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Assessing Soil Water Resource Space: Days Until Dry (DUDC) Method

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Trees require high quality resources in correct proportions to perform best. Water, and soil volume which holds water, are critical to great tree growth. In trees, 80% of growth variability is due to water availability differences, and 85% of tree demand for water is related to a tree's evaporative environment and crown volume.

To better assess soil water resource space needed for trees, a set of calculations can be completed called the Coder Days Until Dry Containerized Soil Water Assessment (DUDC). Specific calculations use measurable values to determine soil volumes required, which are based primarily upon water availability and tree needs. Do not guess at tree water needs – calculate!

DUDC

This soil water assessment helps determine how many days without precipitation (or irrigation) under current site conditions can pass before a tree with a limited soil area can no longer extract water. The time period before a soil has no tree-usable water remaining is critical in preventing major tree damage.

The Coder "Days Until Dry" Containerized soil water assessment (DUDC) is targetted at in-ground and above ground containers, and sites where tree rooting space and soil resources are physically limited. This is only a basic estimate because each container or site will have unique attributes impacting water availability, and can not be accounted for within this simple calculation. The Coder Days Until Dry Containerized soil water assessment method is shown in Figure 1. This assessment can be completed in five (5) steps.

Five Steping

Step #1 is used to determine the crown volume of a tree. The larger the crown volume, the greater number of leaves, buds, and twigs, and the greater potential for water loss. Average crown diameter in feet squared is multiplied by crown height in feet. This value gives the volume of a square cross-sectional shaped crown. Trees are not ideally square shaped, so a reduction in volume is made by picking a shape factor for a tree crown from Figure 2. The shape factor multiplied by crown volume provides an estimate of crown volume for a tree in cubic feet. Figure 3.

Step #2 is used to determine effective crown surface area of a tree. Crown volume in cubic feet determined in Step #1 is divided by crown height in feet. The result is multiplied by an average leaf area index, here with an example value of four (4). A leaf area index is an approximation ratio of how many square feet of leaves are above each square foot of soil below, and depends upon tree age, species, and stress levels. Here a value of four for an average community tree is used. The result of Step #2 calculation is effective crown surface area of a tree in square feet.

Step #3 is used to determine daily water use of a tree. Effective crown surface area in square feet is multiplied by three atmospheric factors which impact tree water use: daily evaporation in feet per day (Figure 4); an evaporative pan factor (Figure 5); and, a heat load multiplier (Figures 6 & 7). The result of this calculation is the daily water use of a tree in cubic feet (ft^3/day). For comparisons, one cubic foot of water is approximately 7.5 gallons ($1ft^3$ = ~7.5 gallons). The daily water use of a tree determined here will be used in Step #5.

Step #4 determines soil water volume present in cubic feet. Because this assessment is designed for general container estimates, it is critical an accurate value for container soil volume be used. Container soil volume in cubic feet is divided by total soil water as a decimal percent (d%) for the soil texture used, as given in Figure 8. This value is then multiplied by one minus the soil water limit (in soil with the same texture) as a decimal percent (d%), also given in Figure 8. This limit is an approximation of the permanent wilting point for a soil.

Step #5 determines the number of days, under similar tree and site conditions, a soil volume can sustain water needs of a tree. Note there is no "grace" period of time included. If no irrigation or precipitation are added to soil water resources, a tree will be damaged or killed due to lack of water. Irrigation can be timed to always be applied before a soil is dry.

Conclusions

It is important tree health professionals better quantify soil volumes and surface areas when planning and installing hardscape surfaces and structures for a landscape which will contain trees. Trees must have adequate soil space and water for good performance.

Citation:

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Step #1: Determine crown volume.

[crown diameter (ft)]^2 **X** crown height (ft) **X** shape factor (value) [FIGURE 2] **=** crown volume (ft^3)

Step #2: Determine effective crown surface area.

[crown volume (ft^3) / crown height (ft)] **X** 4 (LAI) leaf area index **=** effective crown surface area (ft^2)

Step #3: Determine daily tree water use.

effective crown surface area (ft^2) **X** daily water evaporation (ft / day) [FIGURE 4] **X** pan factor (value) [FIGURE 5] **X** heat load (multiplier) [FIGURE 6 & 7] **=**

daily tree water use (ft^3 / day) *NOTE: 1 ft^3 water = ~7.5 gallons*

Step #4: Determine soil water volume.

[container soil volume (ft^3) / total soil water (d%) [FIGURE 8]] **X** [**1 -** soil water limit (d%) [FIGURE 8]] **=** soil water volume (ft^3)

Step #5: Determine days until the soil resource area is dry.

soil water volume (ft^3) / daily tree water use from Step 3 (ft^3 / day) **=** days until dry

Figure 1: Coder "Days Until Dry" Containerized Soil Water Assessment method (DUDC).

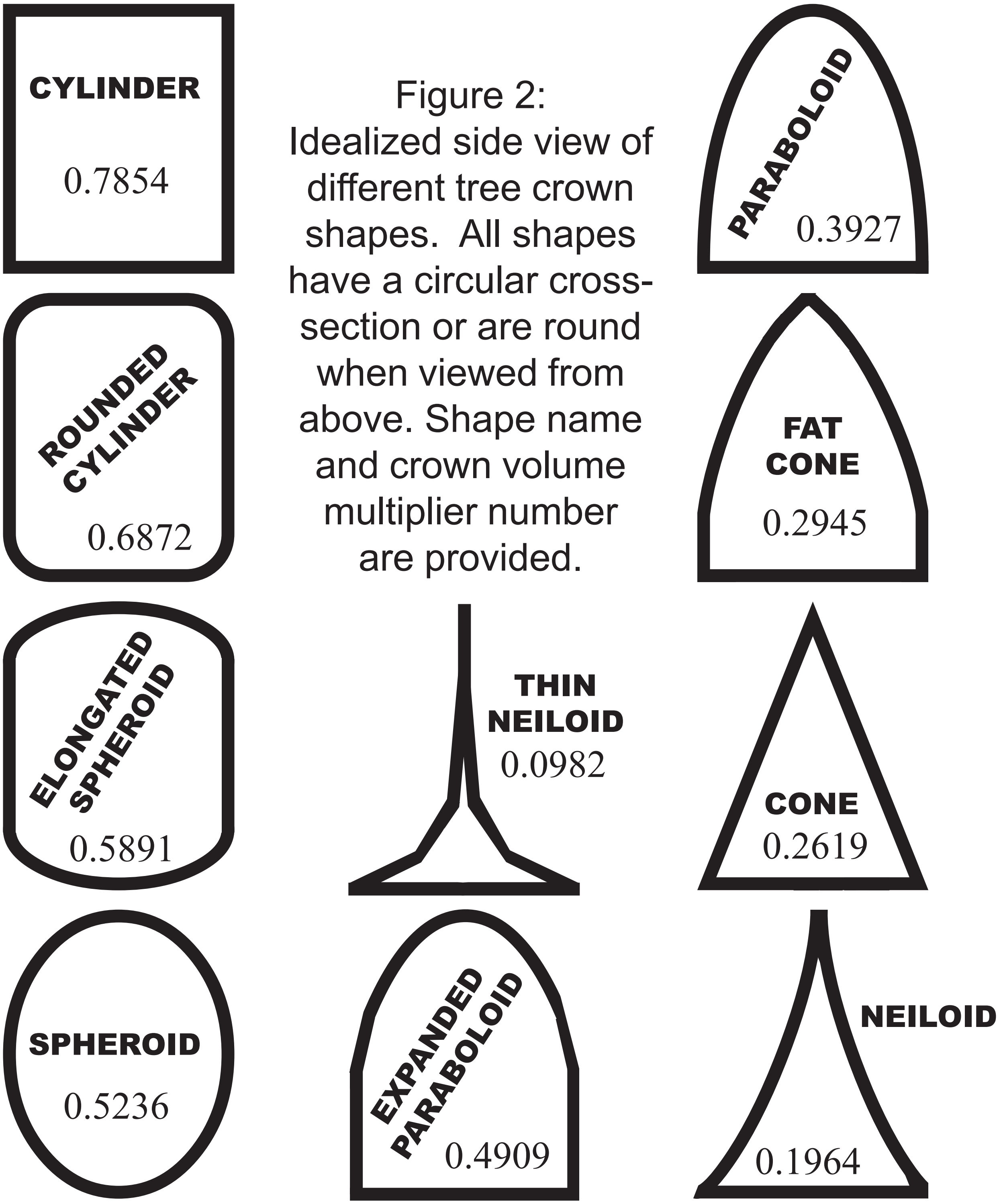

Figure 2:
Idealized side view of different tree crown shapes. All shapes have a circular cross-section or are round when viewed from above. Shape name and crown volume multiplier number are provided.

shape value	shape formula	shape name
8/8 (1.0)	(Crown Diameter)^2 x (Crown Height) x (0.7854)	CYLINDER
7/8 (0.875)	(Crown Diameter)^2 x (Crown Height) x (0.6872)	ROUNDED CYLINDER
3/4 (0.75)	(Crown Diameter)^2 x (Crown Height) x (0.5891)	ELONGATED SPHEROID
2/3 (0.667)	(Crown Diameter)^2 x (Crown Height) x (0.5236)	SPHEROID
5/8 (0.625)	(Crown Diameter)^2 x (Crown Height) x (0.4909)	EXPANDED PARABOLOID
1/2 (0.5)	(Crown Diameter)^2 x (Crown Height) x (0.3927)	PARABOLOID
3/8 (0.375)	(Crown Diameter)^2 x (Crown Height) x (0.2945)	FAT CONE
1/3 (0.333)	(Crown Diameter)^2 x (Crown Height) x (0.2619)	CONE
1/4 (0.25)	(Crown Diameter)^2 x (Crown Height) x (0.1964)	NEILOID
1/8 (0.125)	(Crown Diameter)^2 x (Crown Height) x (0.0982)	THIN NEILOID

Figure 3: Tree crown volume estimates for different crown shapes. Shape formula for these cylindrically based crown shape models range from a multiplier of 0.7854 for an ideal cylinder, to 0.0982 for a thin neiloid crown shape. Crown shape formula use crown diameter and crown height measures in feet to calculate crown volumes in cubic feet. Idealized crown shape names are visualized based upon solid geometric figures.

Note tree crown shape factors with multiplier values between 0.999 and 0.786 have a cylindrical appearing side view but would not have a circular cross-section. A multiplier value of 1.00 would be square in cross-section. Tree crown shape factors or multipliers greater than 0.785 are not shown.

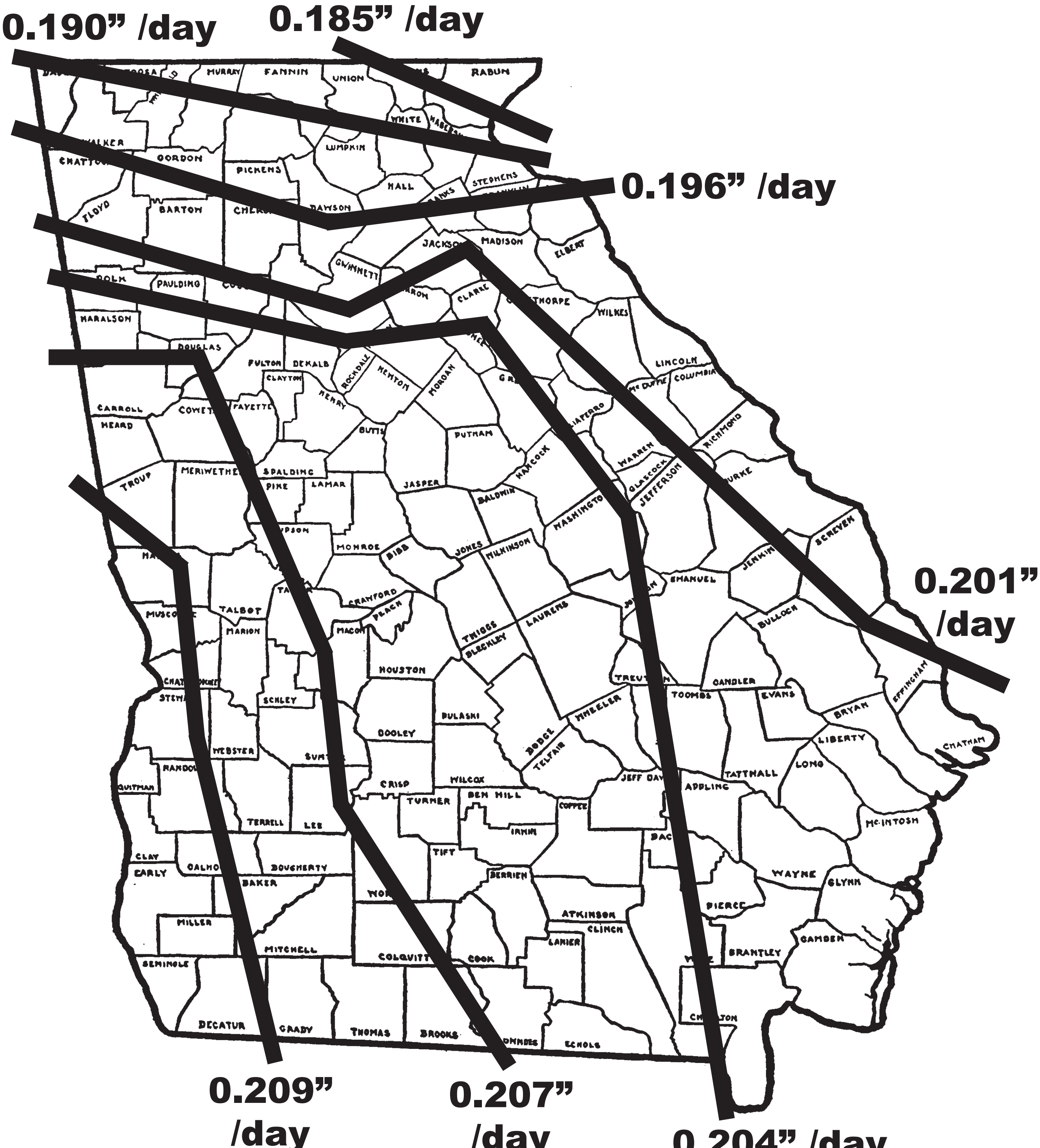

Figure 4: An example pan evaporation map from Georgia.

This map shows historic average daily pan evaporation during the growing season (May through October) in inches per day.

Divide by 12 to calculate feet per day.

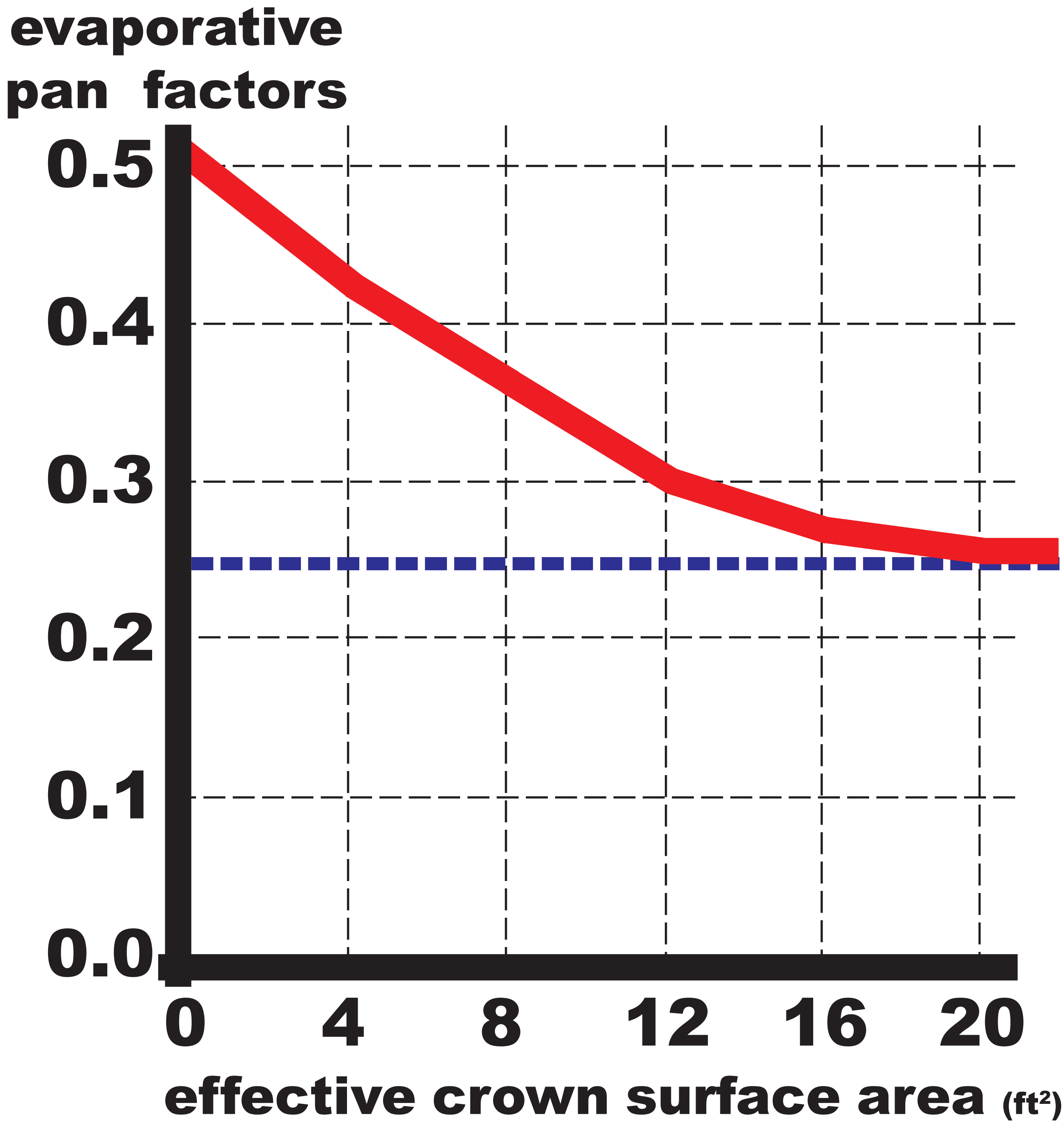

Figure 5: Ratio of tree transpiration to pan evaporation (pan factor or pan coefficient). Pan factors are not less than 0.25 for trees with larger than 20 ft^2 of effective crown surface area. (after Lindsey & Bassuk, 1992)

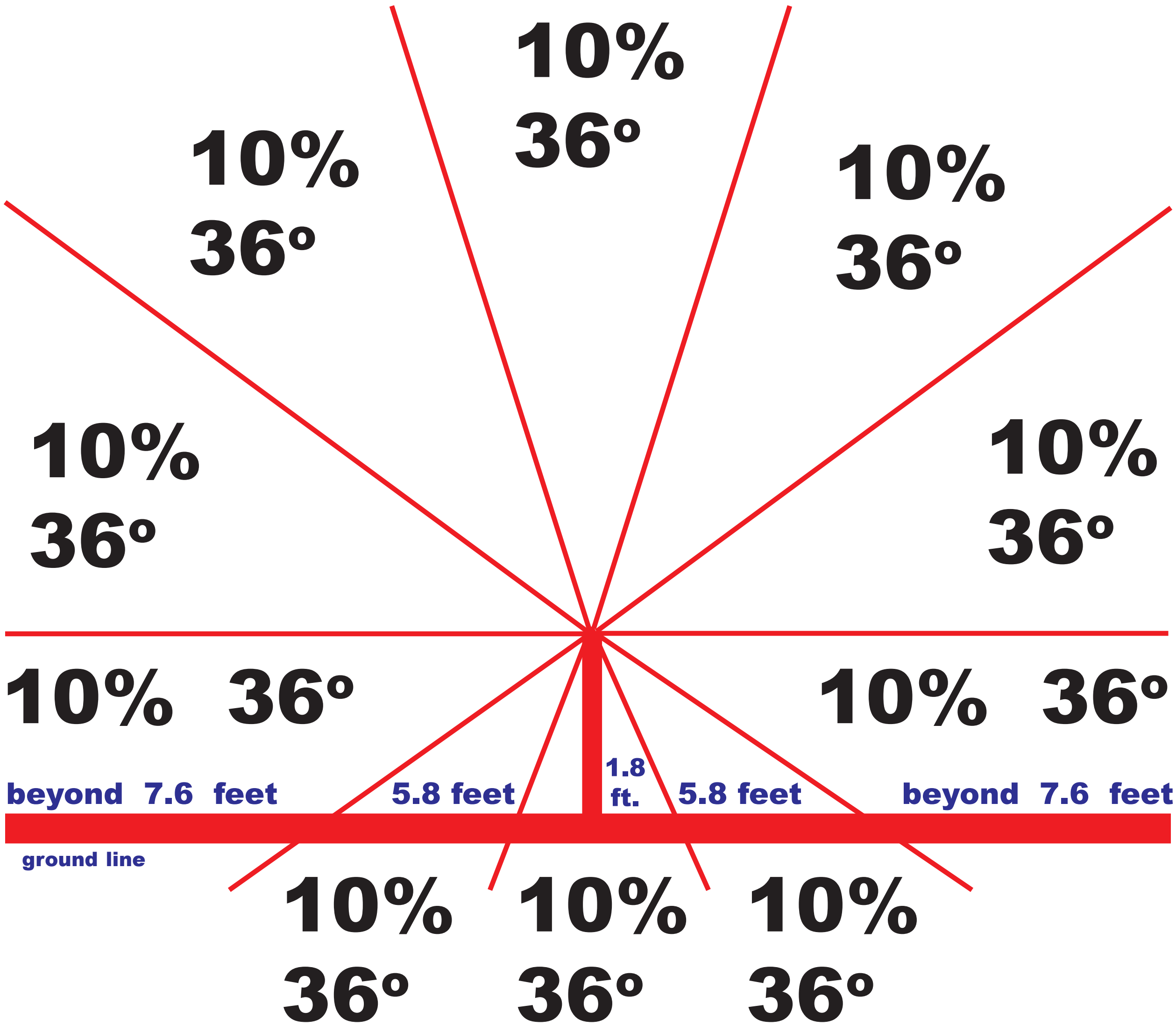

Figure 6: Diagram showing how heat loading can be estimated on a site using the Coder Heat Load Viewfactor containing ten equal (36°) observation angles.

viewfactor percent of non-evaporative, dense surfaces facing a site	heat load multiplier
100%	3.0
90%	2.7
80%	2.4
70%	2.1
60%	1.9
50%	1.7
40%	1.5
30%	1.3
20%	1.2
10%	1.1
0%	1.0

Figure 7: Coder Heat Load Viewfactor multiplier values for various non-evaporative, dense surface viewfactors (nearest 10% class) on a site. Use heat load multipliers to increase water use values for trees.

soil texture	total soil water (d%)	soil water limit (d%)
clay	.39	.23
clay loam	.40	.20
silt loam	.39	.17
loam	.34	.14
sandy loam	.22	.09
sand	.10	.04

Figure 8: Total soil water and soil water limit (~ permanent wilting point) for various soil textures. Values given in decimal percents (d%).