Using Lego© Blocks to Demonstrate Concepts of SDI and Relative Density

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Abstract

The concepts of density and stocking are critical to understanding silvicultural techniques. A variety of measures and approaches are used, including Reineke's Stand Density Index (SDI) and Relative Density (RD). In order to teach these concepts and their applications, the dynamics and interaction of trees within stands were modeled using Lego© blocks. Small boards were filled with Lego© blocks representing various tree sizes to show how RD is used to determine critical stocking levels. Students used a randomly drawn configuration of blocks to investigate stocking reduction options and resultant SDI distributions among size classes. A web-based, interactive program was used to "thin" sample stands. The Landscape Management System was used to predict the long term results of students' proposed thinnings and harvests. This approach effectively furthers students' understanding of SDI, RD and their applications.

Background

The concepts of density and stocking are critical to understanding silvicultural techniques. A variety of measures, such as trees per acre (tpa), basal area per acre (BA/A) and Reineke's Stand Density Index (SDI) are used to determine density (Shaw 2005).

Reineke's Stand Density Index (SDI) describes maximum stand density at the point when natural self thinning (-3/2 Rule) occurs and is mathematically described as

$$\textbf{Log tpa = -1.605 log dbh + k} \qquad \text{(Shaw 2005)}$$

(tpa = trees per acre, dbh = diameter breast height, k = species constant)

When indexed to dbh = 10",

$$\textbf{SDI = tpa * (dbh/10)}^{\textbf{1.605}} \qquad \text{(Shaw 2005)}$$

Thus SDI equals the equivalent trees per acre when average dbh is 10 inches. From the measured SDI and a species or site specific maximum SDI, relative density (RD) can be calculated:

$$\textbf{RD = measured SDI/Max SDI}$$

Drew and Flewelling (1979) demonstrated that canopy closure occurs around RD of 0.15, crown classes start to develop when RD equals 0.35 and competition based mortality occurs when RD is greater than 0.55. Thinning recommendations tend to aim for RD values of 0.15 to 0.4 where SDI can be allocated proportionately among one or more size classes (Cochran 1992).

The Education Model

Students are introduced to the concepts of SDI and RD from the standpoint of the 2 peg Lego© block representing a 10" diameter (dbh) tree, which has an SDI of 1. (The pegs are the extensions on the blocks by which they hook together. The number of pegs denotes block size.) A single peg represents ½ SDI. A 4 peg block represents 2 SDI and so on. A Lego© platform of size 16 pegs by 16 pegs, therefore, has a total SDI of 128. Maximum SDI for an acre varies with site and species, but an SDI of 512 per acre is not atypical for many sites, therefore a 16 by 16 peg platform can reasonably represent ¼ acre. If desired, a 32 by 32 peg platform can be used to represent a full acre.

Approximate dbh equivalents for blocks based on SDI were computed for each standard Lego© block size. The five standard block sizes resulted in 5 size classes, which were distributed as evenly as practically possible at each relative density level (Table 1). The resultant relationship between block number and tree size demonstrates an inverted J-curve (Figure 1) and allows students to visualize and understand an inverted J-curve as well as other types of diameter distributions.

The needed blocks were placed on each platform to show what a distribution pattern might look like in an uneven-aged stand (Figure 2). While these boards represent uneven aged stands, they can be used to represent even-aged stands. It is easier to distinguish the size classes if each size class is all one color of block, if possible.

Although the RD levels seem low, it is actually difficult to fit all the needed blocks onto the platforms. When students envision canopy or root systems around the blocks, they quickly realize how crowded an RD of .55 really is and that competition driven mortality is likely. Completed boards work well to demonstrate initial concepts to students. This demonstration also drives home the concept that growing space is limited and that manipulation of density controls how growing space is allocated.

Table 1: Number of blocks needed for even SDI distribution among 5 dbh classes at various relative densities for a 16 peg by 16 peg platform.

			Relative Density		
Block size in pegs	SDI	Dbh class inches	0.15	0.35	0.55
1	0.5	6.5	8	18	28
2	1	10.0	4	9	14
4	2	15.4	2	4	7
6	3	19.9	1	3	5
8	4	23.8	1	2	4

Figure 1: DBH class distribution in numbers of blocks.

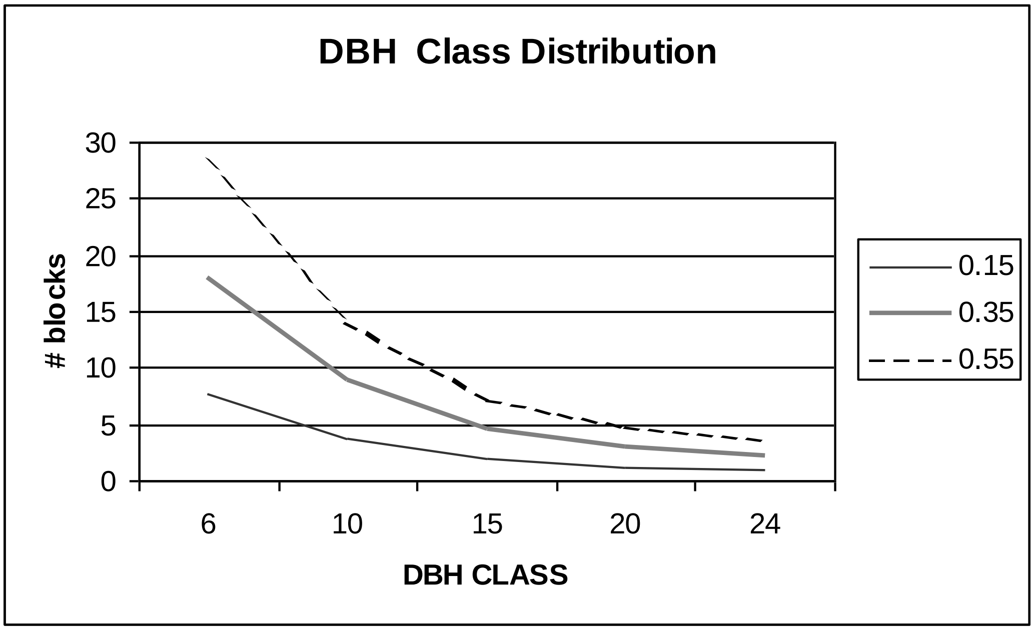
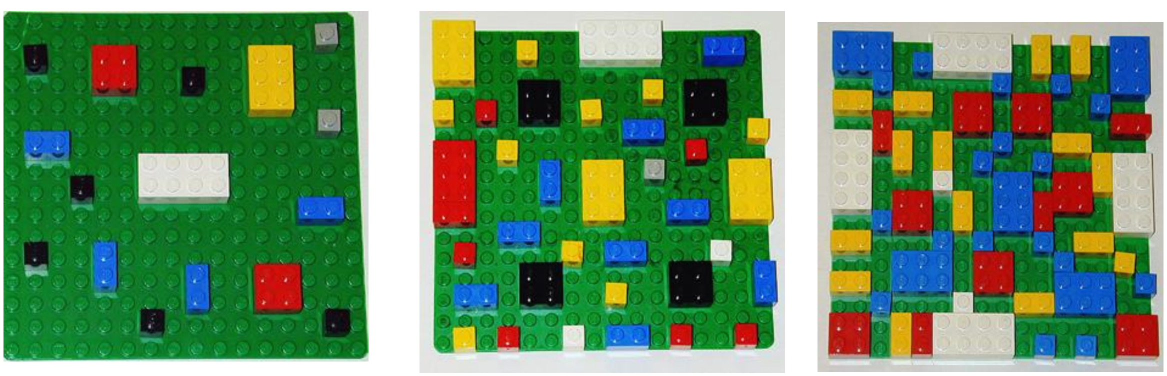


Figure 2: Completed ¼ acre boards at the Relative Densities of .15, .35, and .55.

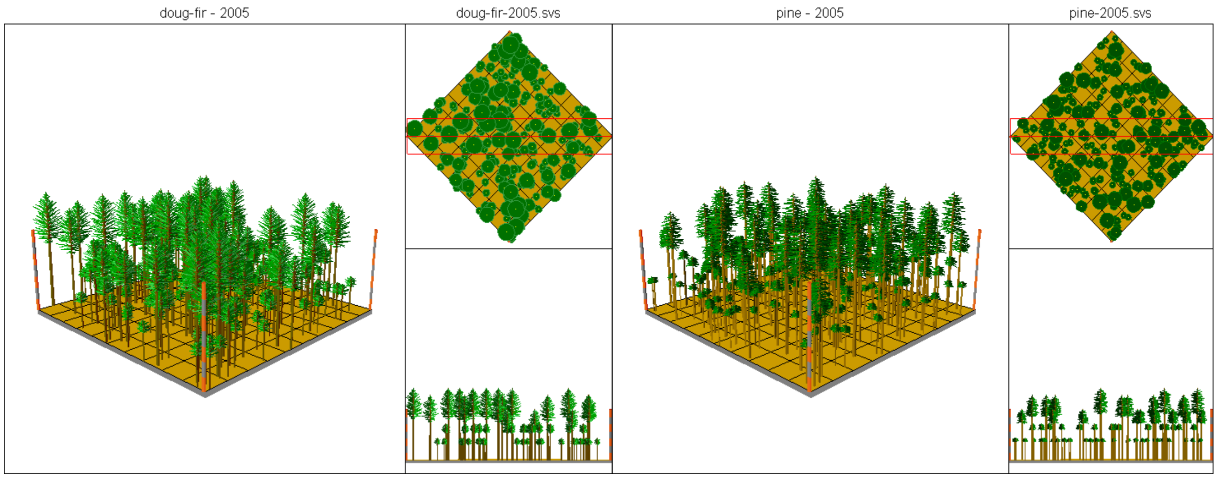


RD = .15 RD = .35 RD = .55

After using completed boards to demonstrate the initial concepts, students then manipulate "stands" to achieve defined management objectives. Students are given a diagram simulating a board. They first inventory the board to determine stand SDI and its allocation into the size groups. Then students decide the target RD and its corresponding SDI. Finally students decide how to distribute the SDI across the size classes and which trees to cut from each class. A web based board (Spicker 2008) allows students to experiment with various cutting strategies to observe the variety of results possible while still meeting the RD and SDI objectives.

In another exercise the data are put into stand and inventory files as two different species on two different sites. Students use the Landscape Management System (LMS) interface to see how their particular prescriptions might behave over time. The visualization (Figure 3) allows students to transition from square blocks to virtual trees with a more random placement and to start considering the long term effects of their decisions. In the case of ponderosa pine, students found an even aged approach provided better growth, while the Douglas-fir stand did well under an uneven-aged system. Additionally, LMS provides a variety of output tables that requires students to be able to understand and compare TPA, basal area, SDI and RD and reinforces the need for understanding these terms and concepts.

Figure 3: The "Lego©" Stands as pure Douglas-fir and as ponderosa pine, visualized in SVS via LMS before thinning.



It is important simulation exercises are followed up with field exercises using real stands, because the field situation adds such complicating factors as slope, scale, species, distribution, defect occurrence and the limitations of a ground based viewpoint rather than an aerial one.

This approach can help teach growing space concepts to non-forestry students and works well in both individual and group settings. It was well received by my students who looked a little bewildered during the lecture about density and stocking concepts. Standard approaches to presenting this type of information were generally ineffective until students had gained some level of comprehension using these models. They clearly improved in their ability to develop well thought out strategies after application of these practical and relatively simple visualization tools.

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