directional felling and designated skid trails can help to reduce these problems but may increase harvesting costs.

Finally, keeping unmerchantable trees and shrubs in the stand as legacy trees or shrub patches is feasible but must be taken into consideration during each cutting cycle to maintain these structures or plan for their replacement as they age and die. These residual plants also occupy growing space and consequently represent a tradeoff between timber production and habitat availability for desired species.

NONTRADITIONAL MANAGEMENT APPROACHES

The uneven-aged systems described in this chapter and the even-aged systems described in Chapter 8 represent only a few examples of stand management approaches that span a spectrum of possibilities (Figure 9.3). The opportunities to develop stand structure and composition to meet land manager objectives is endless and can be crafted to each site to meet those specific objectives. McComb et al. (1993) used the structure and composition of unmanaged stands that were meeting habitat objectives for late seral species as models for proposed managed stands. This is one approach, though certainly not the only approach, to defining a *desired future condition*—a description of the structure and composition of a stand that you would hope to achieve through active management. Defining the desired future condition or specific goals for the stand is the first step in stand management.

One type of management approach described by McComb et al. (1993) is a many-storied stand that uses small group selection cutting to create a stand that is composed of >3 layers of canopy trees

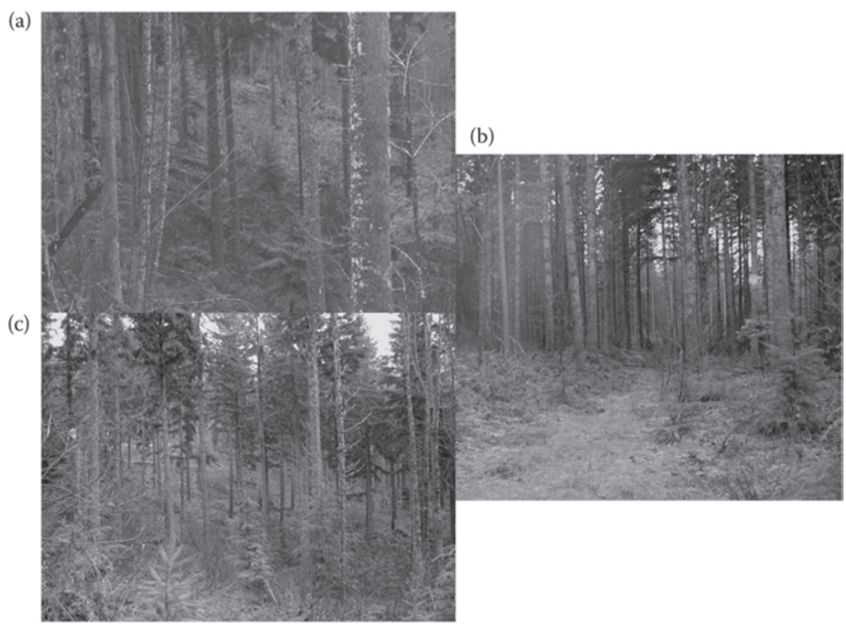

FIGURE 9.3 Several silvicultural approaches to increase complexity in 50-year-old Douglas-fir stands in the Oregon Cascades. (a) an unthinned stand, (b) a stand with 0.2-ha gaps, and (c) a heavily thinned stand with shade-tolerant trees and shrubs in the understory.

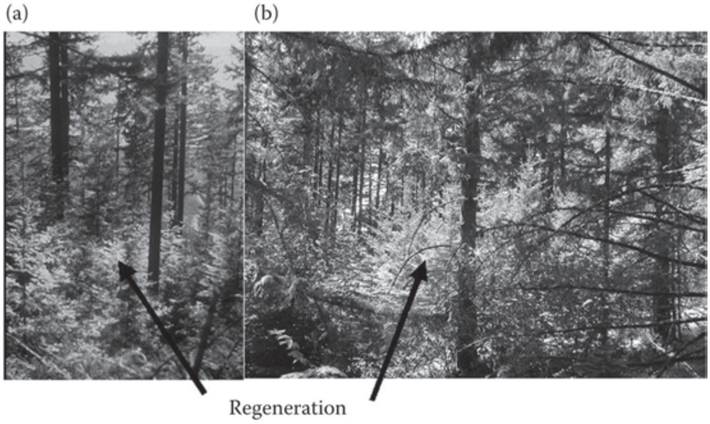

FIGURE 9.4 Vertical complexity arising from regeneration in a single-tree selection stand (a) and a group selection stand (b) in a Douglas-fir–grand fir forest type in Oregon.

in a mosaic of gaps while retaining large legacy trees and snags in the stand. The approach contains elements of a forest found in and produced by gap-phase forest dynamics and may be applicable to many forest types. The many-storied system is patterned after fine-scale natural disturbances. Cut gaps may have to be larger than most natural canopy gaps to allow successful natural regeneration of shade-intolerant species and to make harvesting more efficient. This system would have high within-stand variability in tree size and vertical complexity. This system might provide acceptable habitat for mature forest species while allowing some small but regular timber removal and as such be attractive for nonindustrial forestland managers.

The choice of which silvicultural system to use is determined by the plant community, site conditions, logging constraints, and species of vertebrates of highest interest. Uneven-aged management strategies that could improve habitat quality for species that inhabit late seral stage conditions include establishing a large target tree size, lengthening cutting cycles, minimizing disturbance to the stand during logging with designated skid trails, harvesting with small-group or single-tree selection systems where they are appropriate, managing for shade-tolerant tree species, and maintaining high-density groups of regeneration (Figure 9.4). Bauhus et al. (2009) analyzed a suite of options for developing old-growth structure of stands using a range of silvicultural options with varying levels of complexity in achieving structural goals. An allocation of dead or large, living trees also would increase habitat quality for many species typical of late seral stages.

Altering the scale or frequency of cutting also might influence habitat quality for forest vertebrates. Imposing a single-tree selection system in a forest with a cutting cycle of 10–15 years and target tree sizes of >50 cm dbh, for example, would result in small, widely scattered openings. On the other extreme, locating 60-ha clearcuts side-by-side within a watershed would create huge areas of early seral stage stands. Colonization of parts of this area by relatively less mobile species would be less likely than colonization by larger, more mobile species. Both the silvicultural strategy employed and its arrangement in context with other stands on the landscape, therefore, can have a tremendous influence on the future abundance and distribution of animals in the landscape.

CASE STUDY: MANAGING A SMALL PRIVATELY OWNED FOREST

As an example of using uneven-aged management to provide a variety of ecosystem services, we can examine how a family owning 10 ha of forest land in western Massachusetts might approach management. First it is important to recognize that the family has multiple objectives for the forest that include, in order of priority:

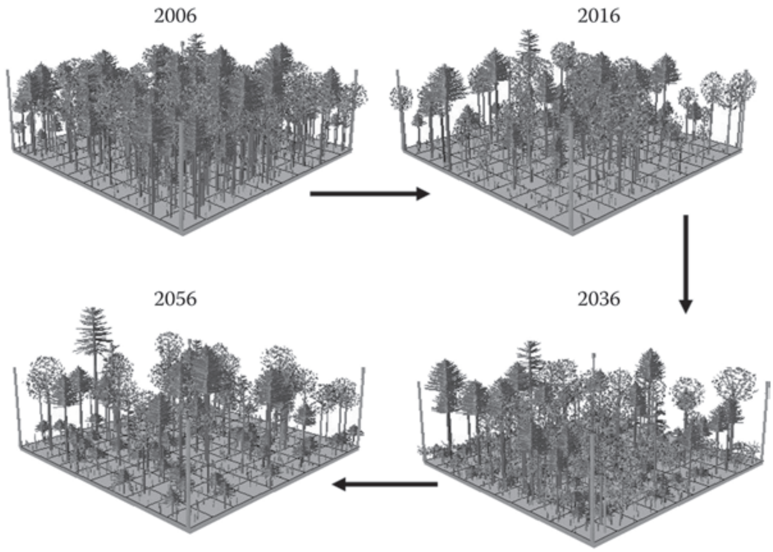

FIGURE 9.5 Example of several cutting cycles in a mixed hardwood pine stand in western Massachusetts. Data are from the UMass-Amherst Cadwell Forest, and projections are from the Landscape Management System. (McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

1. Always having a forest on their land
2. Firewood to help heat their home
3. Periodic income sufficient to cover taxes
4. A multistory forest to support a diversity of nesting songbirds
5. Enough browse and mast production to attract white-tailed deer and ruffed grouse

The stand is a mixed oak–pine forest on glacial till. It is approximately 80 years old and established following farmland abandonment in the early 1900s. There is currently 46 m^2/ha (200 ft^2/acre) of basal area and is dominated by northern red oak, red maple, black birch, and eastern white pine, with seven other tree species common in the stand (Figure 9.5). If we reduce the basal area to 16 m^2/ha (70 ft^2/acre), then that results in about 27 MBF/ha or 271 MBF removed from the property. At current stumpage values that would be yield about $27,000. Using a 20-year cutting cycle, we can have another harvest that yields about $13,000 in 2026. A third harvest 20 years later is a cordwood sale (no sawtimber in cut). During each harvest, 25–50 cords of wood are cut per hectare to provide firewood. At the end of 60 years of management, the stand contains 44 cords of firewood per hectare and 25 MBF of sawtimber per hectare available for future harvests. Openings are sufficient to always have an understory present and large enough to provide browse and soft mast. Red and white oaks average about 30 cm in diameter and should produce regular acorn crops. With careful attention to regeneration of desired tree species, the needs of the landowners should be met for several generations of the family.

SUMMARY

Uneven-aged stands consist of three or more age classes represented in the same stand (Figure 9.6). Uneven-aged stand structure and the structure and function of habitat elements are governed largely by basal area, tree density in each diameter class, and target tree size. These characteristics are manipulated to achieve the desired negative exponential diameter distribution to meet the goals for a stand. This structure can be achieved using single-tree selection or group selection regeneration

FIGURE 9.6 Abundant regeneration following single-tree selection in a ponderosa pine mixed-conifer forest type, Ochoco National Forest, Oregon.

methods. In general, vertical complexity in an uneven-aged stand is high, and horizontal complexity is fine scaled. Browse and mast are less abundant than in early stages of even-aged management unless large gaps are made using group selection systems. Because stocking must be kept low to allow trees to grow, recruitment of dead wood is usually minimal, so active management is usually needed to ensure adequate dead wood for desired wildlife species. Alternative management approaches usually define a desired future condition and then adapt even-aged and uneven-aged approaches to meet that goal.

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