

# DENSITY MANAGEMENT DIAGRAMS: Development and Theory

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**ABSTRACT.**—Density management diagrams are based on the  $-3/2$  power rule (or law) of self-thinning. The diagram relates changes of mean plant size to stand density using logarithmically transformed axes. This concept was first introduced into the North American forestry literature in the late 1970's for Monterey pine and Douglas-fir. The DMD is an age-independent average stand-level model and local variations are to be expected. The prime utility of the model is that it enables forest manager's to evaluate and compare various stand development scenarios quickly and precisely.

The diagram's developed for Ontario consist of a family of six models: four parallel density-dependent lines: maximum size-density (or upper self-thinning/full stocking line), mortality initiation (lower self-thinning) line, maximum stand production initiation line, crown closure line, top height isolines and quadratic mean diameter isolines. Site index curves can also be used in conjunction with the diagram to add a temporal component when interpreting the model.

The maximum size-density line defines the upper limit for any combination of mean size and stand density. In theory the slope of this line is  $-3/2$  and is assigned a relative density of 1.00. Mortality increases significantly for a stand once it transects the mortality initiation line (relative density = 0.55). Between these lines trees undergo the highest rate of density-dependent mortality and enter a prolonged self-thinning phase. This zone is referred as the Zone of Imminent Competition Mortality and stands are considered to be over-stocked in this region of the diagram.

Stands that lie between lines with relative densities of 0.55 and 0.40 lie within the Zone of Optimum Density Management (ZODM). Within this zone stands are optimally stocked, and the rate of stand production is at a maximum due to the high rate of current annual increment growth. The (approximate) crown closure line (relative density = 0.15) defines the boundary where stands have achieved crown closure. The zones below the mortality initiation line are considered to be understocked. The relative density values of 0.55, 0.40 and 0.15 are based on theory.

The DMD's developed for Ontario were constructed using four stand level variables: quadratic mean diameter, density, mean total tree volume, and top (or dominant) height. Of these, volume need not be determined to use the DMD, as it can be read directly from the diagram. Only two of the remaining three parameters are necessary to position a stand on the diagram. However, volume estimates should be used for comparative purposes only when planning management scenarios. For detailed growth and yield estimates a separate model should be used, where size (diameter) distributions within a stand are taken into account.

One of the accepted weakness of the DMD model is the linearity of the maximum size-density line. It is apparent that the size-density relationship is not straight when fitted to the entire range of data, but that it has a general concave form. Between the onset of self-thinning and the break-up of a stand, the slope of the size-density relationship can be regarded as being linear, and an approximate slope of  $-1.5$  is a good approximation. Within this range the DMD offers the greatest benefit to the forest manager, and the natural development of a stand and various thinning and final harvest scenarios can be evaluated with some confidence.

Without doubt, DMD's are regarded as one of the most useful tools available to the forester for making decisions about density manipulation of even-aged pure-species stands.

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