Interior Ponderosa Pine in the Black Hills

Charles E. Boldt and Robert R. Alexander
Rocky Mountain Forest and Range Experiment Station

Milo J. Larson
Rocky Mountain Region

The gross area of the Black Hills of South Dakota and associated Bear Lodge Mountains of eastern Wyoming is about 3.5 million acres (1.4 million ha). Roughly half the area supports forest or woodland. cover. Essentially pure stands of climax Rocky Mountain ponderosa pine *(Pinus ponderosa* var. *scopulorum* Engelm.) predominate on about 1.5 million acres (0.6 million ha). Scattered, smaller aggregations of similar ponderosa pine stands occupy about 250,000 acres (101 170 ha) of butte-top and scarp sites to the north and south of the Black Hills in Nebraska, Wyoming, and Montana (3, 8, 19).

In addition to being isolated from the rest of the interior ponderosa pine forest cover type (Society of American Foresters forest cover type 237) by wide expanses of nonforested land, the ponderosa pine forests of the Black Hills are sufficiently distinctive in their silvical characteristics to warrant separate description and specialized silvicultural treatment (2, 4, 5).

The Black Hills are the weathered remains of a domal uplift of late Cretaceous/early Tertiary origin. A deep mantle of diverse sedimentary deposits, which overlaid the dome as originally uplifted, has been eroded almost entirely from its central portions. Rock types exposed in the core area are a complex of ancient and recent igneous intrusives and associated metasediments (10). Encircling this core of crystalline rock types are irregular, concentric bands of residual sedimentary rock strata. Several of the most recent of these sedimentary layers, steeply uptilted, form a hogback ridge that surrounds the hills like a rampart and boldly marks the prairie/ forest ecotone.

Truncated by erosion, the uplift now rises to only a fraction of its original height. The tallest peak, Harney, of durable Precambrian granite, reaches only 7,240 feet (2205 m) above mean sea level and a modest 4,000 feet (1220 m) above the surrounding plains. Although the topography is locally steep and rugged, the overall relief is gentle for mountainous terrain. It is easily roaded, and the bulk of the productive sites are accessible.

Soils show considerable variability attributable to parent materials and elevation/climate zones; yet, the influences of those factors on soil genesis and morphology evidently have been modified by coniferous forest cover. Most soils show morphological characteristics approximating those of the Eutroboralfs Group (Gray-Wooded Soils). Even within major grassland inclusions, where mixed prairie vegetation has prevailed for long periods, soils usually show some physical and chemical indications of previous occupancy by conifers. Thus, most sites, irrespective of parent material or existing vegetation, probably have the capability of supporting ponderosa pine stands (16, 22).

Soils may be characterized as medium- to fine-textured, moderately deep, and rocky. The upper horizon textural range generally runs from sandy loam through clay loam. A profile with an overall depth of 60 inches (152 cm) would be considered deep; a 24-inch (6 1 -cm) profile is about average. Most residual soil profiles contain moderate volumes of weathered, fragmented parent material. Except where parent materials are of recent igneous origin, soils are usually underlain by deep zones of fractured bedrock. Joints and fissures in this rock admit and store gravitational soil water, and they are often penetrated deeply by roots-particularly those of ponderosa pine (2, 16, 22).

The climate of the Black Hills is similar, qualitatively, to that of the associated High Plains; i.e., typically continental and rigorous, with virtually all climatic elements showing unusual variability, both short- and long-term. Quantitatively, the climate of the Black Hills is sufficiently different from that of the surrounding steppe to favor forest cover over grass. The critical differences - increased precipitation and decreased temperature-are orographic effects (2, 14).

Compared to climates elsewhere in the type, the distinctive feature of the Black Hills climate is the relative abundance-of precipitation early in the growing season (15). May and June are normally the wettest months; April and July are only slightly less so. Precipitation for these 4 months amounts to about one-half of the expected annual total of 30 inches (760 mm) (14). This prolonged moist period in late spring and early summer in most years is ideal for germination and establishment of ponderosa pine seedlings. The wet snows and cool rains of April and early May provide ample moisture for imbibition by pine seeds deposited the previous autumn. When germination occurs late in May, an additional 2 months of periodic rains can be expected to keep the duff moist while seedling roots grow toward the more dependable moisture supplies of the mineral soil. First-season growth of vertical roots of Black Hills pine seedlings averaged 6 inches (15 cm) in limestone soils and 7 inches (18 cm) in metamorphic soils by the first of July (20).

Recurrent, severe droughts also exert a potent influence on the vegetation of the High Plains and Black Hills. A tree ring study of drought in nearby western Nebraska indicated occurrence of 21 major droughts (5 years or longer in duration) during the 748 years between 1220 and 1952 A.D. Average duration was nearly 13 years; the most prolonged lasted an estimated 38 years. The average interval between droughts was about 24 years. The most recent severe drought in the plains-which produced the infamous dust bowl conditions of the 1930's - was, by comparison, well below average in duration (21).

These droughts not only kill vegetation outright but also increase its flammability. Drought and wildfires are the principal reasons why extensive stands of very old ponderosa pine were scarce even in the presettlement, virgin forests (7). Grassland fires, especially frequent during droughts, also tended to inhibit encroachment of ponderosa pine into the interior and surrounding prairies (6). Recently, pine invasion into pastures has become a range management problem, presumably a consequence of human interference with the natural wildfire regime, enhanced by recent absence of drought.

The Black Hills are a veritable melting pot, with tree species representing origins as diverse as the northern boreal, the eastern deciduous, the western subalpine and montane forests, and the pygmy conifer woodlands (2). Of the many indigenous tree species other than ponderosa pine, only three occur extensively enough to influence ponderosa pine silviculture.

White spruce (*Picea glauca* (Moench) Voss) forms pure, mostly even-aged stands on cool, moist sites where it is considered the climax forest type. Ponderosa pine is seral on these sites. Only about 2 percent of the commercial forest land is currently dominated by white spruce, but it is gradually replacing seral pine stands as a result of fire control, pine-killing insects and diseases, and silvicultural practices. On more xeric sites, spruce may mix with but is eventually replaced by pine.

Stands of quaking aspen *(Populus tremuloides* Michx.) occupy about twice as many acres as white spruce but, for the most part, less permanently. Most stands are seral, replacing pine or spruce only temporarily following disturbance. Stands of bur oak *(Quercus macrocarpa* Michx.) of tree form are mostly confined to low elevation bottoms on the eastern and northern margins of the Black Hills. However, a scrub form of oak also mixes with pine on some upland sites in the northern Black Hills and Bear Lodge Mountains. On these sites, loss of the dominant pine cover, through cutting or fire, can lead to capture of the site by oak brush. Natural recapture by pine is a very slow process; artificial restoration is difficult and expensive.

For managers of multi-purpose lands, the main problem with the associated forest types is their restricted occurrence. The predominance of ponderosa pine seriously limits diversity of forest vegetation and complicates management efforts to maintain or increase it (18).

Ponderosa pine is a dependable seed producer in the Black Hills. Seed crops are normally good to excellent every 2 to 5 years; the longtime average interval between good crops is 3 years. This characteristic, coupled with the favorable spring and summer moisture regime, makes natural reproduction readily and abundantly available. Ordinarily, deforested sites within 120 feet (37 m) of an adequate pine seed source restock promptly. Adverse seed bed conditions seldom prevent pine regeneration, but rank stands of grass or brush or heavy slash may delay it (2).

Extremely high stand densities are common in pine regrowth. Established seedling stands often contain more than one tree per square foot (11 trees/m^2). Natural thinning proceeds very slowly; initially overstocked stands are apt to remain crowded from youth to biological maturity. The usual result is early and persistent stagnation of growth. However, many trees in overstocked, even stagnant stands, retain a capacity to respond favorably to release. Satisfactory improvements of growth (especially in stem diameter) are usually attainable by thinning stands less than 100 years old (2).

Ponderosa pine site index is the only means available for rating the productivity of Black Hills sites, whether they support pine, other vegetation, or none at all. Various plant community and habitat types have been identified and described, but type-productivity relationships have not been quantified. Conventional site index curves, developed during the 1930's and based on dominant/codominant tree heights at age 100, are still in use (9). These have been augmented by a vegetation-independent system that derives estimates of index values from soil and topographic parameters (2). The range of site index values is narrow, from 20 feet (6.1 m) to 100 feet (30.5 m). Sites with indexes at or near the maximum are rare, and account for only a small fraction of the forest land area. The modal site index class, 50 to 60 feet (15.2 to 18.3 m), lies between Meyer's classes V and VI (2, 9, 11).

Research on growth and yield of ponderosa pine has a long history in the Black Hills but, from the start, the effort has focused mainly on cutover and regrowth stands; only limited information is available on biological growth potentials of natural stands (2, 9, 12). Unpublished data from old plots indicates that gross mean annual increments will consistently range from 25 to 35 cubic feet per acre (1.8 to 2.5 m^3/ha) at age of culmination (130 to 150 years) in fully stocked, unmanaged stands on average sites. If harvested at age 150 years., such stands could be expected to yield about 3,000 merchantable cubic feet per acre (210.0 m^3/ha) or 14,000 board feet (fbm)[1] per acre, in trees 9 to 11 inches (23 to 28 cm) d.b.h. For comparison, forest survey estimates 32 cubic feet per acre (2.2 m^3 /ha) average annual net growth on commercial forest lands of all ownerships and condition classes. Similarly, Black Hills National Forest growth and mortality plots indicate an average net growth of 33 cubic feet per acre (2.3 m^3/ha) in existing stands, including volumes harvested between remeasurements (8, 18).

While no Black Hills pine stands have been under management long enough to demonstrate the gains in growth and yields attainable through continuous, reasonably intensive management, conservative estimates, based on research and experience, indicate that: trees, 14 to 18 inches (36 to 46 cm) in diameter at breast height (d.b.h.), can be grown on rotations as short as 100 years; and gross mean annual increments can be increased by roughly 50 percent above current levels to 50 cubic feet per acre (3.5 m^3/ha) on average sites or across large forest tracts (18). Best case estimates, derived by using the Rocky Mountain Yield Simulation program (RMYLD) indicate that, with prompt restocking followed by periodic thinnings to maintain proper stocking levels, gross mean annual increment in stands managed at growing stock levels considered optimum for timber production on a 120-year rotation can vary from about 40 cubic feet per acre (2.8 m^3/ha) on site index 50 lands to about 90 cubic feet per acre (6.3 m^3/ha) on site index 80 lands (1). However, these simulations may not fully account for all the diverse social, economic, biological, and physical constraints that limit productivity.

A distinctive pathological characteristic of Black Hills ponderosa pine forests is the absence of dwarf mistletoe *(Arceuthobium* spp.). This permits silviculturists to consider a wide range of harvest/regeneration options, free of the threat of mistletoe transmission from old to new stands. There is some incidence of most other disease problems common to the type (4); shoestring rot *(Armillariella mellea* (Wahl. ex Fr.) Karst.), western gall rust *(Peridermium harknessii* J. P. Moore), and red rot *(Dichomitus squalens* (Karst.) Reid) are prominent and chronically troublesome (2). However, none of these is serious enough to require major modifications of silvicultural practices forestwide.

The most damaging insect pest is the mountain pine beetle *(Dendroctonus ponderosae* Hopkins). Periodic epidemics kill millions of trees, typically in patchwise fashion in uniform, heavily stocked, large pole and small sawtimber stands. The most widely applied control practice is timely harvest and utilization, or burning, of infested trees. Subjective evidence suggests that the beetle problem will be mitigated as intensified intermediate cutting programs reduce the prevalence of overstocked stands and increase diversity of size and age classes (1, 2, 17). Pine engravers *(Ips* spp.) occasionally produce tree-killing populations in heavy thinning slash; the red turpentine beetle *(Dendroctonus valens*

[1] Cubic foot and metric conversions of measurements expressed in board feet should be viewed as estimates because of the assumptions involved in the conversion process.

LeConte) sometimes makes a primary attack on healthy trees; and pine terminal borers often impede height growth of juvenile trees (2).

Because it has posed so few problems, little research has been done on natural regeneration of Black Hills ponderosa pine. Most of what is known about silvicultural systems and harvesting methods has been learned by experience. Fortunately, the experience has been abundant, varied, and instructive. During the more than a century of timber harvesting in the Black Hills, the silvicultural systems applied on Federal lands have covered the spectrum from clearcutting (1876 to 1896), to seed-tree cutting (1897 to 19907), to shelterwood cutting (1908 to 1925), to individual tree selection (1926 to 1955), and then returned to shelterwood cutting (since 1956). Virtually every operable acre has been cutover at least once; the majority have received repeated partial cuts of one kind or another (2, 13).

Several important lessons have been gained from these diverse harvesting experiences: even-aged silviculture is eminently suited to Black Hills ponderosa pine; within the even-aged system, any one of the three standard regeneration methods may be a valid option under appropriate circumstances; the shelterwood method offers more advantages and entails fewer disadvantages than either the seed-tree or clearcut methods; and uneven-aged silviculture is not a desirable option for timber production in Black Hills ponderosa pine, but the selection method is a valid option in special situations.

The shelterwood method capitalizes on the species' natural tendency to form even-aged stands. Furthermore, it combines the advantages of continuous vegetative protection of the site; absence of obvious openings; assurance of an adequate, well-dispersed seed supply; fair control over development of competitive ground cover; good control over accumulations of hazardous and unsightly logging residue; and an esthetically acceptable appearance, provided the harvest job is skillfully planned and executed (2). An important disadvantage is that the parent overwood will hamper development of the replacement stand if it is too dense or left in place too long. Another disadvantage is that even a light shelterwood is likely to supply more seed than is needed, thus aggravating the problem of excess reproduction. The grass-forb seral stage which is desirable for wildlife and livestock forage does not develop fully nor persist for long under a shelterwood (2).

A uniform, two-cut shelterwood appears to be the most efficient and silviculturally acceptable variant of the method. The seed cut should be heavy enough to interrupt the competitive continuity of the mature stand and leave only 12 to 18 good parent trees per acre (30 to 44/ha); the removal cut should be completed soon after regeneration is established. A three-cut variant is an acceptable option in situations where two cuts pose unusual problems of visual impact, residue buildup, risk of windthrow, or logging damage to reproduction (2).

The other even-aged methods-seed-tree or clearcutting - are acceptable alternatives to the shelterwood under some conditions. Each, however, lacks one or more of the advantages of the shelterwood method. The seed-tree cutting method entails the highest risk of loss of seed source, especially from blowdown. Also, the widely spaced seed trees offer little competition to invading ground cover in the unlikely event of delayed pine regeneration. If it is surrounded by well-stocked stands, a seed-tree area has nearly the same visual impact as a cleared opening. In well-stocked stands, a seed-tree cut results in heavy accumulations of logging residue on the first entry. These disadvantages may be partially offset by reduced seed supply, less damage to reproduction during seed stand removal, and higher production of herbage (2).

The clearcutting method creates conspicuous stand openings. The size of opening should normally be restricted to about twice the 250 feet (76.2 m) dispersal distance of ponderosa pine seed if there is a seed-producing stand all around the perimeter. In well-stocked stands, clearcuts generate maximum amounts of logging residues which may require costly abatement. After the slash dissipates, pine regeneration is likely to develop vigorously, free of overhead competition. Lack of timely pine regeneration may lead to site capture by other vegetation for relatively long periods of time. The clearcut method is most likely to produce significant increases in forage and water yields (2).

For regeneration, the uneven-aged system is out of place in the naturally even-aged pine forests of the Black Hills. Light selection cuts, which remove only a few individual trees or small groups, ordinarily do not lead to satisfactory establishment and development of replacement growing stock. Stands of uneven- or all-aged structure can only be produced and maintained at spacings wide enough to make all stand components essentially free growing. For purposes other than regeneration, individual tree selection can be a very useful harvest practice. It is particularly applicable in the management of remnant old-growth stands being perpetuated for esthetic reasons; for manipulation of stands on or adjacent to riparian zones or other sensitive sites; and for management of unusually large trees for high-quality wood, specialized habitats, or visual appeal. The selection method is difficult to prescribe and costly to apply, however (2).

Thinning is an appropriate and generally necessary intermediate cutting method. In typically crowded regeneration stands, precommercial thinning should begin early, before stagnation occurs, while trees are large seedling or small sapling size. One moderately heavy, precommercial thinning is more cost-effective than no precommercial thinning. Commercial thinnings should be made at regular intervals (usually 20 years) throughout the rotation to upgrade the quality and productivity of the growing stock, to reduce susceptibility to mountain pine beetle attack, and to promote development of understory vegetation. Thinning to stocking levels below the optimum for wood production results in significant increases in forage for livestock and wildlife. Low levels of growing stock also favor water yields; fully stocked pine stands are capable of utilizing most of the moisture which infiltrates the soil mantle in years of normal or deficient precipitation (1).

Prescribed burning is an effective, efficient way to eliminate unwanted pine reproduction invading grasslands adjacent to forest; it may be an equally good way to control advance reproduction in lightly stocked, immature pine stands (6). Burning, either in piles or broadcast, is useful for fuel and hazard reduction following harvest cuttings or commercial thinnings; burning may or may not benefit ground cover vegetation. Prescribed burning of precommercial thinning slash is risky in that it is likely to kill small, barked trees.

Intensive management should provide for improving the genetic quality of the forest growing stock. Selection for desirable traits should be routine in the choice of leave trees in intermediate and harvest cuts. Seed used for artificial regeneration should be from recognized, local collection zones or seed production areas. When bona fide improved strains of adapted ponderosa pine become available, their use should be considered for reforestation of at least the most productive sites.

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