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Estimates of site potential for ponderosa pine based on site index for several southwestern habitat types

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ESTIMATES OF SITE POTENTIAL FOR PONDEROSA PINE BASED ON SITE INDEX FOR SEVERAL SOUTHWESTERN HABITAT TYPES

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ABSTRACT.—Estimates of site potential for ponderosa pine based on measured site indexes in 416 stands are compared between seven habitat types and one community type. No significant differences in mean site index are found between the habitat types studied. The habitat types are classified into high or moderate site potential classes based on mean site indexes.

Ponderosa pine (*Pinus ponderosa* Laws.) is the most important commercial timber species in the southwestern United States. Ponderosa pine forests occupy the largest area of commercial forest land in Arizona and New Mexico (Choate 1965, Spencer 1966). Ponderosa pine forests reach their maximum development in the Southwest at elevations between 7,000 and 7,800 feet, but also occur at higher and lower elevations (ranging from 6,000 to 8,500 feet) (Schubert 1974). At the lower elevations ponderosa pine forests intergrade into pinyon-juniper forests. At higher elevations, ponderosa pine grades into the Douglas-fir and white fir forest types (Sheppard et al. 1983).

Because of their commercial value, ponderosa pine forests are intensively managed for timber production in the Southwest. Many management decisions are based on site class or quality classifications. Classification of land into site quality or production potential classes provides a useful means for identifying areas where the potential for improved production is greatest (Schubert 1974). In addition, recently developed growth and yield simulation models for southwestern ponderosa pine rely on site quality determination as an important variable for predicting yields over time (Edminster 1978, Larson and Minor 1983).

Site index is currently the most widely used method of evaluating site quality or potential productivity of forest lands in the United States (Jones 1969, Husch et al. 1972, Daubenmire 1976). Site index is based on the average heights of dominant and codominant trees at a specified index age (usually 50 or 100 years). Because stands of the index age are seldom encountered, site index curves are constructed to allow for estimation of site index for stands older or younger than the index age by interpolation between curves. Site index curves describe the height growth of hypothetical trees of specified site indexes.

Because Meyer's (1961) site curves for ponderosa pine tend to underestimate site quality for the species in the Southwest (Schubert 1974), Minor's (1964) ponderosa pine site curves for Arizona and New Mexico are more frequently used for site potential estimates. Minor's curves are developed for dominant trees with breast-height ages of 20 to 140 years and site classes from 40 to 100 feet. Site index classes over 100 can be calculated using an equation presented by Minor (1964).

The use of habitat types (Daubenmire 1952) to classify forest vegetation is gaining acceptance by land managers and researchers in the western United States (Layser 1974, Pfister 1976, Pfister and Arno 1980). One of the primary uses of habitat types is in timber management where they are used to compare regeneration success, succession patterns, cutting methods, and timber productivity and to develop guidelines for collecting seed and plant nursery stock (Pfister and Arno 1980).

The use of habitat types to predict forest site productivity potential or site quality is proposed by several investigators. Differences in the rate of height growth by habitat type are demonstrated for several tree species

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(Daubenmire 1961, Deitschman and Greene 1965, Stanek 1966, Stage 1975, Hoffman 1976, Monserud 1984). Significant differences between site indexes are also shown for habitat types (Stanek 1966, Stage 1975, Hoffman 1976, Mathiasen et al. 1986). Pfister et al. (1971, 1977) and Steele et al. (1981) use site index curves and normal yield tables to estimate yield capability for habitat types in Montana and Idaho.

Habitat type classifications are recognized for southwestern ponderosa pine forests and for forest types where ponderosa pine is often associated with Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and white fir (*Abies concolor* [Gord. & Glend.] Lindl.) (Alexander 1985). However, little information is available for ponderosa pine site quality for recognized southwestern habitat types (Moir and Ludwig 1979, Hanks et al. 1983, Fitzhugh et al. 1984, DeVelice et al. 1986). Schubert (1974) provides a summary of the silviculture of southwestern ponderosa pine and emphasizes the need for tying growth and yield simulation models to habitat types. Because site quality is a key variable in ponderosa pine growth and yield models, site quality estimates for different habitat types are needed for the Southwest. This study provides additional quantitative data on site quality based on site index measurements for ponderosa pine for several southwestern forest habitat types and one community type.

Methods

Total height and age at breast height were measured for two to six vigorously growing dominant or codominant ponderosa pines in 416 stands representing the southwestern ponderosa pine (314), white fir (92), and Douglas-fir (10) forest types. Trees with visible signs of abiotic, insect, or disease damage were not selected as site trees. The following information was recorded for each stand: national forest, location (township, range, and section), elevation (nearest 100 feet), aspect (four cardinal directions), slope (nearest 5%), slope position (flat, bottom, ridge, slope), and habitat type (HT) (Moir and Ludwig 1979; Hanks et al. 1983; Alexander et al., Lincoln National Forest, 1984; Alexander et al., Douglas-fir habitat, 1984; Alexander et al., Cibola National Forest, 1984; Fitzhugh et al. 1984; Youngblood and Mauk 1985; DeVelice 1986). A total of seven habitat types and one community type (CT) were sampled (Table 1). Stands sampled were located in the Apache (34 stands), Coconino (77 stands), and Kaibab (54 stands) national forests, Arizona; the Carson (36 stands), Cibola (15 stands), Gila (8 stands), Lincoln (11 stands), and Sante Fe (68 stands) national forests, New Mexico; and the San Juan National Forest, Colorado (113 stands).

Site indexes were determined from average total height and breast height age data for each stand using the ponderosa pine site index curves developed by Minor (1964). Site indexes for stands with site indexes greater than 100 feet were calculated using the site index equation presented by Minor (1964). Mean site index and standard deviation were calculated for each habitat type and community type sampled. A one-way analysis of variance, with p = .05, was used to compare mean site indexes among habitat types. The Student-Newman-Keuls test was applied to the analysis to determine where significant differences occurred.

Results

Mean site indexes ranged from a low of 74.3 for the PIPO/BOGR HT to a high of 87.0 for

TABLE 1. Southwestern ponderosa pine, Douglas-fir, and white fir habitat and community types sampled. Refer to Literature Cited for full reference to footnote citations.

Ponderosa Pine Habitat Types	
PIPO/MUVI:	*Pinus ponderosa/Muhlenbergia virescens*[5]
PIPO/FEAR:	*Pinus ponderosa/Festuca arizonica*[3,4,5]
PIPO/BOGR:	*Pinus ponderosa/Bouteloua gracilis*[3,4,5]
PIPO/QUGA:	*Pinus ponderosa/Quercus gambelii*[1,3,4,5]
Ponderosa Pine Community Types	
PIPO/POLO:	*Pinus ponderosa/Poa longiligula*[5]
Douglas-fir Habitat Types	
PSME/FEAR:	*Pseudotsuga menziesii/Festuca arizonica*[2]
White Fir Habitat Types	
ABCO/QUGA:	*Abies concolor/Quercus gambelii*[1,3,4] (*Abies concolor-Pseudotsuga menziesii/Quercus gambelii*[6])
ABCO/BERE:	*Abies concolor/Berberis repens*[7] (*Abies concolor-Pseudotsuga menziesii*/[sparse][6])

[1]Alexander, Ronco, Fitzhugh, and Ludwig 1984.
[2]Alexander, Ronco, White, and Ludwig 1984.
[3]DeVelice et al. 1986.
[4]Fitzhugh et al. 1984.
[5]Hanks et al. 1983.
[6]Moir and Ludwig 1979.
[7]Youngblood and Mauk 1985.

TABLE 2. Mean ponderosa pine site indexes, standard deviations, 95% confidence limits, and site potential classes by habitat and community type.

Habitat type	Number of stands	Mean[1]	95% confidence limits	Site potential class
PSME/FEAR	10	87.0 ± 12.5	78.1 – 95.9	High
PIPO/FEAR	112	83.6 ± 11.2	81.5 – 85.7	High
ABCO/QUGA	72	83.5 ± 11.1	80.9 – 86.1	High
PIPO/QUGA	135	82.3 ± 15.1	79.8 – 84.9	High
PIPO/MUVI	12	81.1 ± 8.6	75.6 – 86.6	High
ABCO/BERE	20	79.3 ± 12.7	73.3 – 85.3	High
PIPO/POLO	16	79.7 ± 8.5	75.2 – 84.2	High
(Comm. Type)				
PIPO/BOGR	39	74.3 ± 13.4	69.9 – 78.6	Moderate
TOTAL	416			

[1]No significant differences were detected between mean site indexes using the Student-Newman-Kuels test, p .05.

the PSME/FEAR HT (Table 2). Standard deviations ranged from 8.5 for the PIPO/POLO CT to 15.1 for the PIPO/QUGA HT. None of the mean site indexes was found to be significantly different at the $p = .05$ level. Ponderosa pine forests in Arizona and New Mexico are grouped into three site classes for management reasons by the U.S. Forest Service (Southwest Region). The groupings are based on potential cubic feet/acre/year productivity estimates and use Minor's (1964) site index curves: Site Class 1 represents site indexes above 75, Site Class 2 represents site indexes from 55 to 74, and Site Class 3 represents site indexes less than 55. Although the mean site indexes for the habitat type sampled in this study were not significantly different, site potential classes for ponderosa pine were assigned for the habitat types based on mean site indexes and the above site class system used by the Forest Service. Our high and moderate site potential classes correspond to Site Class 1 and Site Class 2, respectively (Table 2).

DISCUSSION

Site index is currently the most widely accepted method of evaluating site quality in the United States. Several investigators report significant differences in site index between habitat types for several tree species (Stanek 1966, Roe 1967, Hoffman 1976, Mathiasen et al. 1986). However, our results indicate no significant differences between mean site indexes for ponderosa pine between the seven habitat types and one community type sampled in this study. Daubenmire (1961) rejects the use of ponderosa pine site index curves for predicting potential productivity of habitat types because he found large variations between the site indexes of contiguous young and old stands of ponderosa pine in burned areas representing homogeneous habitats. Daubenmire reports that ponderosa pine grows faster than site index curves predict. Other investigators report similar findings for other tree species (Ilvessalo 1927, 1937, Carmean 1956). In addition, stand density, soil variation, and early suppression of trees can affect the validity of site quality determinations based on site index curves (Jones 1969). Therefore, our estimates of site quality for ponderosa pine presented here and for Douglas-fir (Mathiasen et al. 1986) based on site index may be underestimating actual site potential for the habitat types we have sampled thus far. However, site index is considered to be the best practical indicator of relative site quality at this time (Hodgkins 1956, Vincent 1961, Jones 1969, Husch et al. 1972).

Based on the U.S. Forest Service site class system and our mean site indexes for ponderosa pine, all but one of the habitat types sampled in this study are classified as high site potential (Class 1) habitat types. Although there was a large degree of variation in site index for each of the habitat types sampled (standard deviations averaged 11.6), site potential ranges are represented best by their 95% confidence limits; most of the habitat types' 95% confidence limits are within the high site potential class (Table 2).

In their descriptions of habitat type classifications, several investigators report site quality estimates for ponderosa pine in southwestern forest habitat types (Moir and Ludwig 1979, Hanks et al. 1983, Alexander et al. 1984, Fitzhugh et al. 1984, Youngblood and Mauk 1985, DeVelice et al. 1986). Our estimates of site quality for ponderosa pine by habitat type support the estimates made by Fitzhugh et al. (1984) and Hanks et al. (1983) for the PIPO/FEAR HT (moderate to high). However, DeVelice et al. (1986) report low site potential for ponderosa pine in the PIPO/FEAR HT in northern New Mexico and southern Colorado. Fitzhugh et al. (1984) report high potential for ponderosa pine in the PIPO/MUVI HT. Our results essentially agree with their estimate. Moir and Ludwig (1979) report stands with what they consider low site potential for ponderosa pine (site index of about 65) in the ABCO/QUGA HT. DeVelice et al. (1986) and Hanks et al. (1983) report low or poor site potential for the ABCO/QUGA HT. However, our site index data for this habitat type indicate high site potential for ponderosa pine. Our findings also indicate higher site potential for ponderosa pine in the PSME/FEAR HT (high site potential) than reported by DeVelice et al. (1986) (low site potential). Hanks et al. (1983) report that the PIPO/BOGR HT probably represents the lowest site potential of any ponderosa pine habitat type in the Southwest. However, our results indicate that site potential is moderate for this habitat type. Site potential estimates for ponderosa pine have not been reported for one of the habitat types and the community type sampled in this study. Based on our site index data, site quality for the ABCO/BERE HT and the PIPO/POLO CT is high. Hanks et al. (1983) state that the PIPO/POLO CT is "suitable" for timber production, and we agree with their evaluation.

The reasons for differences in ponderosa pine site quality estimates for southwestern forest habitat types by various investigators are primarily the result of geographic variation in site indexes (Monserud 1985) or differences in criteria for interpreting site index data in relation to site quality. Hanks et al. (1983) and Fitzhugh et al. (1984) do not explain the basis for their estimates of ponderosa pine site quality, but their estimates do not appear to be based on quantitative site index data collected during their field work. DeVelice et al. (1986) base their estimates on site index data and rate ponderosa pine site quality using the standard U.S. Forest Service Southwest Region site class groupings described earlier. We also base our site potential estimates for ponderosa pine on the Forest Service site class groupings and suggest that future habitat type classifications adopt this system to have consistent criteria for estimating site quality for habitat types in the Southwest. Even though we used the same site class system, our estimates of ponderosa pine site potential vary a great deal from those of DeVelice et al. (1986). The most probable explanation for the differences between our site potential estimates and those of DeVelice et al. is that ponderosa pine and Douglas-fir tend to demonstrate much lower site indexes in the Sangre de Cristo Mountains of northern New Mexico and southern Colorado (Moir and Ludwig 1979), where DeVelice et al. (1986) collected much of their site index data. Therefore, site quality estimates for southwestern habitat types based on habitat type classification studies from specific geographic areas or national forests may not adequately represent the range in site potential classes encountered in the Southwest.

Several authors discuss the problems with using site index data to estimate site quality (Hodgkin 1956, Vincent 1961, Daubenmire 1961, 1976, Jones 1969). Although site index data are generally regarded as a somewhat rough estimate for productivity potential of forest land, they are still accepted as the most practical and direct method for evaluating relative productivity (Vincent 1961, Jones 1969, Husch et al. 1972, Daubenmire 1976). Site quality estimates for forest habitat types based on site index data are still applicable to current forest management procedures, but because large variations occur in site indexes within habitat types, the use of habitat types for predicting timber productivity potential is imprecise. However, because timber productivity is primarily estimated from site index information, site class estimates based on site index data should be determined for additional southwestern habitat types and other commercially important tree species. In addition, our site quality estimates for ponderosa pine and for Douglas-fir (Mathiasen et al. 1986) for several southwestern forest habitat types should be supported or modified if necessary with additional site index data collected from stands classified by habitat type.

The development of separate site index curves for different habitat types may improve the accuracy of site index as an estimate of site quality (Monserud 1984). Furthermore, the development and subsequent validation of growth and yield simulation models using growth coefficients based on habitat types (Stage 1973, 1975) may improve productivity estimates for habitat types.

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