Free Selection: A Silvicultural Option[1]

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Abstract

Forest management objectives continue to evolve as the desires and needs of society change. The practice of silviculture has risen to the challenge by supplying silvicultural methods and systems to produce desired stand and forest structures and compositions to meet these changing objectives. For the most part, the practice of silviculture offers a robust set of procedures well suited for the timely and efficient production of timber crops but too often leaves simplified forests that do not necessarily reflect historical conditions, do not provide a full range of wildlife habitats, nor provide a sense of place for many different forest users. To achieve these and similar objectives we propose a silvicultural system that we call "free selection." This multi-entry, uneven-aged system is intended for use in forests in which the remaining structure and composition is paramount. It is well suited for restoring the old-growth character of forests as well as reducing the risk of wildfire within the urban interface. Rather than using precise stand structural guidelines to define the stand treatments, we suggest that a well articulated "vision" of the immediate and desired future conditions is used to guide the planning and to control the marking. This vision accounts for the interaction of all components of a forest from below ground to the high forest canopy. It relies on an integrated ecological view of how forests function. We have applied free selection guided by such a vision to the dry ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forests of southern Idaho to restore their old-growth character. We include a 100-year simulation (using the Forest Vegetation Simulator) of free selection and display stand attributes using the Stand Visualization System.

Forestry and Silviculture's Role

Forestry is a highly integrated profession incorporating the core sciences (mathematics, botany, physics and so forth), applied sciences (silviculture, engineering, fire and so forth), and the political, social and economic sciences (law, policy, decision and so forth) (Nyland 2002). Forestry's professional ethic was articulated by Gifford Pinchot in 1905 as "the use of natural resources for the greatest good of the greatest number for the longest time" (Lewis 2005). The significance of this ethic is exemplified by its use in forming Forest Service policy and its use in forestry texts to express the importance of forests to the citizens of the United States (Meyer et al. 1961, USDA Forest Service 1928). Pinchot, and his ethic, not only set the course for the Forest Service, but because he was instrumental in founding the

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Yale Forestry School, the Society of American Foresters, and the Journal of Forestry, Pinchot all but created the forestry profession in the United States (Lewis 2005). Moreover, within the profession and the conservation ethic that guided it, timber harvesting was permitted but not required for forest management (Lewis 2005). As a result, the interpretation of each phrase of the ethic (use of natural resources, for the greatest good, of the greatest number, for the longest time) has been a struggle for the profession and, in particular, the Forest Service for over 100 years.

Early Forest Service harvesting was in general very light and conservative and concentrated upon the least desirable species and individuals in the stand in an effort to improve the forest (Baker 1934). In doing so, the Forest Service by 1942 was only producing two percent of the nation's timber supply. However, this practice failed to provide sufficient quantities of merchantable material to timber operators, leading to increased use of clearcuts, shelterwoods, and so-called selection systems with long cutting cycles. Although the use of these silvicultural systems allowed heavier and financially attractive cuts, the results were sometimes good and sometimes silviculturally unfortunate (Baker 1934, Lewis 2005).

Following World War II the harvest from private lands decreased and the National Forests were a source of timber to supply the booming housing and consumer markets of the Cold War era (Lewis 2005). The President's Materials Policy Commission during the Eisenhower Administration in 1951 called for developing natural resources quickly to defeat communism. By 1952, the pattern of annual increases in timber production from federal lands was firmly established and by 1960, timber management became the focal point of forest management. Silviculture, being the art and science of influencing the establishment, growth, composition, health, and quality of forests to meet the diverse needs and values (management objectives) of landowners and society on a sustainable basis, responded to the challenge (Helms 1998).

Intensive even-aged silvicultural systems which included the use of herbicides, frequent clearcutting, precise thinning regimes, and relatively short (≈ 60 to 100 years) rotations were prescribed in management plans and dominated forest management during the 1960s and 1970s (Lewis 2005). By the late 1990s, because of public attitudes, laws (for example, Endangered Species Act, National Environmental Policy Act, National Forest Management Act), the recovery of private forest lands and their increased contribution to the timber supply, and the failure of a timber famine to develop, the amount of timber harvest from National Forest lands fell to levels reminiscence of those in 1905. Moreover, by 2001 the Forest Service was committed to ecological restoration and the Chief of the Forest Service, Dale Bosworth, articulated, "what remains in a forest after treatment is more important than what is removed" (Lewis 2005, Miller and Staebler 2004).

Although timber and fiber production are still valid management objectives in many forests (Graham et al. 2005), other values such as water quantity and quality, biodiversity, scenery, old-growth, wildfire resilient and resistant forests, and maintaining the spiritual or sense of place in forests are emerging issues. Sense of place is a holistic concept that focuses on the subjective and often shared experience or attachment to the landscape emotionally or symbolically[4]. It involves a subjective

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[4] The importance of this concept was shown on September 11, 2001 when the USDA Forest Service and the USDI Park Service waived entrance fees during Veteran's Day weekend to "help Americans find comfort and solace." Forest Service Chief Dale Bosworth stated,

experience or view of place description of the meanings, images, and attachments people give to specific locations. These places reflect the perception people have of a physical area where they interact, whether for a few minutes or a lifetime, giving that area special meaning to them, their community, or culture (Galliano and Loeffler 1999, Schroeder 2002).

Many of these values depend upon the development and maintenance of complex and interacting forest elements such as high forest cover (presence of tall and/or large trees), disturbance, vegetation patchiness, multiple canopies (vertical diversity), old trees and decadence, down logs, and the presence and interspersion of a complete suite of vegetative structural stages inherent to a forest (Franklin et al. 2002, Galliano and Loeffler 1999, Reynolds et al. 1992, Thomas 1979). Moreover, these conditions often are required to occur over landscapes and be sustained through time. Even though traditional silvicultural systems have ultimate flexibility, these emerging values and the complex combination of forest elements can not be readily quantified or translated into traditional stand metrics (Backlund and Williams 2004, Franklin et al. 2002, Oliver and Larson 1990). Also, because of fire exclusion, animal grazing, timber harvesting, and other forest disturbances or lack there of, many of the current forests have higher densities, different vegetation compositions, and different disturbance regimes not apparent in past forests (Covington and Moore 1994, Graham 2003, Graham et al. 2004, Quigley et al. 1996). Additionally, a resilient forest today is most likely different than those occurring in the past because of climate change (cycles) and the introduction of exotic plant and animal species that are now an intrinsic part of the environment. This all poses a unique challenge to silviculturists. Yet, because silviculture is founded on studies of the life history of forests and has been honed by experience from more than 100 years of management, it is well suited for meeting these challenges.

Through time, silviculture has evolved as a consequence of the progression in values and needs of landowners and society beginning as early as the 17th Century (Evelyn 1664). As a highly integrative discipline and an applied science, silviculture is a continuing, informal kind of research in which understanding is sought and new ideas are applied (Smith et al. 1997). In particular, the concepts and methods inherent in traditional even-aged and uneven-aged systems can be used for developing and maintaining forests that meet these new and emerging objectives. This is a perspective that the forestry community needs to better recognize and contemplate, and foresters must become emboldened about using and implementing them in innovative and creative ways in order to meet the challenges of the 21st Century (O'Hara et al. 1994).

The Evolution of Selection Systems

In North American silviculture, four primary silvicultural systems are normally recognized: clearcutting, seed-tree systems, shelterwood systems, and selection systems (Baker 1934, Smith et al. 1997). Baker (1934) suggested that the systems are often confused with rigidity when actually they are as flexible as the silvical conditions require. He went on further to stress that there are not three or four or ten

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“National forests and grasslands can offer peaceful experiences and spiritual renewal.” This gesture by public agencies acknowledges the importance of the experiences people have in natural places (Schroeder 2002).

or a hundred separate and discrete silvicultural systems, rather silvicultural systems are more or less arbitrarily named classifications of the almost infinite number of possible combinations under which a forest may be cut. This was very evident early in the 1900s with the formation of silvicultural strategies intended for harvesting and managing forests, in particular those containing irregular structures and complex compositions (Gifford 1902, Schlich 1904). During this time, selection systems were most often used to manage stands and forests to reflect this heterogeneity.

In the 17th Century, John Evelyn (1664) in his presentation to King Charles II, of England, described individual tree treatments that appeared to be early forms of single tree selection to provide timber for England's burgeoning navy. He suggested that for *"vigour and perfection of Trees a Felling should be celebrated; since whiles our Woods are growing it is a pity, and indeed too soon; and when they are decaying, too late."* He also suggested *"for the improvement of the speedy growth of Trees, there is not a more excellent thing than the frequent rubbing of the Boal or Stem, with some piece of hair cloth, or ruder stuff, at the beginning of spring."* He also supplied descriptions of harvesting, drying timber on the stump, and other techniques applicable for managing individual stems in forests.

In the late 1800s, based on his experience in India and England, Schlich (1904) described selection systems, shelterwood selection systems, and two specialized selection systems that were intended to improve game production and domestic animal grazing. In the United States, Gifford (1902) described selection systems as ideal for protecting the soil resource and "an excellent system for the production of park effects where variety is desirable." He went on to say "in this system the best is constantly favored. It is a process of weeding out the poor kinds and favoring the good. It is just the opposite of what has been practiced heretofore in this country."

Krauch (1926) described several different cuttings on Forest Service (Coconino and Tusayan National Forests) and private lands near Flagstaff, Arizona. His study was designed to determine volume increment, and he classified the trees as blackjacks or yellow pines (*Pinus ponderosa* Dougl. ex Laws.) and further divided these classes into thrifty and unthrifty trees. Furthermore, because of the heterogeneity of the stands, he concluded that (based on tree classifications) determining volume increment per tree was far superior than determining volume increment per acre even when sample plots exceeded 450 acres.

Baker (1934) described the selection system as harvesting technically ripe trees, simultaneous thinning or improvement cutting, and the reservation of seed trees where necessary. Also, he described a transition selection system used on National Forest lands in the western United States that utilized cutting cycles of 30 to 40 years. This cutting was a temporary and crude method of harvesting which would later give way to more intensive methods. Hawley (1937), to counter this crude selection, stressed the concept of defined cutting cycles for use with selection systems. He used diagrams to describe the age distributions of trees dispersed in an ideal selection system and the random spatial extent of the 100 different age classes. He also described a maturity selection system used in ponderosa pine forests of the Pacific Northwestern United States in which approximately 40 percent of the volume was removed and another harvest was planned in about 30 years.

These selection systems were designed to reserve 20 to 40 percent of the sound and thrifty trees in a stand. A shortcoming of these prescriptions was when the percentage guidelines (quantification) were strictly followed it resulted in unsatisfactory results (Dunning 1928). Dunning (1928), using European tree classifications, as well as those presented by Krauch (1926), developed a tree classification for use in selection forests of the Sierra Nevada. He demonstrated how seven qualitative tree classes could be used to mark ponderosa pine stands and he quantified the prescriptions by determining the proportion of basal area and trees per acre occurring in each of the tree classifications.

Keen (1936), using a similar approach as Dunning, defined four age classes of ponderosa pine and further divided each age class into four crown-vigor classes for determining a tree's susceptibility to bark beetle attack. He redefined his classification (Keen 1943) for use in the Pacific Northwest and indicated it had been adopted in the Black Hills of South Dakota and Wyoming and in the southwestern United States. Roe (1948) provided tree vigor classifications for western larch (*Larix occidentali* Nutt.) and Douglas-fir (*Pseudotsuga menziesii* Mirb.) Franco var. *glauca* (Beissn.) Franco). Wellner (1952) developed a vigor classification for western white pine (*Pinus monticola* Dougl. ex D. Don).

Throughout the western United States these vigor classes were used to select individual trees to leave or harvest in partial, improvement, high risk, salvage, and other cuttings. Harvesting occurred but a portion of the value (volume) was reserved for later harvest and often these cuttings were repeated (≈ 5 to 20 year intervals) allowing uneven-aged or irregular structures and compositions to develop (Graham et al. 1999).

Meyer (1934) indicated that ponderosa pine responds well to many different silvicultural practices and described the Forest Service ponderosa pine management in Oregon and Washington as approximating heavy grade selection cutting. It had characteristics of tree selection, group selection, and a shelterwood. The system stipulated that the faster growing trees and trees less subject to windfall and insect damage be left. At least 15 to 30 percent of the merchantable volume would be reserved for accelerated increment and insurance of seed supply and for a later cut planned in 40 to 75 years. He illustrated the concept visually in diagrams and photos.

Meyer (1934) also recognized that even-aged yield tables had little value for estimating the yields of uneven-aged stands and, in particular, those treated by selection cutting. He used Dunning's (1928) seven crown classes to represent structure based on the proportion of the basal area or cubic volume occurring in each crown class within a stand. However, he suggested using all seven classes would be too unwieldy and that classes 1, 2, and 3 exert the most powerful influence upon volume growth. Therefore, a 25-50 structure indicated 25 percent of the basal area or cubic volume occurred in crown classes 1 and 2 and 50 percent occurred in crown class 3. This structure information and the correction factors he developed could be used to project the yields of uneven-aged ponderosa pine stands. He illustrated how tree classifications could be used in different cutting methods and showed the effects the different prescriptions had on yield and increment.

Pearson (1950) described several forms of selection silviculture that had been used in the southwestern United States. Group selection systems in which yellow pine groups of large trees were removed leaving blackjack groups were commonly used in the early 1900s. To favor regeneration which was poor in 1913, light selection systems were used in which more mature trees were left between the groups of black jacks. As stated earlier, Keen's (1943) tree classification had been adapted for use in the Southwest and maturity selection was devised using these classifications. Thus on Forest Service lands, prior to 1946 a variety of stand conditions were created using these systems. Pearson (1950) indicated that using tree classifications in the Southwest for selecting trees to leave and harvest had mixed results. Pearson recognized the heterogeneity of the spatial distribution of ponderosa pine, and that a tree's position on the ground was an important determinant of its growth. Keen's (1943) tree classifications did not reflect this heterogeneity. To explain this phenomena, he explored the implications of the groupy nature of ponderosa pine on the resulting root patterns. Taking all of his understanding of ponderosa pine regeneration and development, he devised a selection system called, "improvement." In general, the aim of this selection system was to build up an effective growing stock and this goal would take precedence over immediate timber sale receipts and yield in the near future. This qualitatively described system integrated tree classes, soil moisture, and bole descriptions. The system removed fewer yellow pines and the limbiest blackjacks. Pearson (1950) indicated that the increment borer was a better guide than spacing rules for implementing the system.

Kohm and Franklin (1997) have suggested modifying traditional even-aged systems in particular clearcuts with the addition of reserve trees or retaining green trees. Even though they do not term their work as silvicultural selection, it does reflect some of the characteristics of early selection systems in which a proportion of the stand and forest was retained (Meyer 1934, Pearson 1950). By using this method, the stand and structures they suggest to maintain take on more of a multi-aged condition than an even-aged condition. They suggest such systems for use in the Douglas-fir region of the Pacific Northwest for commercial timber harvest, and they stress maintaining structural and functional legacies such as snags and down-logs as important forest characteristics.

For use in the Pacific Northwest, Camp (1984) described what he termed natural selection, an all-aged and all species management system. The strategy he described was aimed at the small landowner and emphasized the characteristics of selected trees to be removed. He emphasized removing trees that were diseased, broken, suppressed, or those having no ecological value. His system stressed producing a variety of products, including mushrooms, hardwood for furniture, fence posts, huckleberries, and so forth, while at the same time providing an environment of great pleasure.

Timber Management and Selection Systems

Meyer (1934, Meyer et al. 1961) described the classic reversed-j shaped diameter distribution as an approach of forest regulation for obtaining a sustained yield of raw materials for industry and economic support. They based their descriptions of uneven-aged stands or forests on work by the Frenchman De Liocourt in 1898. However, they also emphasized that forests expressing this structure were practically nonexistent in the United States. They went on to indicate that an uneven-aged forest is a forest in which no separate age classes are recognized and even-aged stands may be present but are not treated as permanent units. Under this concept of management, the actual age of trees has little or no practical importance. They indicated that stand/age relations, yield tables based on age, site index, and other even-aged concepts applied to uneven-aged management were misleading, inaccurate, and a waste of time. They also suggested that an entirely different philosophy of management concepts and characteristics must evolve.

Davis (1966) also described the regulation of forests using uneven-aged stands for the production of timber. He stressed that a clear distinction should be made between silvicultural treatments and the general timber management framework. By doing so, he suggested that much confusion could be avoided. In contrast to Meyer et al. (1961), Davis placed less emphasis on diameter distributions and more on volume control for regulating uneven-aged forests. He concluded his discussion by indicating that uneven-aged management is simple when using a general outline but complex when applied.

Davis (1966) and Meyer et al. (1961) eloquently described the concepts and procedures for regulating uneven-aged forests and inferred that the application of uneven-aged regulation was fraught with difficulties. As a result, it is not surprising that there are few examples where uneven-aged management has been planned and implemented in the United States. This was apparent when workshops held in both the eastern and western United States in 1975 and 1976 reviewed the concepts of uneven-aged management, no examples of operational uneven-aged application were offered, but excellent examples of selection systems (uneven-aged management), applied experimentally, were shown (USDA Forest Service 1978). Similarly, in 1997, an international symposium on uneven-aged management affirmed the above observation, but examples of operational uneven-aged management in Europe were presented (Emmingham 1999).

Haight and Monserud (1990a) evaluated optimum any-aged management of mixed species stands. For their optimization they chose a mixed conifer stand represented by the western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) habitat type that occurs in northern Idaho. Grand fir (*Abies grandis* Dougl. ex D. Don), western white pine, Douglas-fir, ponderosa pine, western redcedar (*Thuja plicata* Donn. ex D. Don) along with western hemlock naturally regenerate in these forests in response to canopy opening. They illustrated that commercially thinning all trees between 7 and 18 inches produced the optimum and sustainable management evaluated by present value. Haight and Monserud (1990b) refined this prescription to show that optimal any-aged management during the first 40 years of a stand's life included thinning heavily from above removing all trees greater than 10 inches and precommercially thinning a portion of the trees between 2 and 7 inches. In 60 years and beyond, optimal harvesting approached a steady state by commercially thinning all merchantable trees and controlling the number of younger trees with precommercial thinnings. Using this approach, Haight et al. (1992) showed the unconstrained optimal any-aged management (determined by maximizing present value) for mixed conifer stands occurring on the grand fir habitat type to consist of cutting all merchantable trees every 20 years and precommercially thinning trees between 4 and 7 inches in diameter.

The previous discussion illustrates that timber management and silviculture are two distinct but highly related disciplines involved in the forestry profession (Graham and Jain 2004, Nyland 2002). Meyer (1934) illustrated uneven-aged (60 to 579 years) ponderosa pine stand structures both spatially and by the proportions of trees occurring in different crown classes. He went on to project the annual volume increment 60 years into the future of these qualitatively defined structures. The work of Haight and associates (Haight and Monserud 1990a, 1990b, Haight et al. 1992) illustrate what they termed any-aged management was sustainable but the diameter and/or age distributions were far from the reversed j-shaped curve that Meyer presented for timber management. Even though Meyer (1934) and Davis (1966) described the balanced diameter distribution as a way of regulating uneven-aged forests, or working circles for timber production (in other words, the forest area at which a sustained yield of products was determined), these distributions are frequently associated with selection silviculture. They are often used as targets for stand structure and the presence of a balanced uneven-aged (diameter) distribution(s) is often used as an indication of sustainability even though they were not designed to do so (Graham and Smith 1983, Graham et al. 1999). This discussion of selection systems and the forest management settings in which they have been developed and used illustrates that they take on many forms. Most importantly they have been developed and applied since the 17th Century to meet the objectives of the forest land owner. Within this context we present a selection system that we feel has applicability for meeting many of the challenges of forest management and silviculturists of the 21st Century that is built upon this foundation of selection system development and application (for example, Davis 1966, Keen 1973, Meyer 1934, Pearson 1950).

Free Selection

Selection silvicultural systems (uneven-aged) have a longer, more diverse history of definition and application than any other system. In general they were designed to maintain high forest cover through the use of treatments that ensure the development of desired forest structures and compositions that produce a continual flow of goods and services. These systems are particularly well suited for meeting many of the emerging and current management objectives (Graham and Jain 2004, Marquis 1978, Nyland 2002, Smith et al. 1997). However, silviculturists responding to these management issues have not only applied uneven-aged systems but have modified even-aged systems by specifying reserve tree components, patch size and group metrics, ground level vegetation requirements, and deadwood components to name a few (Camp 1984, Kohm and Franklin 1997, Meyer 1934, Pearson 1950). By doing so, the distinction between even and uneven-aged systems becomes less obvious and such systems, even though they appear to be new, are reminiscent of those applied early in the 20th Century (for example Dunning 1928, Keen 1943, Gifford 1902). Even with the specific quantitative designations of reserve trees and other metrics, such defined structures and compositions will not generally emulate horizontal tree distributions or the juxtaposition of the different structural stages inherent to natural forests that are often the focus of numerous management objectives (Franklin et al. 2002, Reynolds et al. 1992, Thomas 1979).

Elements from both even-aged and uneven-aged silviculture can be integrated to produce diverse stand compositions and structures (Nyland 2002). In contrast to early silvicultural systems, an integrated system might include provisions for maintaining a variety of structural stages, tree densities, patch sizes, compositions, tree sizes and so forth within stands and across landscapes in a pattern reminiscent of those that historically occurred (Long and Smith, 2000). Such a system would provide for snags, decadence, down wood, and other often overlooked forest components (for example, interlocking crowns, interspersion of structural stages, disturbance) that are relevant to many current forests and management objectives. We call such a hybrid system “free selection.” It is a silvicultural system suited for maintaining forests with high cover and heterogeneity both in composition and structure. Because it is a selection system (uneven-aged system), it utilizes multiple tending and regenerating entries at various intervals to develop and maintain the desired forest conditions.

Similar to traditional uneven-aged systems, the full range of silvicultural methods from regeneration to thinning can occur at each entry, if needed (Smith et al. 1997). Successful regeneration (natural or artificial) is required when implementing the system to ensure that future desired forest conditions are developed and maintained. All tree, shrub, forest floor, and other components need to be evaluated and managed to create, develop, and maintain the desired forest compositions and structures. Free selection may also incorporate openings (for example, as done in group selection systems) of sufficient size to regenerate early and mid-seral species (for example, western white pine, western larch) but not necessarily provide them optimum space for long-term development. Because it is a selection system, subsequent treatments would tend to these regenerated cohorts, releasing selected trees while insuring that they contribute to the desired stand and forest composition and structure in the immediate and long-term (Jain et al. 2004).

Because free selection incorporates multiple entries, patience can be exercised in developing the desired forest structures and compositions. The term “free” indicates that the frequency, kind, and intensity of entries are undetermined but will depend on how the stand develops within the context of the biological and physical environment when fulfilling the desired conditions. The system could be viewed as stand or landscape level adaptive management (Franklin et al. 2002). In addition, it is similar in concept to applying an even-aged system in a fine scale mosaic or group selection using area regulation. Even though the practice of silviculture strives to create desirable residual stand conditions, free selection appears to be very appropriate in situations where the condition of the forest after treatment is of paramount importance, such as maintaining conditions for wildlife or providing a feeling of security and wildness in the urban interface (*see footnote 4*). We suggest that free selection is applicable in both the moist and dry forests in the western United States for addressing hazardous wildfire conditions within the wildland-urban interface, for restoring and maintaining old forest structures, or for other objectives that require the maintenance of high forest cover and a diversity of forest structures and compositions at various spatial scales. In contrast to traditional single-tree and group selection systems that depend on precise diameter (age) distributions, we believe that free selection is best applied using a vision that describes a desirable set of forest and stand conditions in both the short- and long-term.

The Free Selection Vision

A vision articulates a comprehensive description of the desired forest conditions both in the short-term (10s of years) and long-term (100s of years) over multiple spatial scales ranging from canopy gaps to landscapes (Long and Smith 2000). The use of a vision encourages collaboration and a common understanding between and among natural resource disciplines as to the forest conditions required to fulfill the management objectives. Moreover, a vision can be an excellent communication tool among and within disciplines and with the public at large. Excellent visualization systems are available to illustrate a vision within stands and across landscapes (for example, Forest Vegetation Simulator, Stand Visualization System) (Dixon 2002, USDA Forest Service no date).

Based on our experience of implementing strict quantitative uneven-aged systems we believe a vision, based on silvics and ecology, is preferred to highly technical stand descriptors that may have limited practical use (Graham et al. 1999). No matter how complex and precise a quantitative silvicultural prescription is, it cannot encompass all of the structures, compositions, processes, and functions inherent in forests, nor can it include all of the forest conditions that are presented when a prescription is applied. We believe a vision can incorporate a diversity of structures, spatial pattern richness, long time periods, and the complex contribution of disturbances that Franklin et al. (2002) indicate are lacking in traditional silviculture[5]. However, stand descriptors and especially their variation (for example, range of tree density in basal area, or range of tree numbers per unit area, variable tree spacing) and ecological thresholds (for example, basal area at which bark beetles become problematic, or canopy openings where one tree species can have a competitive advantage over another) are often beneficial when communicating a vision.

A well expressed vision includes management objectives to insure an appropriate outcome at an appropriate temporal and spatial scale is achieved. Also, it should include the relevant structural features (for example, big trees, patchiness, horizontal diversity) of a forest that fulfill the management objectives. Included in a vision is a well conceived view of forests incorporating complex structures (for example, soils, vegetation, biological legacies), processes (for example, succession, disturbance), appropriate concepts (for example, wildlife habitat connectivity, vegetative structural stages), and the recognition of ecological variation relevant to a particular setting (Franklin et al. 2002). A comprehensive and inclusive description of the sub-stand components, stands, and forests, is suggested as more important than precise and complex quantification. This description would include such things as the desired composition, seral stages, horizontal and vertical structure (mix of structural stages), patchiness, decadence, forest floor conditions, down logs both in the short-term and into the future, and other features as required. The tree species preferences for a given situation can be described, as well as the regeneration requirements of the various species (tree, forb, and shrub) that may occur on a site. Detailed information about each attribute is not necessary; rather an integrative view of the attributes is suggested when describing the vision.

Reference conditions (for example, historical, hypothetical, functional and so forth) can further explain the vision with the understanding that these conditions may not be possible, or necessarily desired. However, reference conditions can be used to provide context or give practitioners and the public with a view, feeling, or concept of what the vision is attempting to express (Franklin et al. 2002). However, the vision must be set in context with the current stand conditions (for example, soils, down wood, ground level vegetation, overstory, wildlife use) and the ongoing disturbances, or lack thereof, thus providing the boundaries that are essential for planning silvicultural activities and ensuring the desired future condition (vision) is fulfilled.

Quantifying Complex Forests

We have found that traditional stand and forest descriptors, such as trees per unit area, basal area, tree spacing, species preference lists, and similar metrics, are deficient in their ability to effectively disclose complex forest structure and

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[5] Franklin et al. (2002) suggest that foresters can and must learn to manage stands that sustain biological diversity and a range of essential processes. They describe over 40 complex structures, structural processes, and spatial patterns of structural elements that operate during stand development and they list nine developmental stages of forests.

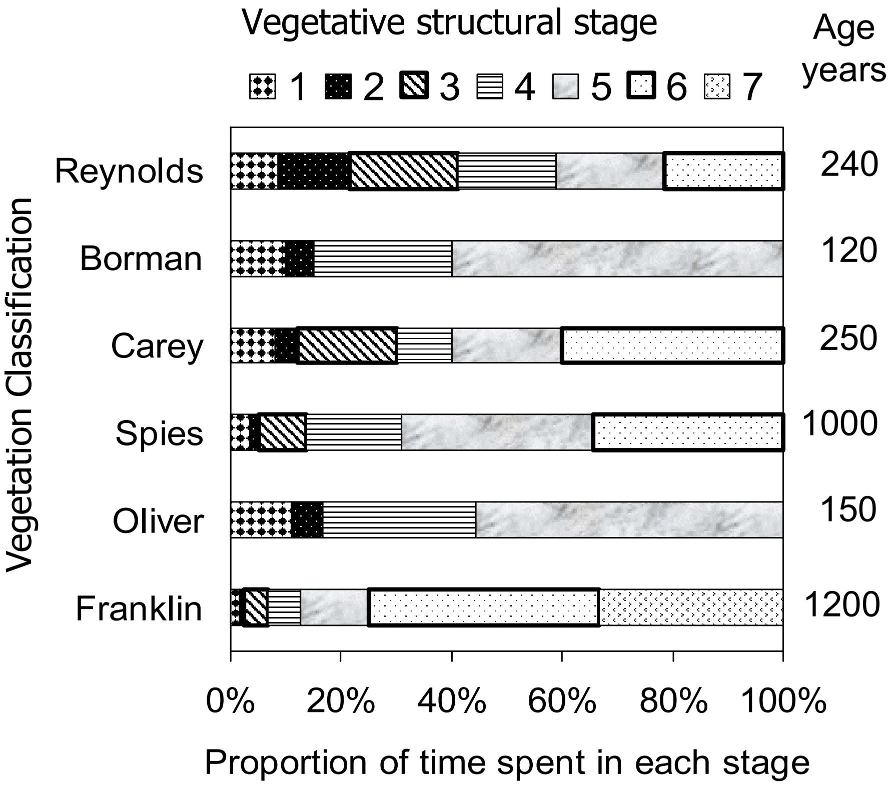
composition. One alternative is to classify relevant forest structure and/or composition and describe the distribution and proportion of the stand or landscape to be created and maintained in the desired vegetation class. Oliver and Larson (1990), Franklin et al. (2002), Thomas et al. (1979), have proposed forest structural classifications that can be related to wildlife habitat, timber production, a functioning forest, sense of place, old-growth, or other forest attributes that society values. In general they have described forest development from vegetation initiation after a disturbance through various stages of maturation. Franklin et al. (2002) and Spies and Franklin (1996) described multiple (six or greater) developmental stages for periods exceeding 1,000 years (*fig. 1*). Reynolds et al. (1992) described six structural stages and related their occurrence to wildlife populations. They went on to suggest that proportions of a landscape should mirror the proportions of the years that each structural stage occurs within the life of a forest.

In general, the amount of time a landscape spends in the early vegetative structural stages tends to be less than the time spent in the older structural stages. However, even in the longest lived forests, a portion of the landscape contains early vegetative structural stages. These stages are often given names such as initiation, cohort establishment, ecosystem initiative, or other terms (*fig. 1*). Most often these structural stages occur across the landscape in a highly intermixed fine scale mosaic, especially forests frequented by low severity, mixed or frequent fire regimes. On these settings, fire, insects, diseases, wind, snow, and ice can facilitate the development of the different structural stages (Franklin et al. 2002, Long and Smith 2000, Reynolds et al. 1992). In contrast, forests frequented by severe lethal crown fires (in other words, lodgepole pine, *Pinus contorta* Dougl. ex. Loud.) tend to have vegetative mosaics with larger patch structure (Fischer et al. 1987).

Vegetative classifications such as those presented by Oliver and Larson (1990), Franklin et al. (2002), Thomas (1979), Reynolds et al. (1992), or others may capture issues of importance, such as fuel condition class or sense of place (*fig. 1*). However, there is difficulty when attempting to identify areas characterizing a particular classification level from traditional stand metrics (for example, height, diameter, density). Therefore, we suggest classifying the vegetation prior to quantifying its attributes. The proportion of each structural stage occurring can be estimated for stands, landscapes, polygons, or other aerial extents (Meyer 1934). A useful analogy for understanding this approach is to consider a room with 100 people. Often in forestry, heights and diameters of trees are estimated in a stand and they are used to classify the stand, for example, as old-growth. This approach would be similar to taking the height and weight of each person in the room and using this information to estimate the number of males and females in the room, a very dubious undertaking at best. A far better approach is to classify each person as either female or male and then describe their weights and heights. Using vegetation classifications in this way may be very appropriate for quantifying free selection prescriptions to determine if the variation within and among aerial extents is being achieved and can be used to determine the location and intensity of subsequent entries (Meyer 1934) (*Appendix A*).

Free Selection in the Dry Forests

We suggest that free selection has the most applicability in forests in which a fine scale mosaic of vegetative structural stages is desired and treatments can be



Examples of names given by authors
to similar structural stages

Structural stage

1. Establishment, initiation, ecosystem initiative, reorganization, grass/forb/shrub
2. Canopy closure, stem exclusion, thinning phase, aggregation phase, seedlings/saplings
3. Biomass accumulation, young forest
4. Maturation, understory re-initiation, mature phase, transition phase
5. Vertical diversification, old-growth, early transition, niche diversification, steady state
6. Mature, horizontal diversification, late transition
7. Old, pioneer cohort loss, shifting gap phase

Figure 1—The proportion and amount of time a forest spends within a structural stage depends on the classification system used, the total forest age represented by the classification system, and the rate at which the vegetative structural stage develops and passes into another stage (Bormann and Likens 1979, Carey and Curtis 1996, Franklin et al. 2002, Oliver and Larson 1990, Reynolds et al. 1992, Spies and Franklin 1996).

applied at relatively frequent intervals to maintain the desired structures and compositions (Reynolds et al. 1992). Beginning in the 1990s, we used free selection to successfully treat stands within the dry forests (for example, those growing on Douglas-fir potential vegetation types) of southern Idaho (*Appendix A*). Our objective was to restore and maintain the old-growth character of ponderosa pine stands and, in particular, decrease the risk of lethal stand replacing fires in the Boise Basin Experimental Forest located near Idaho City, Idaho.

Reports of forest settings prior to European settlement (late 1800s) (Fulé et al. 1997) and those desired by wildlife (Reynolds et al. 1992, Thomas 1979) were used as reference conditions to develop our vision, target stands, and the desired future conditions. Most working hypotheses suggest that dry forests were dominated by ponderosa pine but species composition has changed since the late 1800s (Covington et al. 1994, Everett et al. 1994, Hann et al. 1997). Low intensity, non-lethal surface fires were frequent in the dry forests and endemic populations of insects and diseases interacted with these fires to create a mosaic of forest conditions (Agee 1993, Fulé et al. 1997, Hann et al. 1997, Kaufmann et al. 2000, Sloan 1998, Steele et al. 1986). In general, minimal amounts of shrubs and trees (ladder fuels) occupied the lower vegetative layers (Harrod et al. 1999, Pearson 1950, White 1985) and snags, decadence, grasses and forbs, and down logs were irregularly distributed across landscapes (Hann et al. 1997). Because of frequent fires that occurred prior to 1900, surface organic materials did not usually accumulate and ectomycorrhizae and fine roots tended to develop deep in the mineral soil, thereby protecting them from damage during the frequent surface fires (Harvey et al. 1999).

Using this information, we defined the immediate and desired future conditions for the ponderosa pine stands in southern Idaho as consisting of an aggregation of the forested clumps of structural stages ranging from stand initiation to old forest, like those that existed prior to 1900 (Long and Smith 2000). Grasses and other ground level vegetation are an integral component of the desired setting reflecting the open, park-like appearance. Organic layers fluctuate in depth reminiscent to those maintained by low intensity surface fires. Crown base heights will be high (>30 ft.), and because of the tree patches and low tree density, canopy bulk density will be low. Ladder fuels will vary depending on structural stage, but canopy discontinuity will minimize crown fire risk. The current condition (what was presented) bounded the vision and guided the kind, intensity, and location of treatments that would fulfill the vision (*Appendix A*).

Untreated Stand Conditions

In areas within the Experimental Forest where harvesting had not occurred, large ponderosa pines tended to dominate the ridge tops and side slopes. Because fire had been excluded in the Forest for over 100 years, a mixture of Douglas-fir and ponderosa pine occupied the intermediate and mid-canopy layers (*fig. 2*). These small trees create ladder fuels that allow wildfires or prescribed fires to burn crowns of the large ponderosa pine. The dominant trees, 150 to 450 years-old, occurred as isolated trees and in groups of trees with interlocking crowns (5 to 8 groups per acre) (*fig. 3*).

Figure 2—An example of an untreated stand within the dry forests of southern Idaho. Note the inherent groupiness of the stems and the low crown base heights.

The size of these tree groups ranged from 0.008 to 0.10 acre and tree density within the groups ranged from 22 to 800 trees per acre (*fig. 4*). The mean stand density of live trees averaged 73 trees per acre and the diameters of the dominant trees ranged from 8.0 to 33.9 inches.

At the base of the large ponderosa pine, needle and bark slough had accumulated resulting in deep layers (over 3.5 inches) of organic material. These layers contained over 0.005 grams per cm^3 of fine roots (obtained from soil cores, 4 by 12 inches, extracted from around the base of large ponderosa pine). Because of the presence of fine roots in these layers, the destruction of these layers could stress or even kill these large trees. This observation exemplifies the importance of incorporating the full range of forest components (for example, soil, trees, snags, shrubs) when developing a vision and free selection prescriptions.

Stand Conditions After Treatments

We decreased the ladder fuels and removed as much Douglas-fir as possible while still maintaining the integrity of the stands (*Appendix A).* We wanted to maintain the clumpy nature of the large ponderosa pine, plus increase regeneration of ponderosa pine, grasses, forbs, and shrubs. When marking, we were aware of stand densities (>120 ft^2 basal area pre acre) at which bark beetles (*Dendroctonus* spp.) become problematic (Schmid and Mata 1992) and watched for locations where root disease (*Armillaria* spp.) would likely threaten or kill Douglas-fir. We also expect future mortality from disease, insects, weather, and fire (*Appendix A*). This

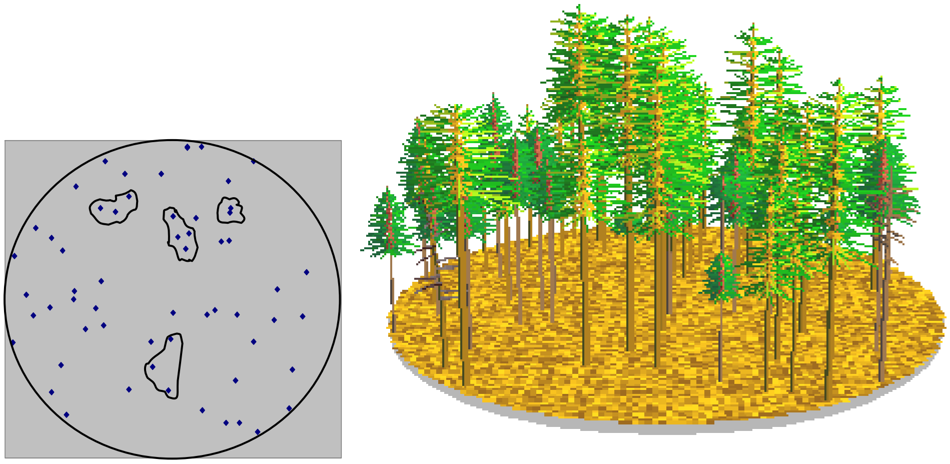


Figure 3—A stand map and visualization of an untreated (plot 10) mature stand of ponderosa pine and Douglas-fir growing on the Boise Basin Experimental Forest in southern Idaho. Four groups of pines were defined as those with touching or overlapping crowns.

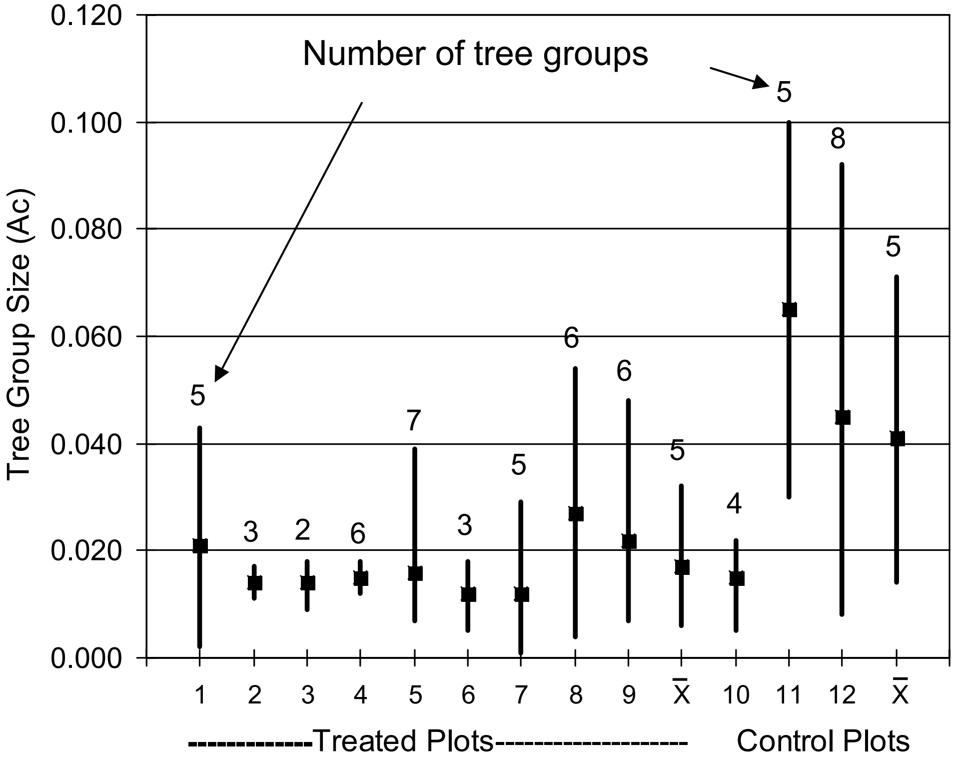


Figure 4—Stand structure within the dry forests of southern Idaho. The maximum, minimum, and mean size of tree groups defined as overstory trees with touching crowns occurring within treated areas (plots 1-9, 1.0 acre in size) and control areas (plots 10-12, 1.0 acre in size) and their respective means ($\bar{x}$). The values above the bars equal the number of tree groups identified per acre.

current and future endemic mortality was included in our vision.

The stands have gentle, sloping (< 35 percent slope) and undulating topography, requiring shifts in tree density and species composition from one place to another. Along ridges we kept large ponderosa pine but often emphasized shrub communities on more northerly exposures and at the base of slopes where tree root diseases tended to occur. On the steeper (> 30 percent), southerly slopes, we created or maintained conditions which encouraged the development of grass and forb communities. By maintaining this pattern of species occurrence and stand structure, we maintained the natural heterogeneity of the site (*Appendix A*).

The cutting and cleaning operations reduced the canopy bulk density and continuity along with reducing the ground level and mid-story ponderosa pine trees (ladder fuels) (*fig. 5, Appendix A*). After treatment, 91 percent of the trees in the stands were ponderosa pine and 9 percent Douglas-fir. The remaining 150 to 450 year-old high canopy was irregularly distributed (*figs. 5, 6, Appendix A*) with up to 7 tree groups per acre ranging in size from 0.001 to 0.048 acres (*fig. 4*). Basal area within some tree groups exceeded 1800 ft^2 per acre (*fig. 7*) but the stand containing this group averaged 64 ft^2 per acre of basal area (*fig. 8*). This density is below the threshold where bark beetles frequently stress or kill trees (Schmid and Mata 1992).

Mechanical methods and/or prescribed fire are being used to reduce the organic layers around large ponderosa pine but in a way that prevents fine root mortality and encourages their development in the deeper mineral soil layers. This includes mixing the organic layers and burning the surface organic material when moisture content of lower organic layers exceeds 100 percent and temperatures at similar depths are below 40^o F (fine root activity is minimal at this temperature). Mixing the surface organic layers allows moisture to more readily penetrate and, because canopy cover was reduced, more heat reaches these layers fostering decomposition. Burning under these conditions allows the surface layers (1 to 3 inches in depth) to be consumed, similar to peeling an onion. These conservative techniques reduce the deep organic layers and encourage fine root development in the mineral soil (*fig. 9*). After we found the fine roots concentrated in the mineral soil, we used a low intensity surface fire to clean the forest floor and to create the desired conditions (*fig. 9*). This is an example of how the intensity and timing of treatments used in free selection are predicated on how forest components (in other words, surface organic layers and fine roots) respond to treatments.

Discussion

The forestry profession in the United States was founded in the conservation ethic articulated by Gifford Pinchot in 1905 (Lewis 2005). Timber production was not a requirement of this ethic; however, it was permitted. By the 1960s, in the United States, timber management was the primary objective of forest management and this objective was firmly associated with the practice of silviculture; nonetheless, they are two distinct disciplines (Meyers et al. 1961, Nyland 2002). Silviculture was described early in the 1900s as applying silvicultural systems within forests to produce desired forest conditions to meet the objectives of the land owner (Gifford 1902, Schlick 1904). In general, this definition is still valid today (Helms 1998). What continues to evolve and change and cause confrontation since the dawn (1900) of the forestry profession in the United States are the objectives for forest management, especially those occurring on public lands (Lewis 2005). In that light,

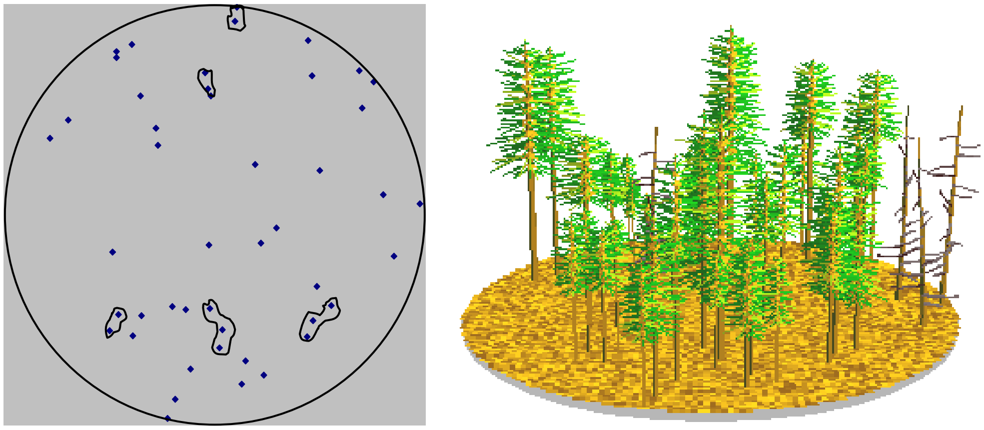


Figure 5—A stand map and visualization of a treated (plot 7) mature stand of ponderosa pine and Douglas-fir growing on the Boise Basin Experimental Forest in southern Idaho. Five groups of pines were defined as those with touching or overlapping crowns. Note the 3 snags showing on both the stem map and the visualization on the right side of the plot. *Figs. 4, 7,* and *8* display the group and stand metrics of plot 7.

Figure 6—An example of a treated stand within the dry forests of southern Idaho. Note the presence of large ponderosa pine with yellow bark. The small trees and surface fuels were masticated.

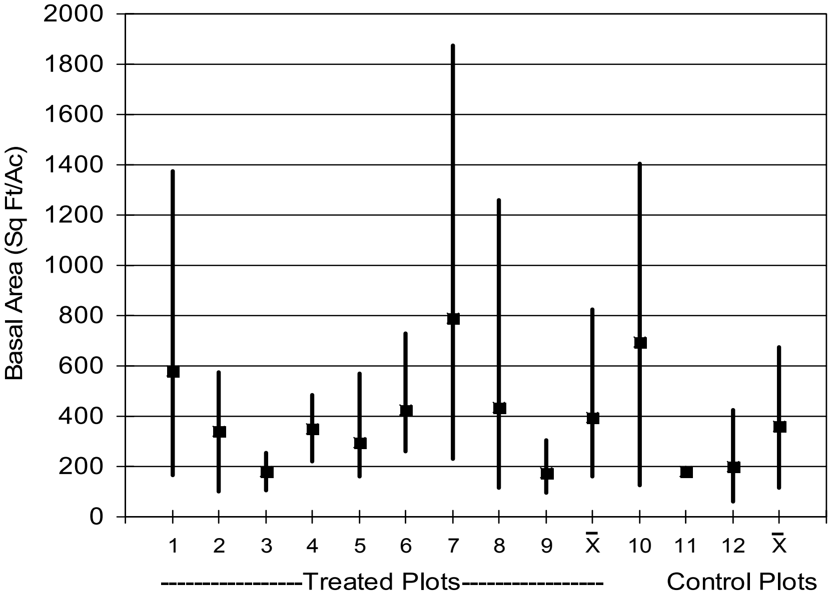


Figure 7—Stand structure within the dry forests of southern Idaho. The maximum, mean, and minimum basal area of tree groups defined as overstory trees with touching crowns occurring within treated areas (plots 1-9, 1.0 acre in size) and control areas (plots 10-12, 1.0 acre in size) and their respective means ($\bar{x}$). Note the extreme variation in basal area showing in plot 7.

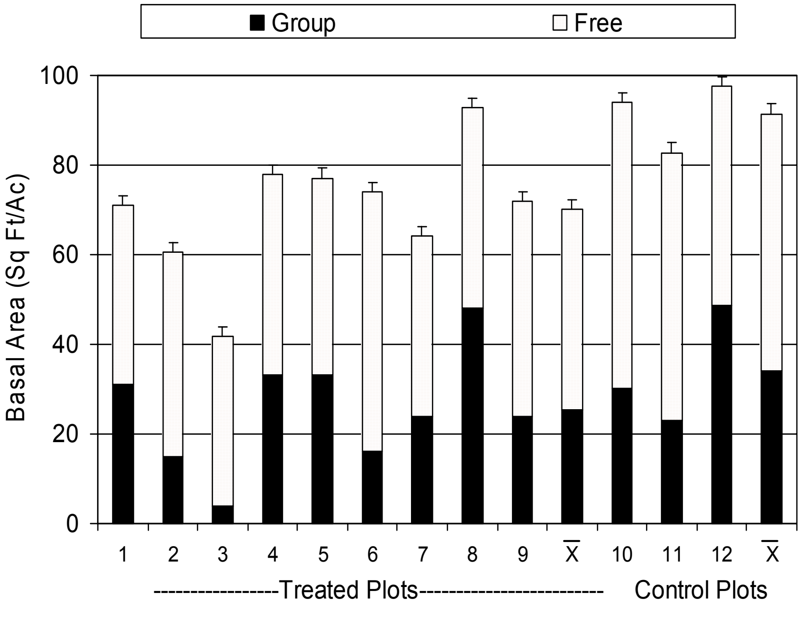


Figure 8—The stand basal area occurring within groups (group) of trees and basal area occurring within trees not associated with groups (free). Treated areas are (plots 1-9, 1.0 acre in size) and control areas are (plots 10-12, 1.0 acre in size) and their respective means ($\bar{x}$) are displayed. Note the stand basal area shown in plot 7 compared to the group basal area for plot 7 shown in *fig. 7*.

Figure 9—Fire being used to decrease the amount of organic material that developed at the base of this large ponderosa pine most likely because of fire exclusion. Fire was applied early in the spring when the temperature of the lower organic layers was below 40^{o} F (when fine root activity is minimal) and when their moisture contents exceeded 100%. Lower photo is the application of a low intensity prescribed fire treating the entire area after three spring “snow well” treatments to reduce the organic layers at the base of the trees.

we offer the free selection silvicultural system as an option for many of the emerging management objectives of the 21st Century.

There are numerous examples of which selection systems have been developed and used to create a variety of stand and forest conditions over the last century. Free selection is grounded in forest ecology and draws upon proven silvicultural practices while building on past knowledge. As early as 1524, group selection systems were used in Europe to enhance natural regeneration and protect seed trees from damaging winds (Fernow 1907). Numerous examples of selection systems used in the United States early in the 20th Century were based on tree and/or stand classifications (Dunning 1928, Meyer 1934, Pearson 1950). Moreover, the classic reversed j-shaped diameter distributions commonly associated with selection silvicultural systems were developed for timber management and were suggested to be applied at the working circle or forest scale (Davis 1966, Meyer et al. 1961). The sustainability of all silvicultural systems is predicated on how they are implemented and this assertion is no different for free selection. Haight and Monserud showed that a simple silvicultural prescription of removing commercial material and precommercial thinning was sustainable and would produce a continual flow of products (Haight and Monserud 1990a, 1990b). Even though Marquis (1978) eloquently showed how reversed j-shaped diameter distributions could be used to apply selection systems, he also showed how patch cuttings could be used to create multi-aged stands and favor the regeneration of shade-intolerant species (Marquis 1965). Building on this information, the concept of patch-selection system was introduced by Leak and Filip (1977). This hybrid selection system combined the cutting of fixed-area patches with single-tree selection system designed to regenerate both shade-intolerant and shade-tolerant species. We suggest that many of these hybrid systems have been planned, applied, and monitored qualitatively rather than using complex and strict quantification (Baker 1934, Dunning 1928, Gifford 1902, Meyer 1934, Pearson 1950).

By no means do we suggest that traditional even-aged and uneven-aged silvicultural systems not be developed and presented quantitatively in prescriptions to address many emerging forest management issues. What we are offering is an alternative to traditional even-aged and uneven-aged systems for those situations in which the quantification and/or decision making rule-sets required are so complex that they become unwieldy and/or impossible to implement. In addition, by using a comprehensive description of the short- and long-term desired conditions of a forest presented in a vision, it may be more readily communicated to disciplines outside of forestry (for example, law, social, recreation, wildlife) and to the public at large (*Appendix A*). These disciplines and the public may respond more favorably to a comprehensive and well thought out forest description than a list of technical forest descriptors (such as, crown competition factor, species preference rules, stand density index, torching index, or canopy bulk density). However, we suggest prescriptions can be quantified using vegetative classifications (*fig. 1*) and displayed geographically by using visualization systems (*Appendix A*).

Rarely have silvicultural systems and/or methods been recognized as a means for addressing objectives like sustaining the sense of place in forests (see *footnote 4*), emulating natural stand development, or for maintaining ectomycorrhizae habitat (important for the habitat of goshawk [*Accipiter gentilis* Linnaeus] prey). Free selection, and using a vision to guide it, is well suited to these objectives that are not readily quantifiable (see Franklin et al. 2002, *footnote 5*). Forest products would also be produced, albeit in uncertain quantities and at indeterminate intervals. In southern Idaho, the ponderosa pine restoration project yielded approximately 500 ft^3 per acre of commercial products and an undetermined amount of domestic firewood. In addition, projecting the system for 100 years would produce over 14,000 board feet per acre (*Appendix A*).

As we implemented the free selection system, we found it initially challenging but exciting. Nevertheless, within a couple of days, the implementation of our vision became effortless. Rather than choosing trees for removal in the treatments, we concentrated on the forest components that were to be left (for example, soil, trees, shrubs, disease), and projected how they would respond in both the short- and long-term (*Appendix A*). Moreover, the process of implementing the treatments necessitated continued discussion among the people doing the marking. That helped to channel their collective silvicultural knowledge into an integrated vision when making on-the-ground decisions. The vision of naturally occurring clumps and groups of vegetation in the stands served as a reference point for decisions on where to remove trees and in what numbers (*figs. 2-7, Appendix A*). A shared concept of maintaining a functioning forest guided the treatments even while we made the stands more resilient and resistant to crown fire. We did this by decreasing the overall stand density, decreasing surface fuels, and raising crown base heights. We created openings for regeneration (for example, tree, shrub, grass), thereby meeting a prerequisite for long-term success of the selection system (*figs. 5, 6, 9, Appendix A*). However, we recognize that subsequent treatments (for example, canopy removal, prescribed fire, cleanings, thinning, site preparation, planting) must occur to further promote the development of the desired forest structures and compositions as disclosed in the vision. These follow-up treatments are critical to the success of any selection system and many will provide commercial products (*Appendix A*).

The demands on forests by society are ever changing, as are the forest management objectives that guide our stewardship of the forests in our care. This is exemplified by the passing of the Healthy Forest Restoration Act of 2003 which includes provisions to reduce hazardous fuels and restore healthy forest conditions on lands of all ownerships (USDA 2004). However, it will take 10s to 100s of years before management will create forest conditions that fulfill these goals (vision). The free selection system we propose, and the kind of vision statements that we suggest for guiding its implementation, will serve as additional tools for future forest management. Its successful application requires a strong appreciation of the art and science of silviculture (*Appendix A*). Smith (1972) predicted "Silviculture fitted to demonstratable realities of nature and human need will call forth the evolution of methods or treatments more varied than our wildest present imagination can encompass." Our concept of free selection may help to bring that prophecy to reality.

Acknowledgements

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Appendix A: Free Selection Illustrated Using the Forest Vegetation Simulator and the Stand Visualization System

Approximately 100 acres within the Boise Basin Experimental Forest located in southern Idaho were treated using free selection. The vision informing the immediate and future stand treatments was to maintain and sustain the old growth character of a mature to old (150 to 400+ year) ponderosa pine stand. This vision included all forest elements including snags, down logs, vertical and horizontal heterogeneity, tree group dynamics, shrub, grass, and forb conditions, forest floor characteristics (duff and needle layers), and the sense of place that is inherent to big, old, and yellow-barked ponderosa pines. This vision also wanted to create forest conditions that reduced the risk of uncharacteristically severe wildfires.

The mature ponderosa pine stand grew at an elevation of 4800 feet on a northerly aspect with a slope of 35 percent, representing a Douglas-fir/ninebark (*Physocarpus malvaceus* (Greene) Kuntze) habitat type. Large ponderosa pine dominated the site; however, numerous small Douglas-fir and ponderosa pine occupied the understory as a result of fire exclusion. The initial entry of the free selection system consisted of removing the majority of the small trees $\leq$ 12 inches diameter breast height (dbh) that currently did not or were not likely to develop into essential elements fulfilling the vision in the future. In addition the majority of the seedlings and samplings were removed as commercial fire wood and through the use of prescribed fire.

We used nine, circular one-acre plots randomly located to describe the stand after the treatments were complete (*figs. 4, 5*). Diameter, height, crown ratio, and location of each tree ($\geq$ 8 inches) were recorded. However, for illustrating the free selection silvicultural system for 100 years, we chose plot 7 (*figs. 5 and A1*). The central Idaho variant of the Forest Vegetation Simulator (FVS) was locally adjusted using habitat type, slope, aspect, and elevation of the stand (Stage 1973, Dixon 2002). Because we had the location of each tree, the Stand Visualization System (SVS) attached to FVS reflected the actual horizontal and vertical distributions of the trees (USDA Forest Service no date).

FVS is capable of projecting stands (plots) through different time horizons using a variety of intervals. Our concept of free selection indicates that the interval between entries is predicated on how the stand develops to fulfill the vision. To simplify our illustration, we chose to use only 10-year intervals in FVS; however, multiple simulations with different time intervals could have been used. To project growth and mortality of plot 7 (*figs. 4, 5, 7, 8*), a 100-year simulation was used and the TIMEINT keyword set the number of cycles at 10 and the length of each cycle to 10 years. The Regeneration Establishment Model was used to estimate regeneration for each cycle throughout the projection. One hundred percent of the plot was burned every 10 years and the BURNPREP keyword was used to simulate this treatment.

With the initial inventory (2005) of plot 7, we could identify each tree used in the simulation and give it a unique code (integer 2-99) in the Prsc.code (IPRSC) field. We used integers 2-6 to identify trees that we would subsequently remove in a specific simulation cycle using the THINPRSC keyword. The THINDBH key word was used to target trees within specific dbh ranges for removal. All decisions of removing trees that did not fulfill the immediate or future forest elements of the vision were chosen using SVS. We used the “Marking and Treatment” window in

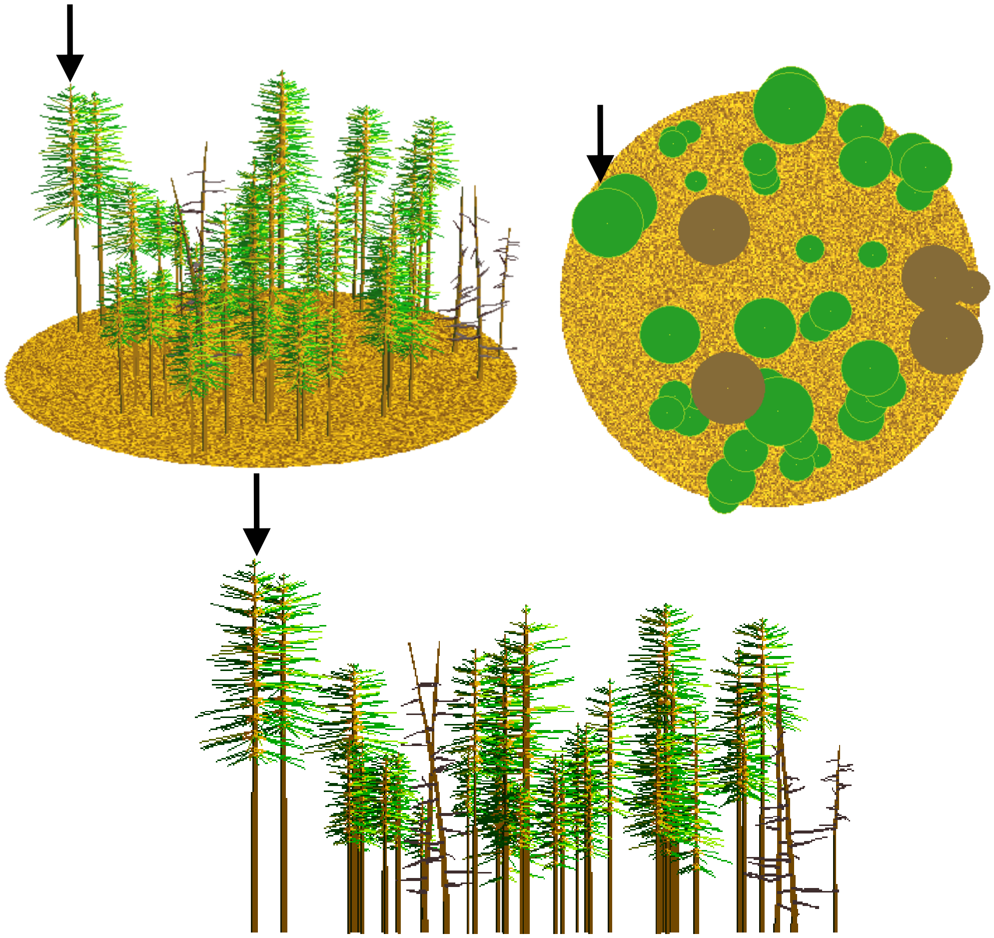
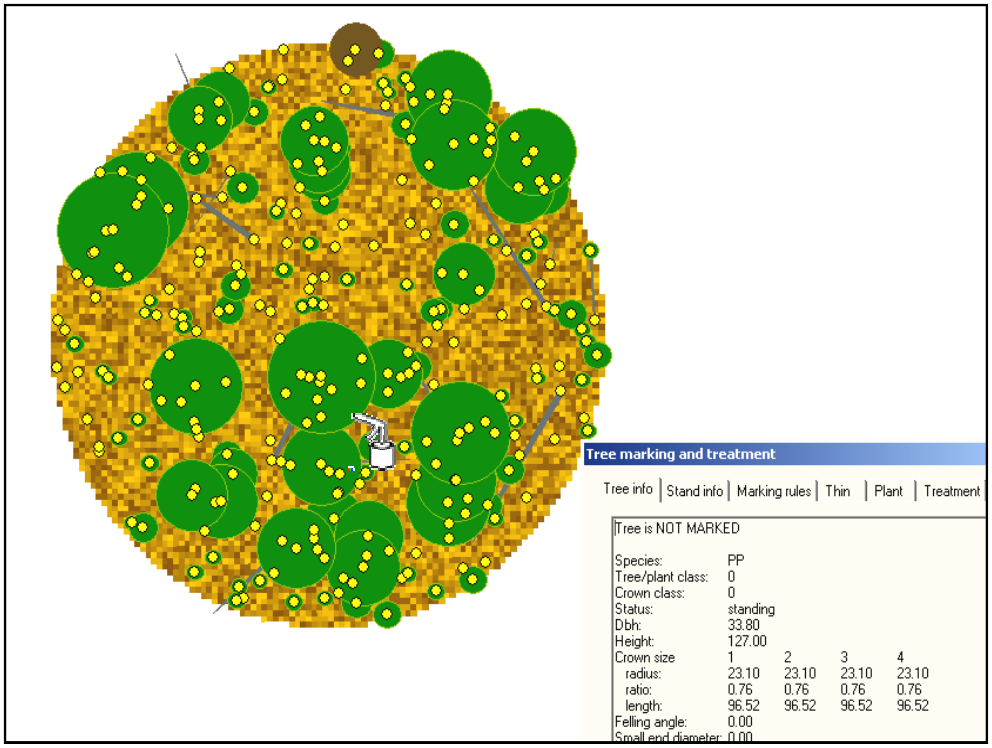


Figure A1—Ponderosa pine stand located on the Boise Basin Experimental Forest in southern Idaho after the initial entry (2005) using free selection. Tree locations in the visualization reflect the actual tree locations occurring on the one-acre plot. Note the snags, groups of trees and the diverse horizontal and vertical structure. This visualization reflects conditions that fulfill the goals of the vision. Trees marked with the arrows lived the entire simulation (see *fig. A11*).

SVS in conjunction with the overhead view of the plot to move a paint gun pointer across the view, displaying the characteristics of each tree (*fig. A2*). This process determined the fate of each tree and established the parameters associated with the THINPRSC and THINDBH keywords. Because Douglas-fir was not a preferred forest element in the vision, all Douglas-firs were removed each cycle. In practice this would occur through prescribed fire and/or precommercial thinning. The Fire and Fuels Extension (FFE) was used to simulate these fires (keyword SIMFIRE). However, we turned off the FFE tree mortality and preferred to more precisely control mortality through our management actions.



```
Tree is NOT MARKED

Species:            PP
Tree/plant class:   0
Crown class:        0
Status:             standing
Dbh:                33.80
Height:             127.00
Crown size          1        2        3        4
   radius:          23.10    23.10    23.10    23.10
   ratio:           0.76     0.76     0.76     0.76
   length:          96.52    96.52    96.52    96.52
Felling angle:      0.00
Small end diameter: 0.00
```

Figure A2—An example of the ponderosa pine stand projected using the Forest Vegetation Simulator and displayed using the Stand Visualizations System. The window in the lower right shows the characteristics of each tree as a paint gun pointer moves across the plot. Using this information, individual trees or groups of trees were chosen to leave or remove every 10 years ensuring that the stand fulfilled the vision of sustaining old-growth character.

Listed below is a summary of our management activities for plot 7 for the 100 year projection. Note that they are not consistent, nor do they reflect how the stand developed. Moreover, this is only one of many series of treatments that could be used in a free selection silvicultural system to fulfill the vision of maintaining the old forest character of this ponderosa pine stand. As Baker (1934) suggested, there are a multitude of forest treatments that can be assembled into silvicultural systems to meet management objectives.

2015:	All Douglas-fir seedlings were removed. All ponderosa pines between 0.0 and 1.0 inches dbh were removed.
2025:	All Douglas-fir seedlings were removed. All ponderosa pines between 0.0 and 2.5 inches dbh were removed.
2035:	All Douglas-fir seedlings were removed. Individual ponderosa pines indicated by a “2” in the IPRSC field were removed using the THINPRSC keyword.

2045: All Douglas-fir seedlings were removed.
All ponderosa pines between 5.3 and 5.8 inches dbh were removed.

2055: All Douglas-fir seedlings were removed.
All ponderosa pines between 2.0 and 6.0 inches dbh were removed.
Individual ponderosa pines were removed using the THINPRSC keyword.

2065: All Douglas-fir seedlings were removed.
All ponderosa pines between 9.4 and 18.0 inches dbh were removed.
All ponderosa pines between 0.0 and 4.0 inches dbh were removed.

2075: All Douglas-fir seedlings were removed.

2085: All Douglas-fir seedlings were removed.
All ponderosa pines between 0.0 and 2.5 inches dbh were removed.
All ponderosa pines between 11.5 and 12.5 inches dbh were removed.
All ponderosa pines between 20.0 and 22.0 inches dbh were removed.
Individual ponderosa pines were removed using the THINPRSC keyword.

2095: All Douglas fir seedlings were removed.
All ponderosa pines between 0.0 and 3.5 inches dbh were removed.
All ponderosa pines between 26.0 and 26.5 inches dbh were removed.

At the beginning of the simulation (2005), the diameters of the old-growth ponderosa pine stand ranged from 8 inches to over 32 inches with considerable vertical and horizontal diversity meeting the goals set forth in the vision. (*figs. A1, A3*). Through the 100-year simulation, precommercial thinning and prescribed fire were intended to remove all Douglas-fir regeneration and a portion of the ponderosa pine regeneration in most cycles (*fig. A4*). In the simulation, tree numbers less than 6 inches dbh peaked in 2055. In 2065, we removed all regeneration less than 4.0 inches dbh. These data show how diverse the treatments meeting the free selection vision can be, but also show the constant need for treating ground level vegetation in order to keep in check the risk of severe wildfire.

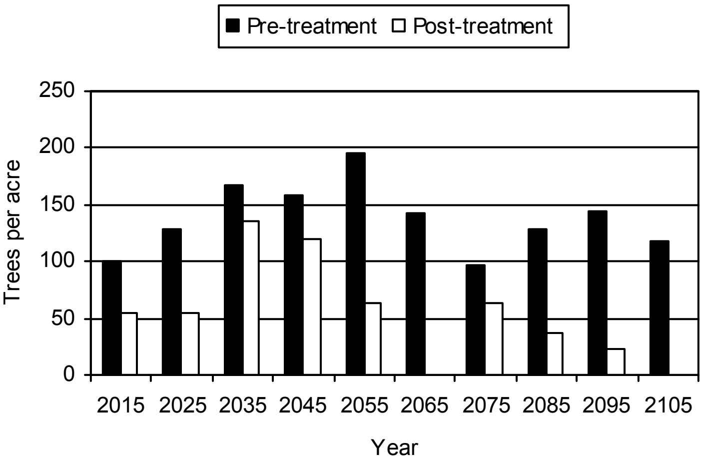


Figure A3—Distribution of tree diameters after the first (2005) free selection entry in a ponderosa pine stand located in southern Idaho.

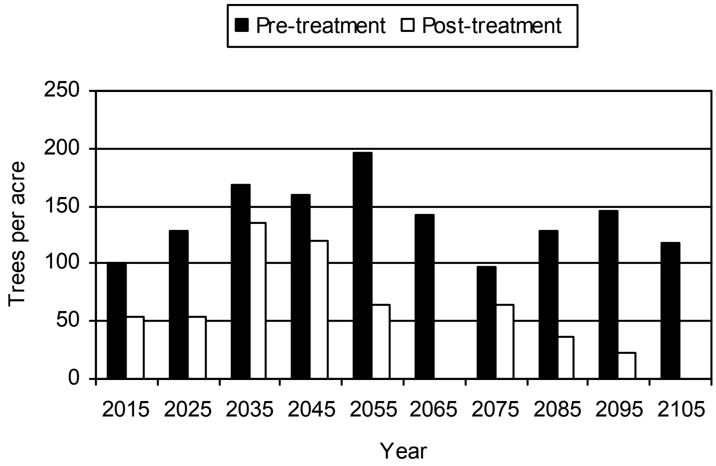


Figure A4—Amount of Douglas-fir and ponderosa pine regeneration (≤ 6 inches) estimated using the Forest Vegetation Simulator. The regeneration was treated using prescribed fire and precommercial thinning. In 2065 we removed all regeneration less than 4.0 inches dbh.

When locating trees in the field, a group was identified when tree crowns were touching and/or overlapping. A similar procedure was used in the simulation. To determine the distribution of tree groups for each cycle during the projection, a 20 point grid was randomly placed on the overhead view of the stand and the presence of a tree group, snag, or down log was determined. At the beginning of the simulation in 2005, approximately 20 ft^2 per acre of basal area occurred in groups (*fig. 8* plot 7, *A5*). The distribution of groups of trees and trees not associated with groups was dynamic and explained by different factors. Decreases in basal area associated with tree groups may occur when large trees in a group fall or become snags. For example, at the beginning of the 2015 cycle, a 28-inch (dbh) tree associated with a tree group

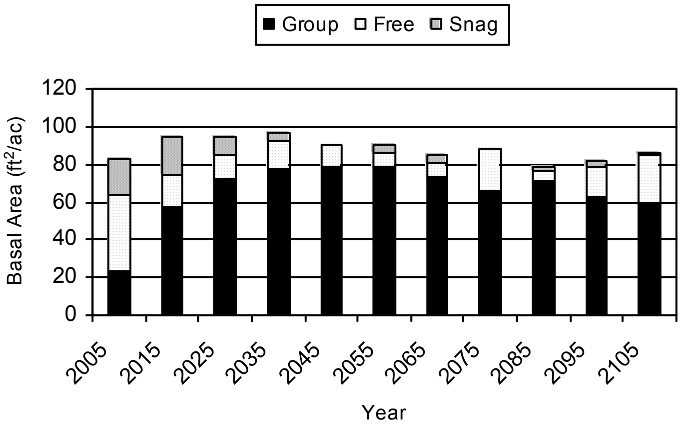


Figure A5—Stand basal area apportioned among group trees, free trees, and snags for the initial free selection treatment (2005) and subsequent treatments projected through 2105 using the Forest Vegetation Simulator. Group trees are defined as trees with touching or overlapping crowns and free trees are defined as those not associated with groups. See appendix *figs. 1, 2, 9, 10* for illustrations of the overhead view of the stand showing the groups and free trees.

fell. Decreases in basal area associated with tree groups also occurred during the middle of the projection, when some co-dominant trees were removed. Increases in basal area associated with groups occurred when group trees increased in size, or when free trees become associated with a group when their crowns touched or overlapped with crowns of nearby trees. Also during the simulation we were able to regenerate ponderosa pines and have them develop into tree groups containing trees exceeding 16 inches (dbh) in diameter and over 100 feet tall. Two of the groups at the end of the projection consisted entirely of trees established after 2005. As a result of these dynamics inherent to the application of free selection, we were able to increase the amount of stand basal area occurring in groups to the vicinity of 80 ft^2 in 2045. By the end of the simulation, we had approximately 60 ft^2 of basal area per acre occurring in groups of trees with a total stand basal area of 85 ft^2 per acre (*fig. A5*).

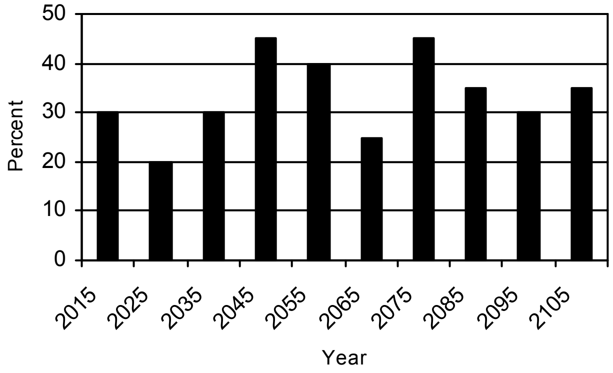


Figure A6—Proportion of the stand occupied by groups of trees determined by locating 20 random points on the overhead views as projected by the Forest Vegetation Simulator through 2105 and displayed by the Stand Visualization System. See appendix *figs. 1, 2, 9, 10* for overhead stand views.

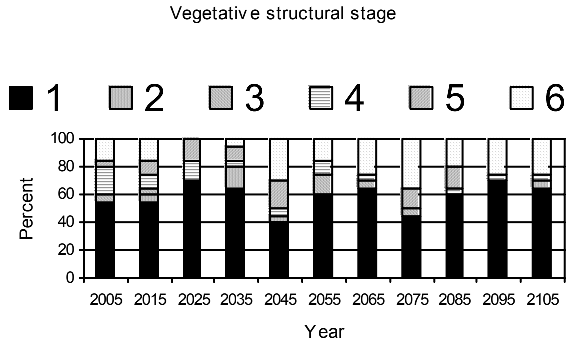


Figure A7—The estimated proportion of the stand occupied by different vegetative structural stages (VSS) determined by 20 points randomly located on the overhead views. VSS 1=grass, forb, seedling, 2=sapling, 3=young, 4=mid-aged, 5=mature, 6=old (Reynolds et al. 1992).

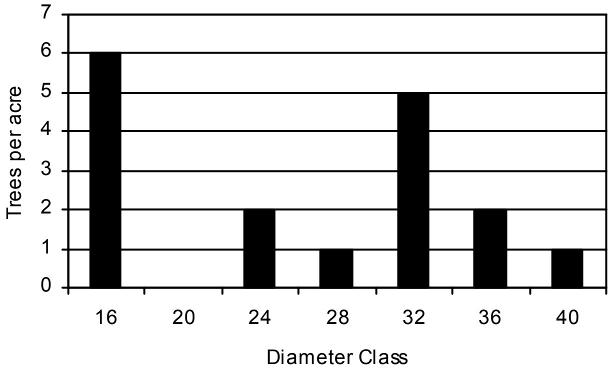


Figure A8—Distribution of tree diameters after 100 years (2105) of treatment using free selection as projected with the Forest Vegetation Simulator.

In fulfilling the vision, the presence and distribution of tree groups were important considerations. Through the simulation, we were able to maintain a large proportion of the aerial extent of the stand in groups of trees. The proportion of the stand occupied by tree groups peaked in 2045 and 2075 at 45 percent and, by the end of the simulation in 2105, 35 percent of the stand was occupied by tree groups (*figs. A1 A6, A9, A11*). The vegetative structural stage (VSS) that each tree group represents was also quite variable.

The per acre values and averages are not as telling of the success of the free selection system as are the views available from the FVS projections, using SVS. After treatment, mean stand diameter ranged from 10.0 to 20.7 inches during the 100-year simulation and the stand density index remained below 170 during the simulation (*table A1*). Through the 100-year simulation, 14,347 board feet per acre were removed and fewer than 150 trees per acre were removed during each of the precommercial thinnings and prescribed fires every 10 years (*table A1*). In most years, at least one snag per acre existed and over 10 down logs per acre existed. What this stand summary does not show is the high amount of horizontal and vertical diversity that occurred in the stand and the maintenance of the old-growth character that was paramount for fulfilling the essence of the vision.

Free selection, as we describe it, follows the development of silvicultural systems used in forestry for over 100 years. It is adaptive management at the stand and landscape level and is preferably guided by a vision rather than rigid marking guides trying to describe the highly diverse stand structures of which free selection is most suited for developing and sustaining. By using FVS, and by displaying the results of the simulation with SVS, we have shown how free selection can be applied in maintaining the old-growth character of a ponderosa pine stand located in southern Idaho. We suggest that free selection, directed by a well conceived and articulated vision, can be used to address many forest management objectives in which high forest cover is required, and when what is left after treatment is of paramount importance. This example of free selection shows that such an approach is sustainable and that the Forest Vegetation Simulator and the Stand Visualization System are excellent tools for displaying such a silvicultural system.

Table A1—*Summary of the stand characteristics for the 100 year simulation using free selection in a stand of ponderosa pine located on the Boise Basin Experimental Forest in southern Idaho. The central Idaho variant of the Forest Vegetation Simulator was used and adjusted for the Douglas-fir habitat type, 4,800 feet elevation, and a northern aspect.*

	Pre-treatment						Removals		Post treatment		
	Dead		Live				Live		Live		
Year	Sg[1]	Lg[2]	Tr[3]	BA[4]	CF[5]	BF[6]	BF[6]	Tr[3]	BA[4]	SDI[7]	QMD[8]
	Per acre										inch
2005	5	0	41	64	2130	11601	0	0	64	95	16.9
2015	6	1	140	74	2590	14527	0	46	74	126	12.0
2025	3	6	165	85	3092	17697	0	72	85	141	13.0
2035	2	13	204	97	3606	20994	866	36	92	168	10.0
2045	0	16	205	105	3929	23050	3408	43	90	164	10.1
2055	1	19	250	104	3868	22464	2727	134	86	148	11.7
2065	1	15	191	98	3884	23211	2200	157	81	111	20.7
2075	0	14	128	88	3827	23789	0	30	88	147	12.8
2085	2	14	161	98	4248	26531	4443	106	76	116	15.8
2095	3	14	164	82	3783	24493	703	122	79	113	18.5
2105	1	18	135	85	3984	23083	0	0	85	151	10.7

[1]Snags, [2]down logs, [3]trees, [4]basal area, [5]stand volume in cubic feet, [6]stand volume in board feet, [7]stand density index, [8]quadratic mean diameter.

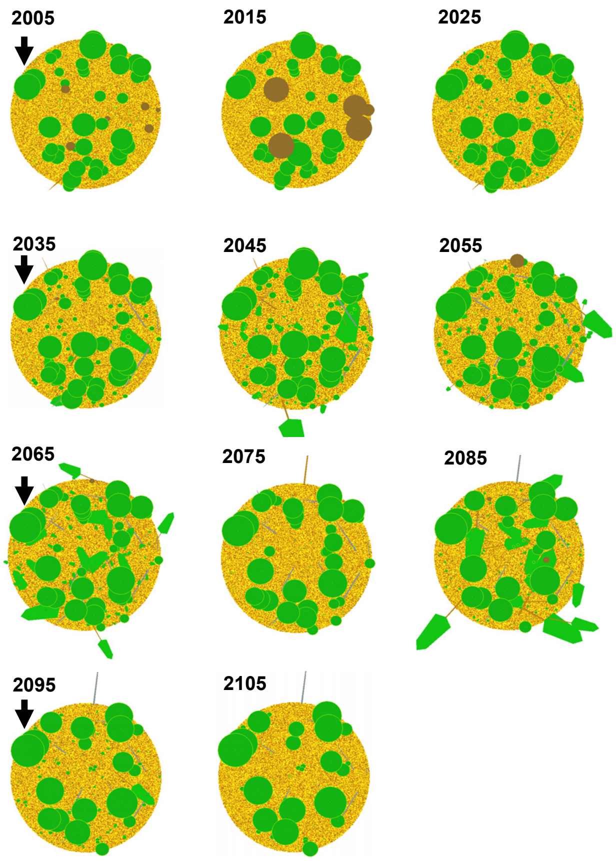
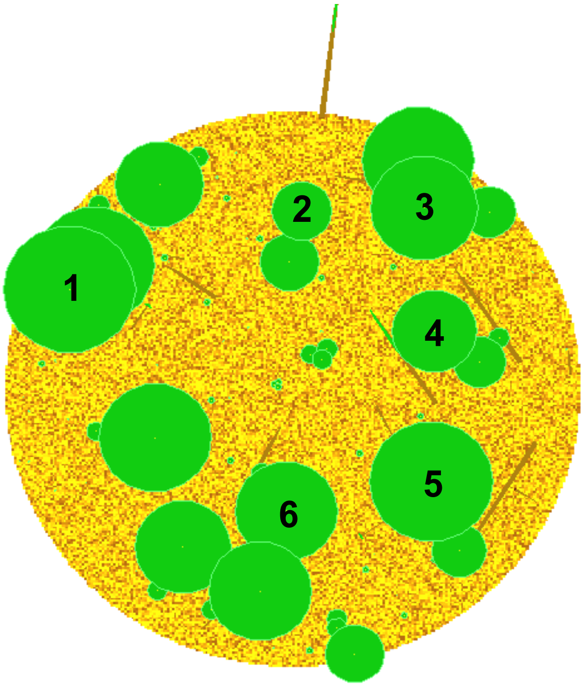


Figure A9 — Overhead views for each year of the simulation after a treatment (for example, prescribed fire, precommercial thinning, commercial harvest). Note the crown expansion of the trees (marked by the arrows) in the upper left of each view.



Group	Number of trees	Size in acres	Basal Area in ft^2/ acre
1	2	0.064	251
2	2	0.020	149
3	3	0.050	260
4	2	0.026	172
5	2	0.047	190
6	3	0.082	179

Figure A10—Overhead view of a ponderosa pine stand after 100 years of applying free selection. As a result 6 groups of trees were created and/or maintained.

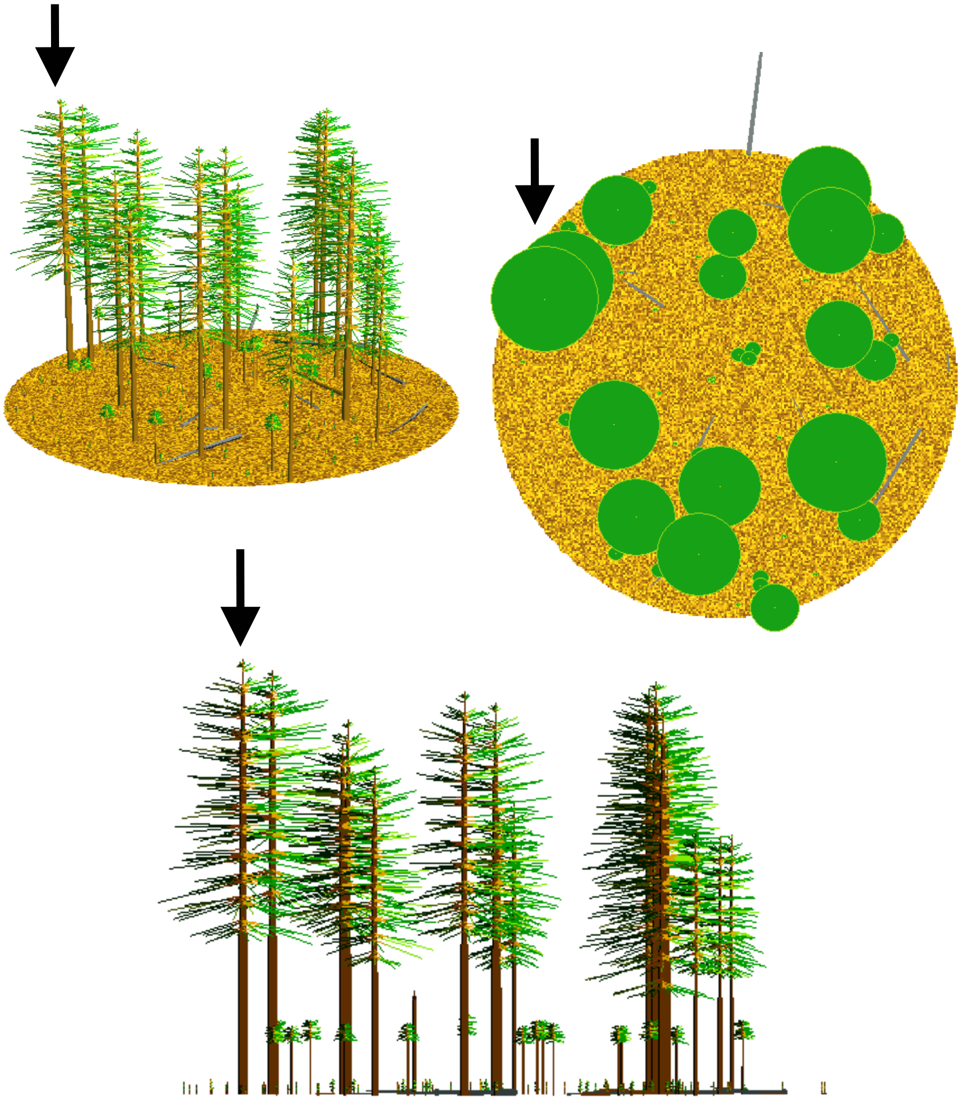


Figure A11—Ponderosa pine stand located on the Boise Basin Experimental Forest in southern Idaho after 100 (2005-2105) years of applying free selection as projected using the Forest Vegetation Simulator and displayed by the Stand Visualization System. Note the down logs and the horizontal and vertical diversity. At least 5 cohorts of trees are noticeable. Trees marked with the arrows lived the entire simulation (see *fig. A1*).