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Measures for Forest Health in Eastern Washington Habitat Types

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Stand density index (SDI) has been used to rank eastern Washington forest conditions relative to stocking targets for forest health (see RTI FS 25). However, the SDI approach assumes that we have an accurate assessment of stand viability at a given density and quadratic mean diameter (DBHq). To better determine what SDI level is indicative of stands that are likely to be healthy, we use a measure of stand vigor called growth basal area (GBA). Stand vigor has historically been linked to GBA in eastern Washington dry sites as it reflects inherent site carrying capacity better than measures of density, relative density, and basal area. An examination of estimated GBA across eastern Washington habitat types shows wide variability depending upon species and site characteristics. Categorizing this variability into a usable system will be of value to policy makers and small landowners in the development of stocking level targets that meet forest health goals in a sustainable manner.

Of current concern in eastern Washington forests is the proliferation of stand replacing disturbances of a magnitude thought to be beyond the historic range of variability (Everett et al. 2000). These stand replacing events, whether from fire, insect epidemic, or disease have garnered the attention of policy makers and the public, especially the people who live in affected communities. The premise in the forest health discussion is that the forests are 'stressed' and thus subject to increasing pressure from natural vectors because of 'overstocking'. In looking for solutions to forest health problems, we need to combine knowledge of plant physiology, stand dynamics, and site specific ecological metrics to determine when a forest is 'overstocked' and vulnerable to health decline. Only then can we determine optimal treatments, designed for density reductions to maintain healthy forest conditions.

The historic management approach over the last 100 years has favored continuous forest cover and 'uneven-aged' management strategies combined with fire suppression. The result has been multi-layered stands of shade-tolerant species across much of the landscape**.** Insects and disease build up in multi-layered stand structures resulting in extensive epidemics because of the continuity of food sources for these forest health vectors. In addition, the focus of many foresters on a 'normal forest' or full stocking management emphasis may have led to broad misunderstanding of 'overstocked' conditions relative to stand carrying capacity. Metrics such as Curtis' Relative Density (RD) and Reineke's Stand Density Index (SDI) were developed to provide standardized stocking metrics relative to a 'fully stocked' stand, but only with Hall's (1989) growth basal area (GBA) do we get an actual measure of stand vigor relative to site. Growth basal area is defined as the basal area measured in square feet/acre that a stand can carry and still maintain growth rates of 1"in diameter at breast height/decade for dominant trees at 100 years of age. By keying stocking levels to growth rate, a site specific determination of when the stand is 'carrying a high basal area' is possible. Using GBA, the range of potential forest health impacts that an individual forest owner might encounter for different stocking levels can be estimated. For example, GBA is indexed to a growth rate where susceptibility to attack by mountain pine beetle (MPB) (*Dendroctonus ponderosae,* Hopkins.) is reduced (Hall 1989, Sartwell 1971).

The mechanics of tree physiology support the use of GBA as a response variable for measuring site carrying capacity and as a useful proxy for relative tree stress as a function of stocking densities, diameter distributions, and species. Trees allocate resources to diameter growth and defense against insects and disease after a host of other priorities including root and shoot growth, scar tissue development, cone development, and height growth. By virtue of location in the ranking of resource allocation, diameter growth provides a useable estimator for tree vigor and stand health, both of which are closely linked to the potential for insect and disease impacts *when* these vectors are present. At epidemic levels, the relationship between the tree host and insect and disease vectors requires a substantially different approach to management beyond application of density control measures.

Carrying capacity as measured by stand basal area growth is best estimated after the initial spring flush of root, shoot, cone, and height growth is complete. Diameter growth is more responsive to growing-season water stress than height growth which occurs in the early part of the growing season for most eastern Washington coniferous species. Since stand stress is related to limitations on the availability of growing-season moisture and nutrients, we can use diameter growth of dominant trees and the stocking density of the forest stand as measured by basal area (BA) and quadratic mean diameter (DBHq) to estimate stand stress and the subsequent reduced resilience to forest pests. To test the correlation between basal area growth and stand stress causing reduced resistance to forest health vectors, we simulated growth across a variety of habitat types and mapped these outputs against the threshold basal areas reported in field studies on stands having similar site indices and/or habitat types. Simulations of ponderosa pine (*Pinus ponderosa*) regenerated at an initial density of 400 trees/acre using default site index and stand density index by habitat type for the East Cascades (EC) variant of the Forest Vegetation Simulator (FVS) were used to generate the range of curves shown in **Figure 1**. As expected, growth limiting factors vary by habitat type resulting in different basal area maxima over the 100 year simulation period.

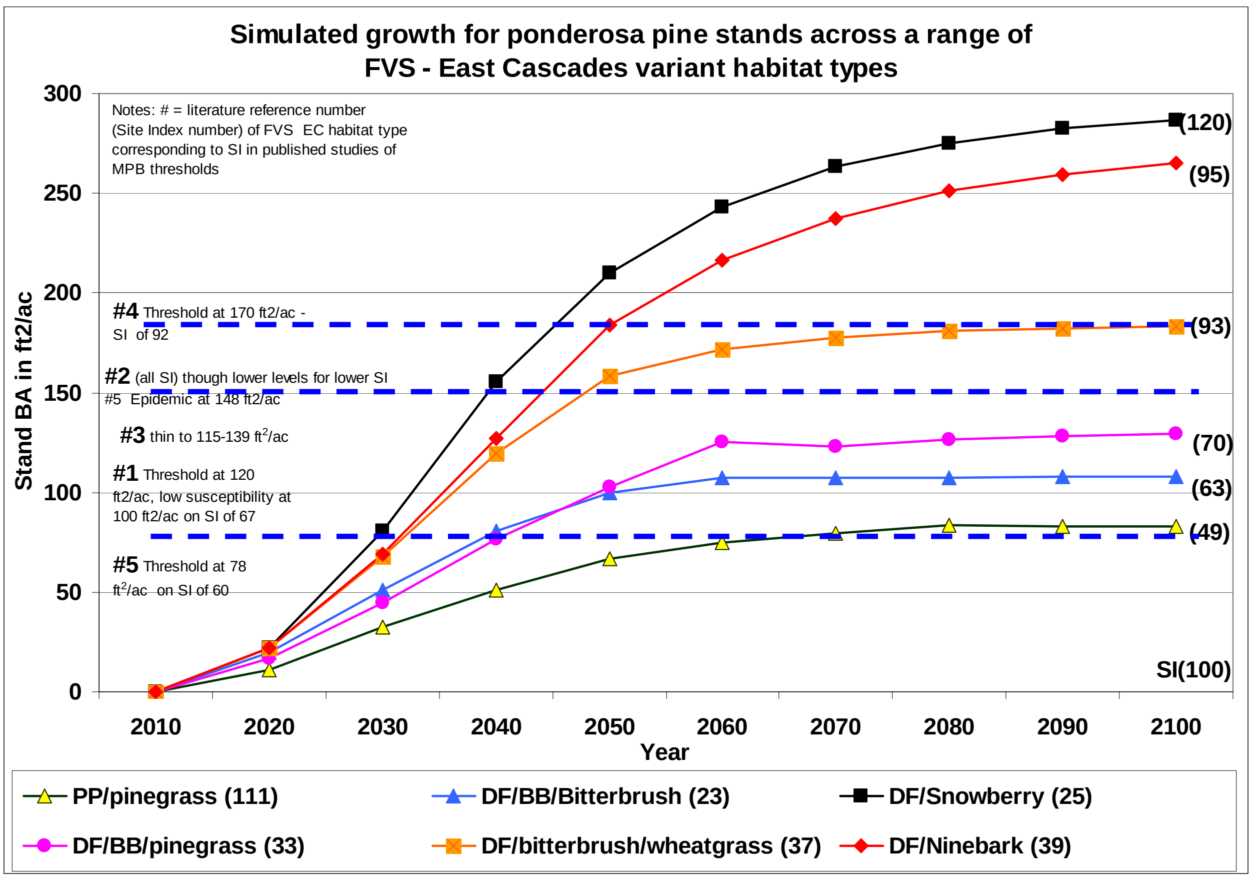

Figure 1: Ponderosa pine growth on various habitat types in the East Cascades as simulated by FVS
Threshold values are from: #1 Schmid and Mata 1992, #2 Sartwell and Stevens 1975, #3 Sartwell 1971, #4 Oliver, W.W. 1995, #5 Larsson et al. 1983.

Basal area 'thresholds' (the dotted lines) for Mountain pine beetle (MPB) reported in the literature plotted against these growth curves demonstrate a trend toward increasing the estimated stocking 'threshold' for bark beetle outbreak as site quality increases. While the basal area threshold of 150 ft^2/acre reported by Sartwell and Stevens (1975) has been accepted as an average threshold for MPB in ponderosa pine, there have been a wide range of reported thresholds for differing site conditions. At the lower end, Larsson et al. (1983) report a basal area threshold for MPB outbreak of 78 ft^2/acre on stands with an estimated site index of 60 feet in 100 years, while Oliver (1992) reports a threshold of 170 ft^2/acre of basal area on stands with a site index of 92 feet in 100 years. The broad range of thresholds reported suggests that site quality plays an important role in determining maximum stocking levels that can be sustained such that the forest stand retains adequate resistance to endemic levels of insects and disease.

A suitable measure of site quality for estimating the potential for forest health problems across the landscape should be sensitive to diameter growth. The most commonly used measure of site quality is site index which is relatively insensitive to stand density and is a poor indicator of diameter growth potential. However, site index is useful to separate diameter growth potentials into smaller 'bins' for eventual classification and application of 'rules of thumb'. As an example, **Figure 2** shows the relationship between GBA and site index for Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine, and lodgepole pine (*Pinus contorta*) on mapped upland habitat types in eastern Washington. An overlay of site class (site index groupings) on the GBA/SI relationship in **Figure 2** demonstrates that there is a broad range of GBA that occurs within a given site class and for a given species. The variability in GBA would imply that an approach to forest health using average metrics may not address the thresholds of risk associated with multiple species and different habitat types. A system that specifies assessment criteria based on habitat type groups may be appropriate in meeting forest health goals in the context of other management criteria, but it will take time to develop this approach and provide the necessary training and education for its implementation in the field. Conversely, grouping the GBA values by site index 'bins' provides a simple means of reducing forest variability into management subsets for most species. An exception is lodgepole pine which has GBA values that are not well correlated to site index.

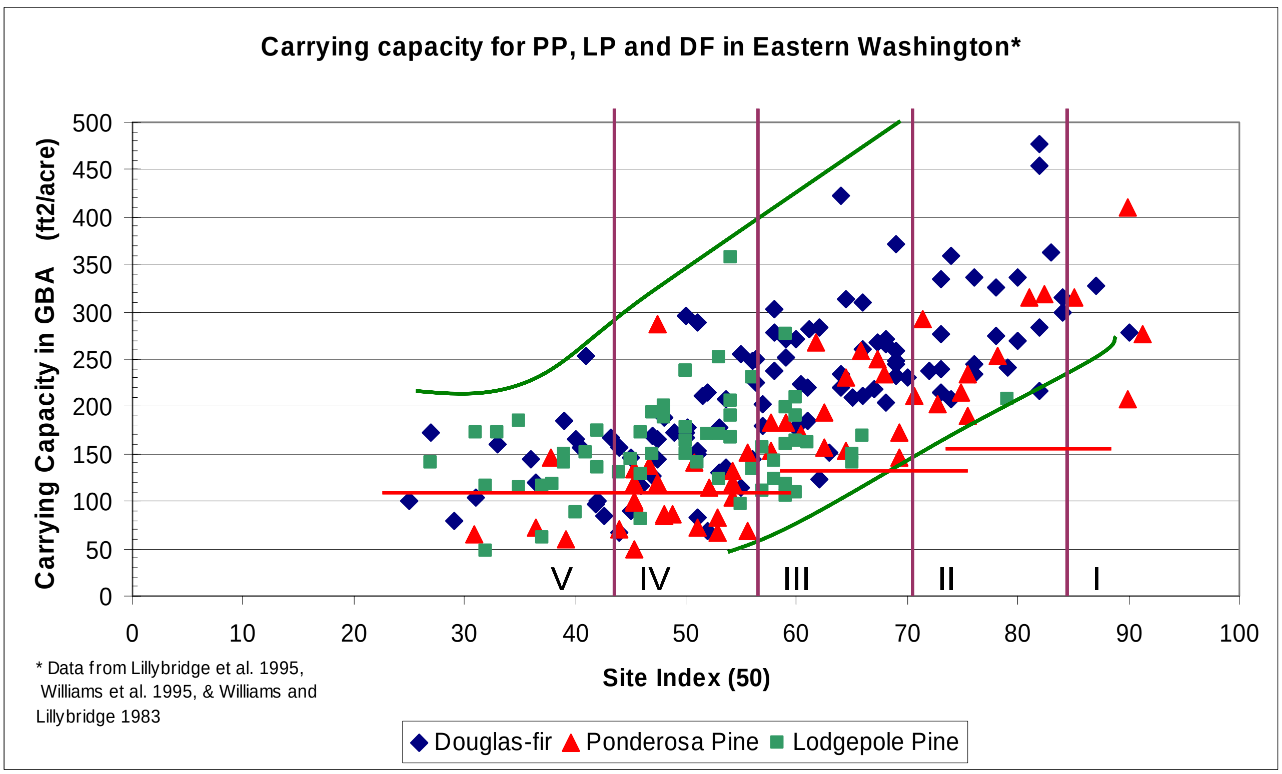

Figure 2: Stand carrying capacity by species and site index for eastern Washington habitat types.

Use of site index or site class for forest growth classification is commonly accepted in current forest practices rules and within the larger field forestry community. By using site class 'bins' to estimate the biological thresholds for insects and disease, a series of look-up tables can be generated that would identify risk thresholds by diameter, stocking level and/or basal area target. An example table is given in **Table 1**.

Table 1 uses target densities of 150 TPA to illustrate carrying capacity thresholds leading to forest health risks as derived from the relationship between *minimum* GBA and site class (Good, Medium, Poor) as given in **Figure 2**. Tables can be created for any diameter and density target to assess forest health risks relative to stand carrying capacity and site quality. The look-up table simplifies the threshold decision criteria for a given density or diameter target, but does not substitute for the need to collect stand data to confirm site GBA and adapt management targets to integrate forest health with volume, habitat, or structural goals. It is worthy of note that the data used to derive these look-up tables have been developed from national forest ecological classification inventory plots. Carrying capacity may be reduced if expectations of changing future climatic conditions are realized (McKenzie et al. 2004).

Table 1: Stand metrics for a target density of 150 TPA including assessment of forest health risk by site class.

	SDI	TPA	DBHq	BA
Safe	49	150	5	20
Zone	66	150	6	29
	85	150	7	40
Poor	105	150	8	52
Site	127	150	9	66
Threshold	150	150	10	82
	175	150	11	99
Medium	201	150	12	118
Site	228	150	13	138
Threshold	257	150	14	160
	287	150	15	184
Good	318	150	16	209
Site	351	150	17	236
Threshold	384	150	18	265
	419	150	19	295
	455	150	20	327
	492	150	21	361
	530	150	22	396

Conclusions

Forest health challenges can be addressed by considering site parameters and the multiple metrics that influence stand dynamics. Defining appropriate stocking levels across a range of density, diameter and basal area targets is one step toward developing desired future forest health conditions. Immediate classification steps are possible using existing data on site index and GBA by habitat type, but an assessment procedure that specifically incorporates habitat type and measured growth basal area into site quality equations for forest health is needed to determine appropriate stocking levels across the landscape. Categorization of forest variability into a usable system for policy makers and landowners will help to ensure density management strategies can meet desired future conditions and forest health goals simultaneously.

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