Sustainable Tree Systems:
Multi-Generational Success

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generations time-frame

for benefits / values

TREE SUSTAINABILITY

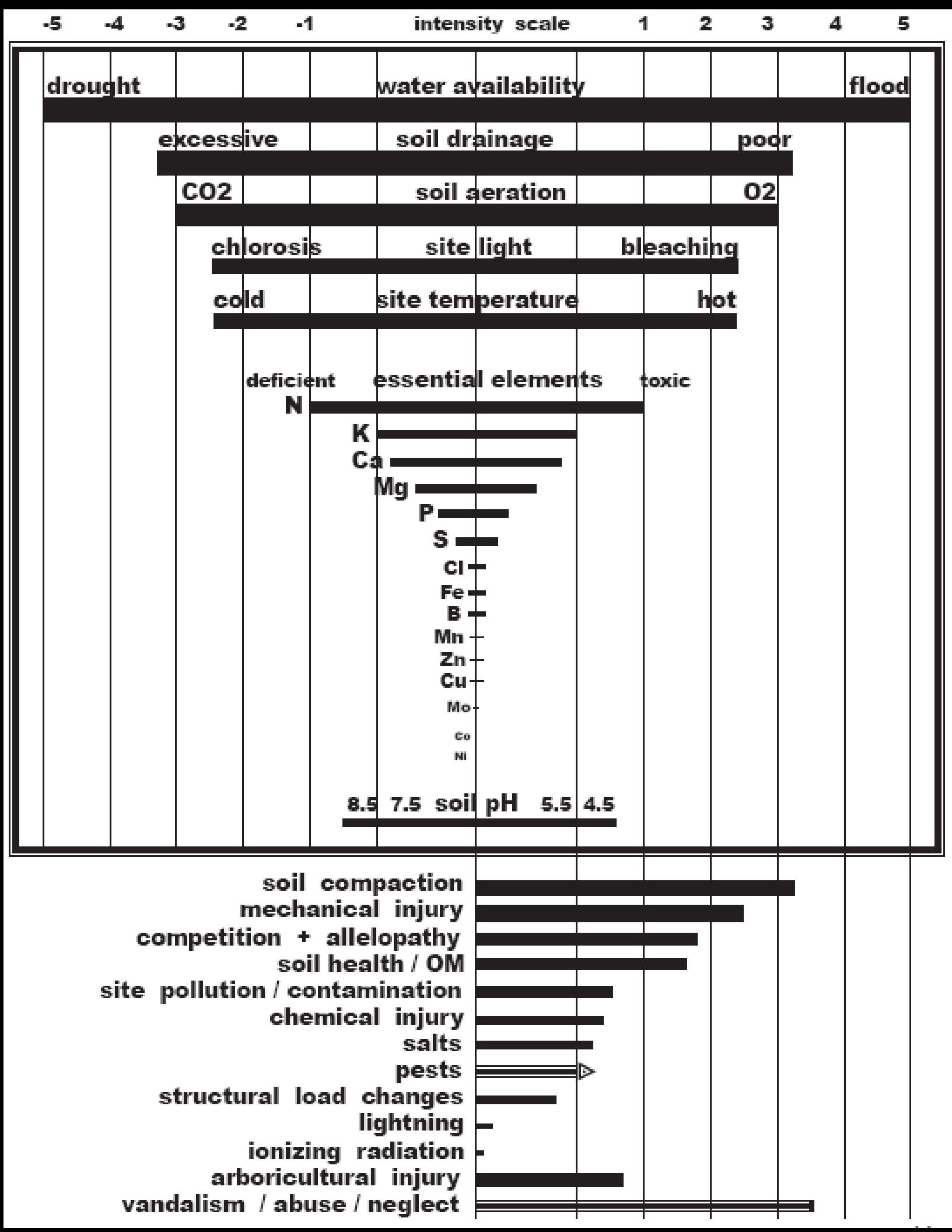
NOT maintaining what you have !

(not a museum)

make better to survive !

make MUCH BETTER to thrive !

(thermodynamics)


-5
-4
-3
-2
-1
intensity scale
1
2
3
4
5
drought
water availability
flood
excessive
soil drainage
poor
CO2
soil aeration
O2
chlorosis
site light
bleaching
cold
site temperature
hot
deficient
essential elements
toxic
N
K
Ca
Mg
P
S
Cl
Fe
B
Mn
Zn
Cu
Mo
Co
Ni
8.5
7.5
soil pH
5.5
4.5
soil compaction
mechanical injury
competition + allelopathy
soil health / OM
site pollution / contamination
chemical injury
salts
pests
structural load changes
lightning
ionizing radiation
arboricultural injury
vandalism / abuse / neglect

Sustainable Trees

examine how trees survive & thrive

(things we can adjust!)

SUSTAINABLE TREES

Major changes !

1. Ecologically Viable Space
2. Quantify Water Availability

3. Soil Aeration & Drainage
4. Soil Compaction

5. Light Impacts & Heat Load
6. Structural Architecture

7. Injury & Damage
8. Soil Resource Enrichment

Ecologically Viable Space

TREE + SITE

=

1 ecological pixel

tree health care resolution eco-pixel level

ECOPLEX

matrix of hardscapes & eco-pixels

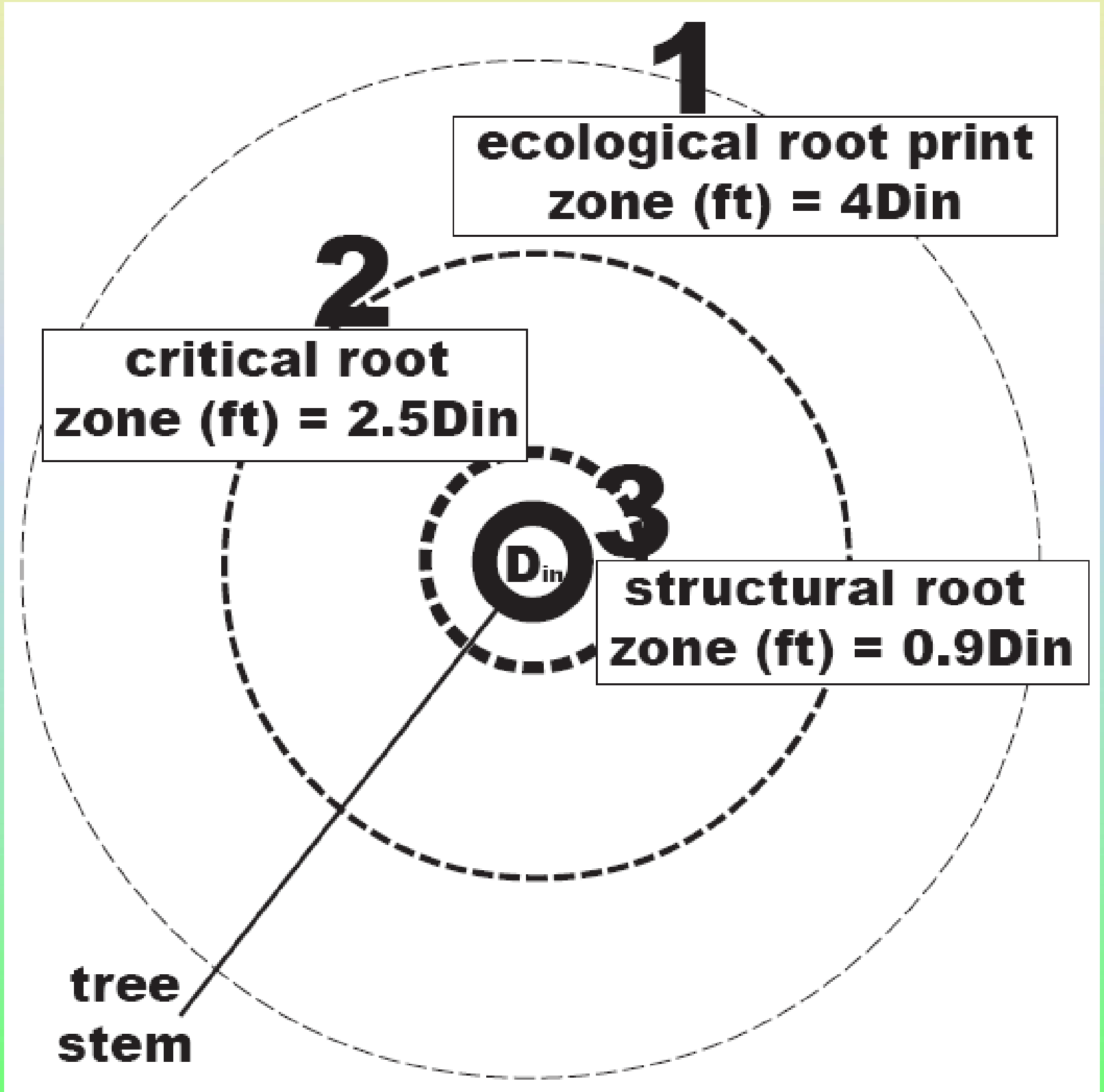
HARDSCAPES

impervious dense
heat absorbing
heat radiating
non-evaporative
non-gas pervious

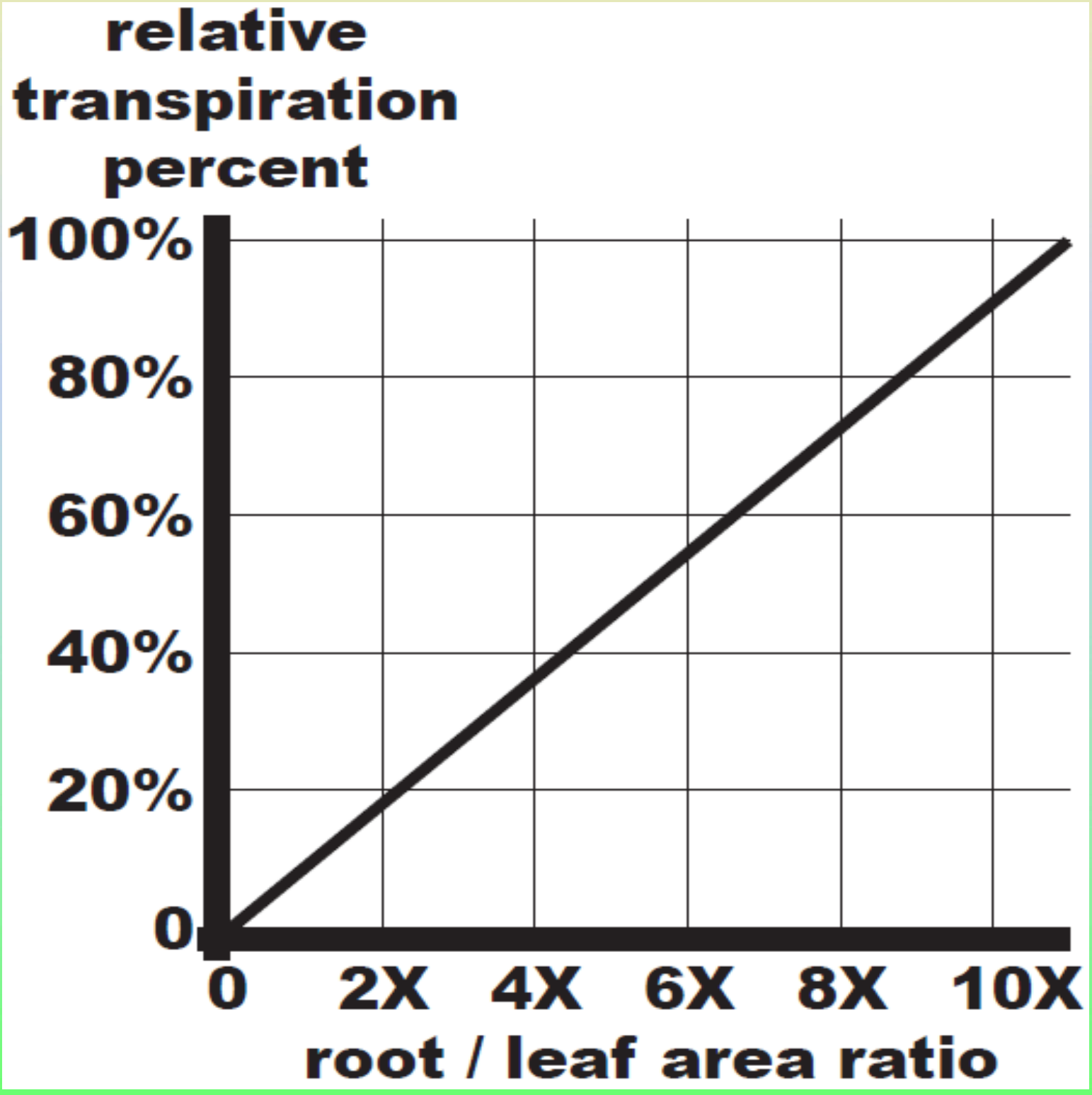
isolate hardscapes with eco-pixels

no hardscape interconnections

ROOTING AREAS AROUND TREE



More Root Per Leaf



TREE

mirror

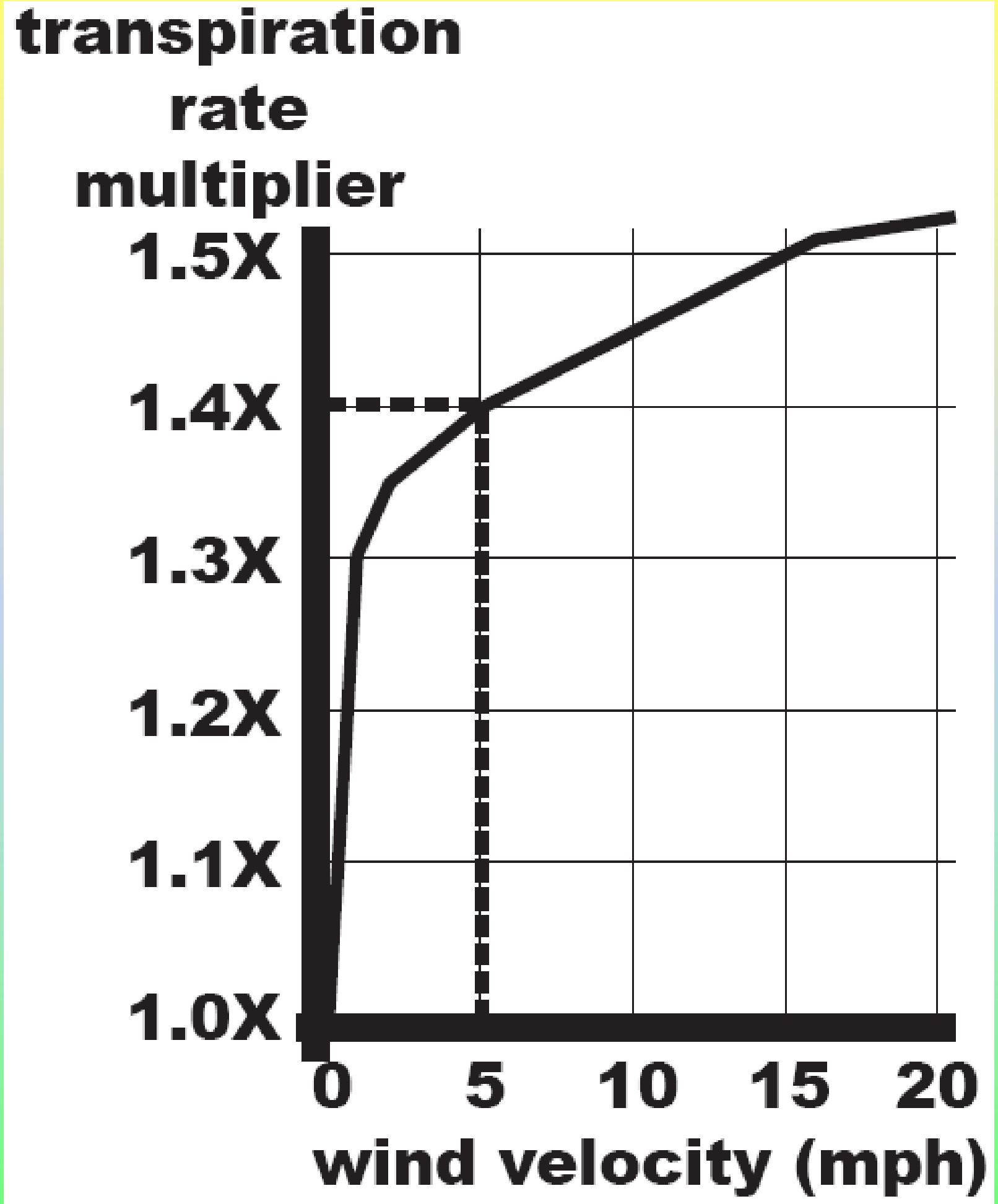
of site

quality

Quantify Water Availability

Dryness of Air

relative humidity (%)	air temperature (F°)				
	50°	60°	70°	80°	90°
100	0	0	0	0	0
99	-13	-13	-14	-14	-14
98	-26	-27	-27	-28	-28
95	-67	-68	-70	-71	-72
90	-138	-140	-143	-145	-148
70	-466	-475	-483	-492	-500
50	-905	-922	-939	-956	-971
30	-1,572	-1,602	-1,631	-1,660	-1.687
10	-3,006	-3,064	-3,119	-3,175	-3,226


transpiration
rate
multiplier
1.5X
1.4X
1.3X
1.2X
1.1X
1.0X
0
5
10
15
20
wind velocity (mph)

HOW MUCH TREE WATER USE ?

DAYS UNTIL DRY

Step #1: Determine crown volume.

$$\left[\text{crown diameter (ft)}\right]^2 \times \text{crown height (ft)} \times \text{shape factor (value)} = \text{crown volume (ft}^3\text{)}$$

Step #2: Determine effective crown surface area.

$$\left[\text{crown volume (ft}^3\text{)} \div \text{crown height (ft)}\right] \times 5\ \text{(LAI) leaf area index} = \text{effective crown surface area (ft}^2\text{)}$$

Step #3: Determine daily tree water use.

$$\text{effective crown surface area (ft}^2\text{)} \times \text{daily water evaporation (ft / day)} \times \text{pan factor (value)} \times \text{heat load (multiplier)} =$$

daily tree water use (ft³ / day)

NOTE: 1 ft³ water = ~7.5 gallons

Step #4: Determine soil water volume.

$$\left[\text{container soil volume (ft}^3\text{)} \div \text{total soil water (d\%)}\right] \times \left[1 - \text{soil water limit (d\%)}\right] = \text{soil water volume (ft}^3\text{)}$$

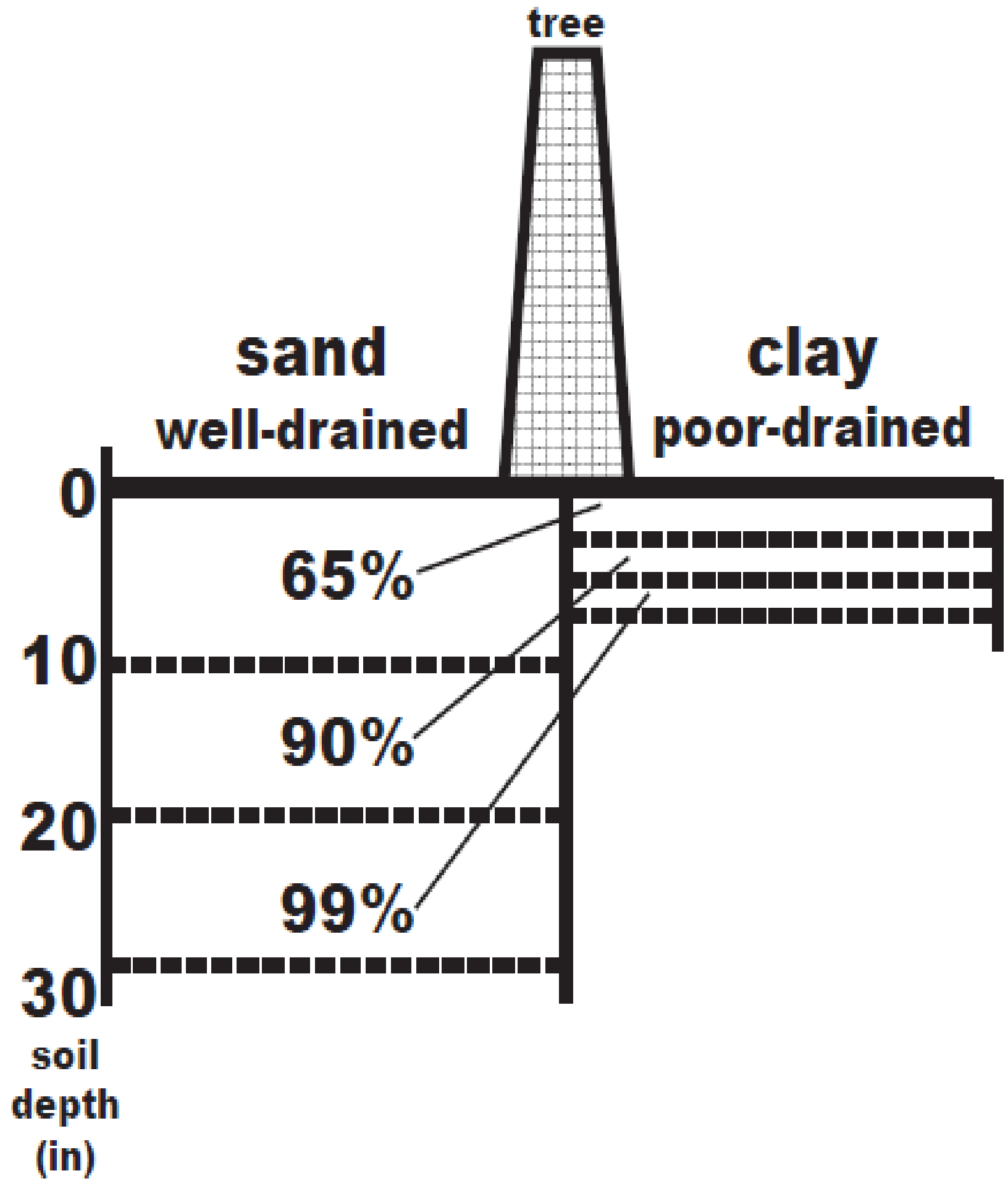
Step #5: Determine days until the soil resource area is dry.

$$\text{soil water volume (ft}^3\text{)} \div \text{daily tree water use from Step 3 (ft}^3\text{ / day)} = \text{days until dry}$$

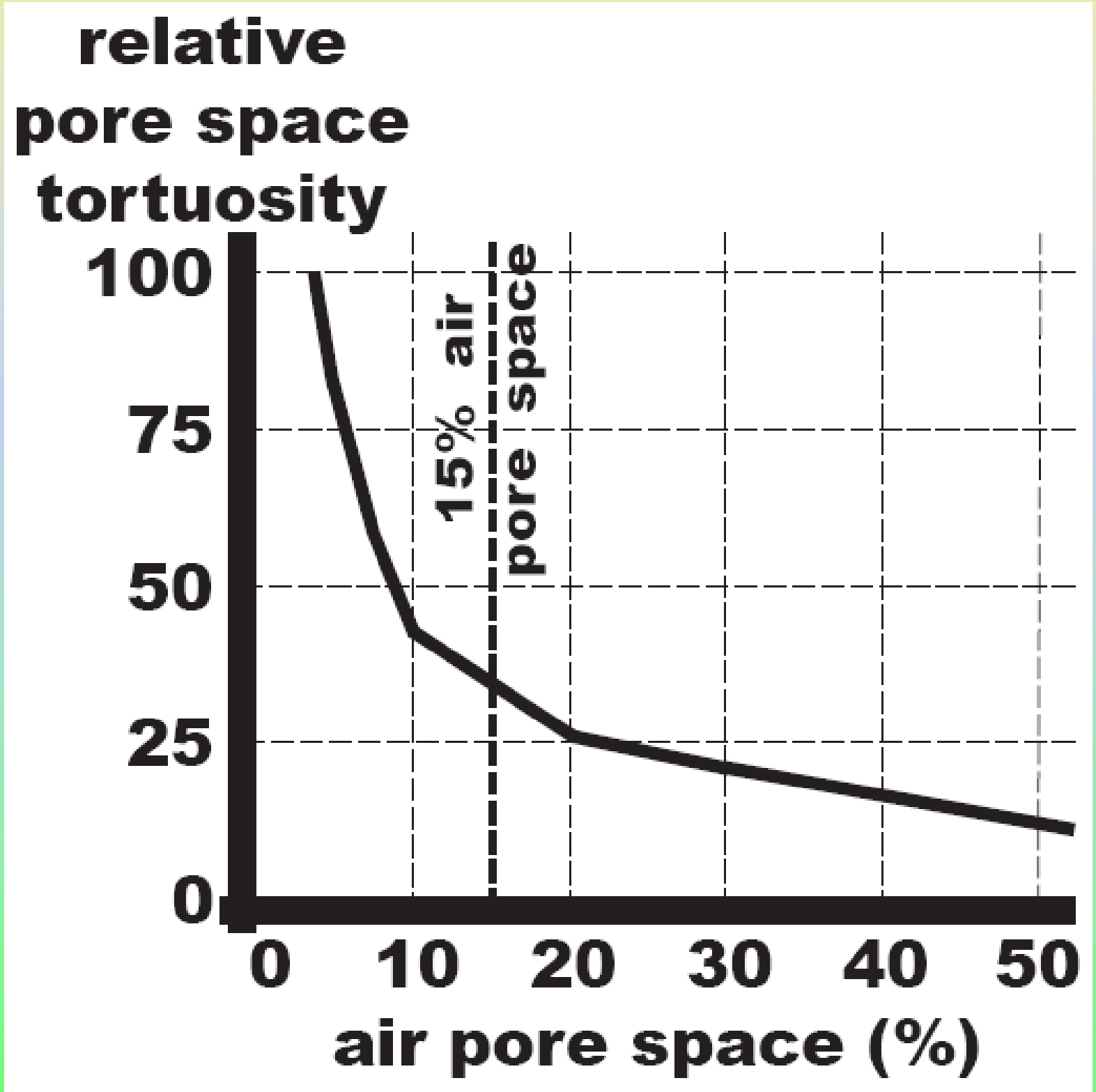
AERATION / DRAINAGE

soil pore interconnections & constraints

TREE ROOT LOCATION



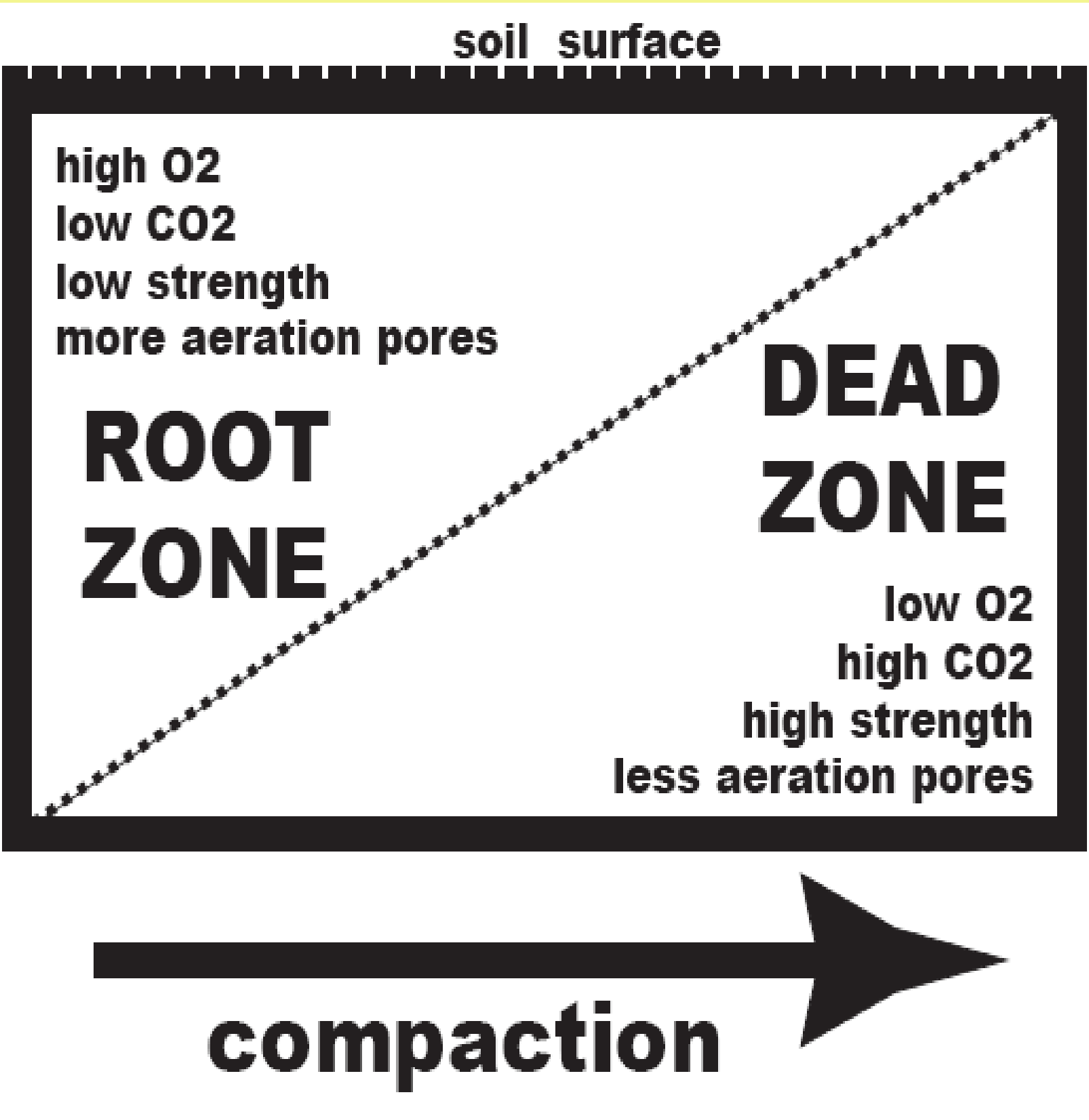
<15% AIR PORE ROOT GROWTH LIMIT

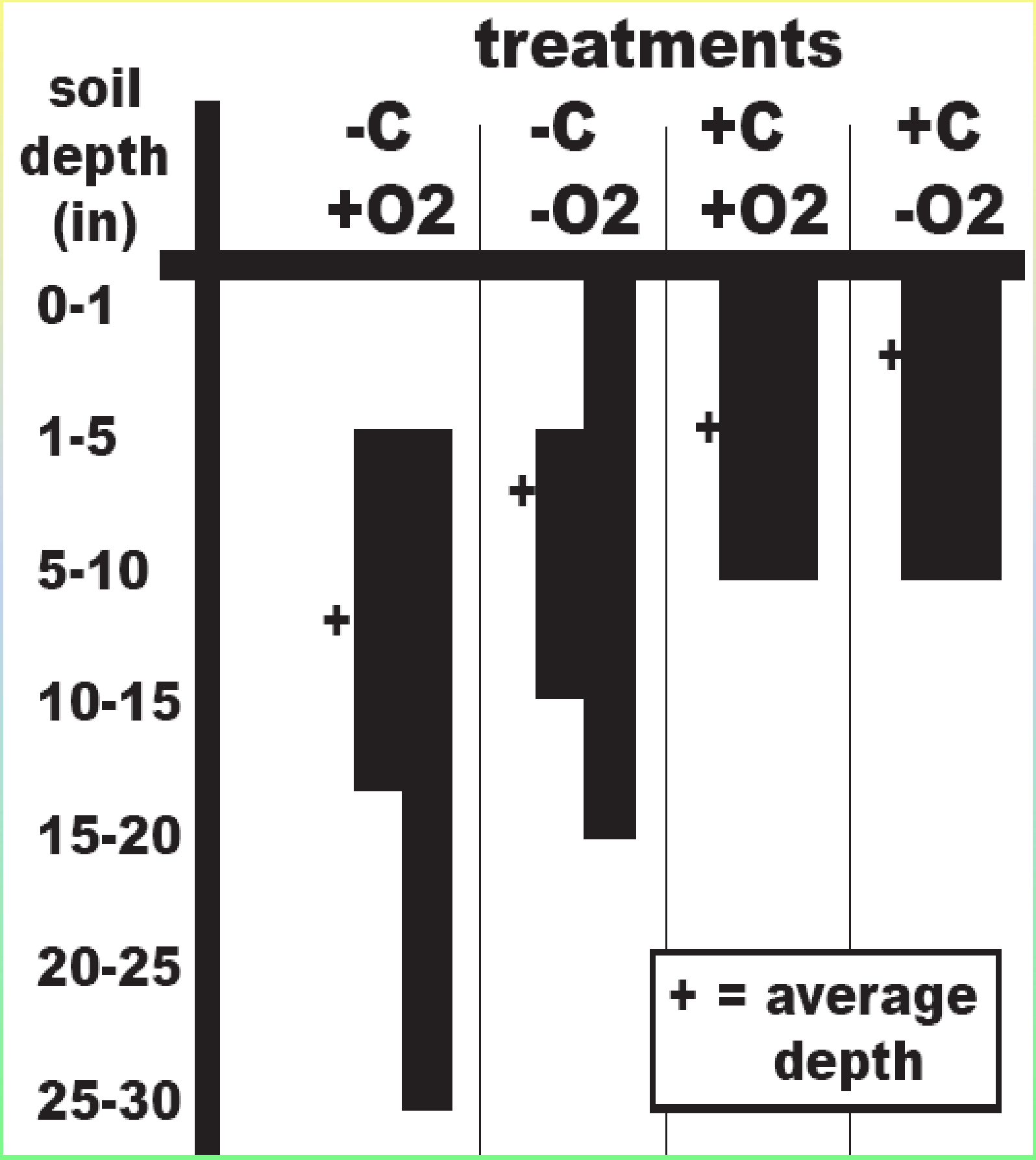


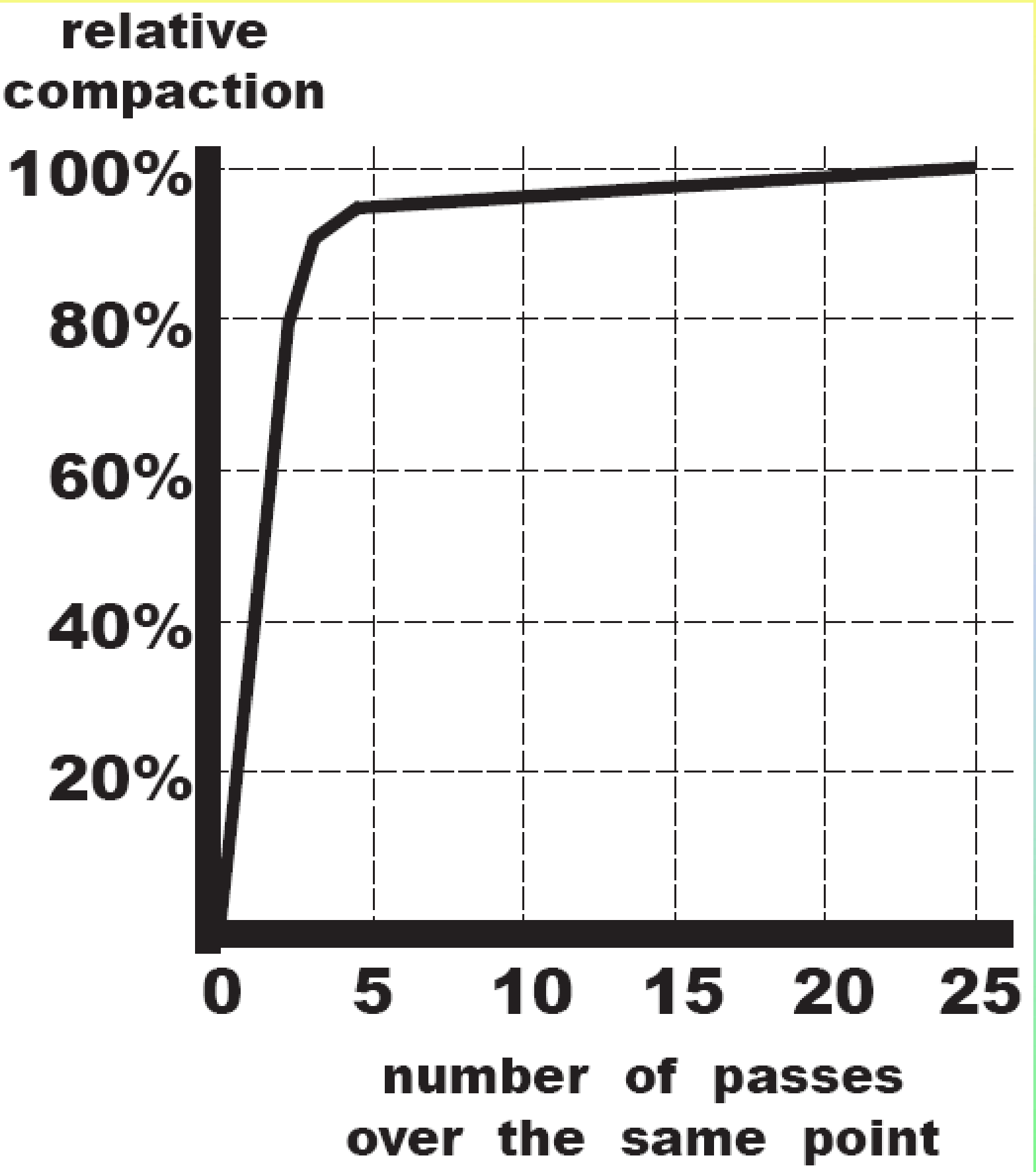
AIR PORE LIMITS BY SOIL TEXTURE

soil texture	root-limiting air pore %
sand	24 %
fine sand	21
sandy loam	19
fine sandy loam	15
	major limit
loam	14
silt loam	17
clay loam	11
clay	13

SOIL COMPACTION


soil surface
high O2
low CO2
low strength
more aeration pores
ROOT ZONE
DEAD ZONE
low O2
high CO2
high strength
less aeration pores
compaction


treatments
soil depth (in)
-C +O2
-C -O2
+C +O2
+C -O2
0-1
1-5
5-10
10-15
15-20
20-25
25-30
+ = average depth


relative
compaction
100%
80%
60%
40%
20%
0
5
10
15
20
25
number of passes
over the same point

soil texture	root-limiting bulk density (g/cc)	
sand	1.8	
fine sand	1.75	major limit
sandy loam	1.7	
fine sandy loam	1.65	
loam	1.55	
silt loam	1.45	
clay loam	1.5	
clay	1.4	

ENERGY Impacts

Energy

Sustaining Trees

(% of full sunlight)

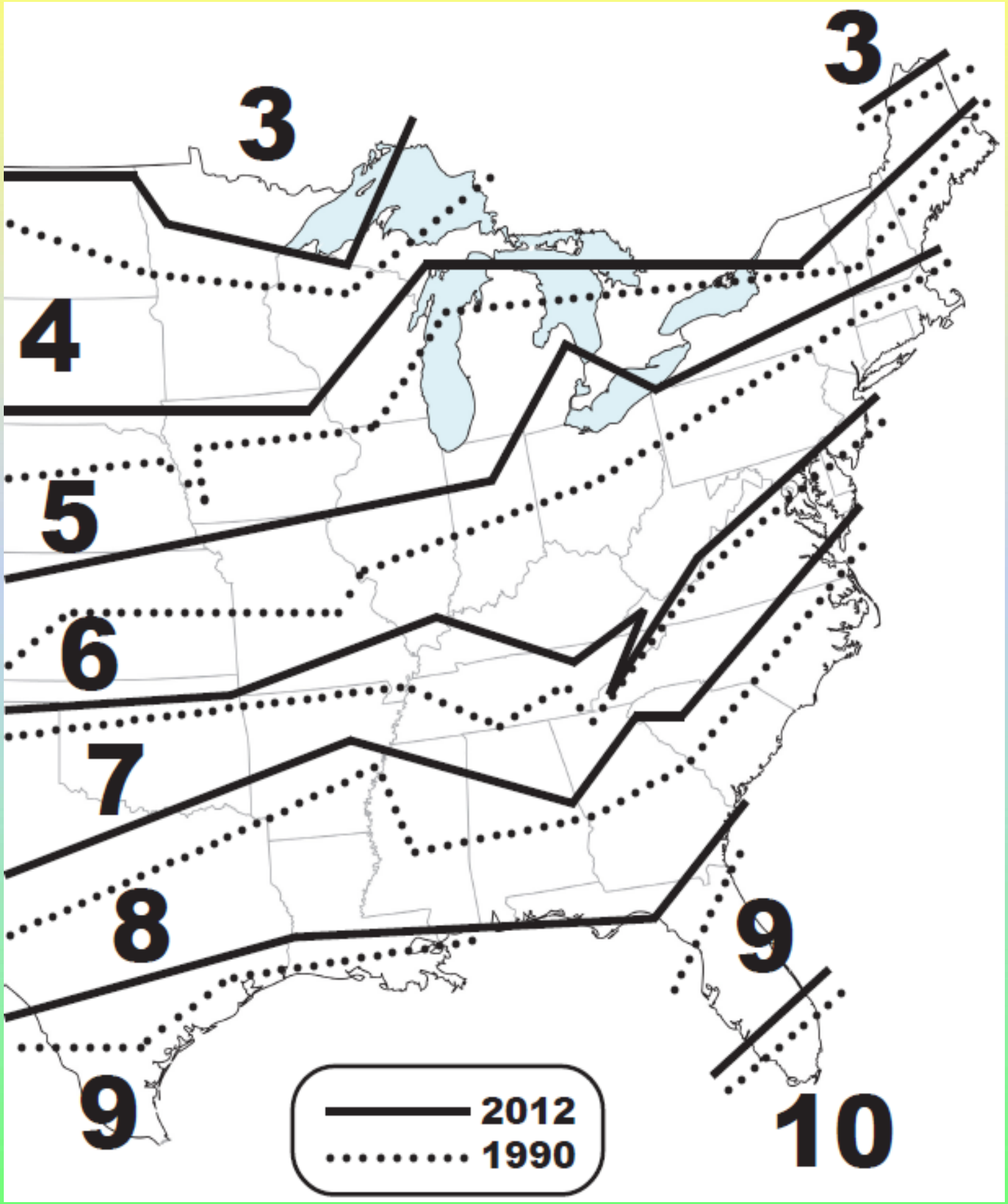
>90% sun

60% to 90% shade

30% to 60% marginal

<30% decline & death

HARDINESS ZONE CHANGES

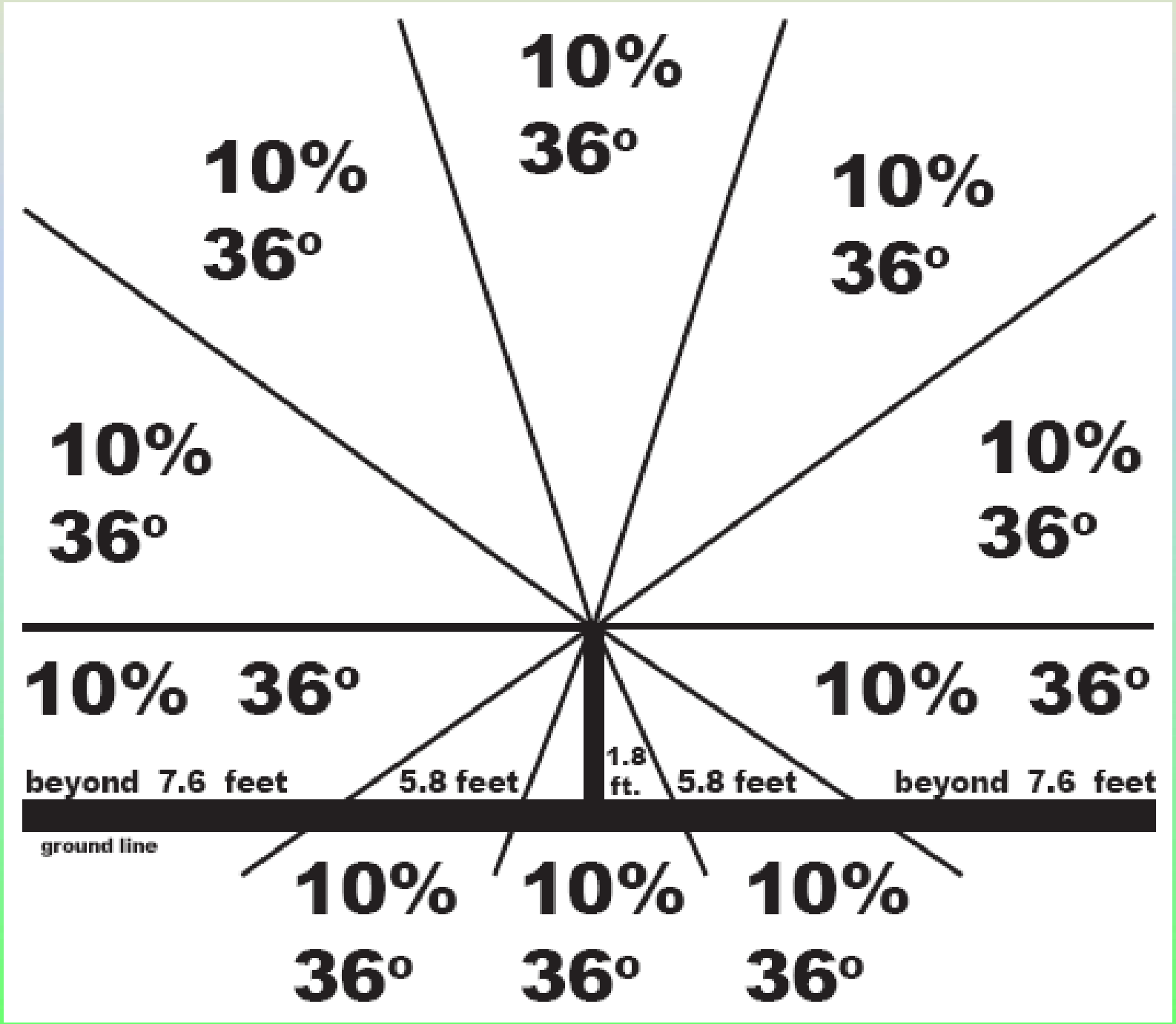


DOUBLING EFFECT OF HEAT ON WATER & CHO USE

temperature	multiplier effect
40°F	1X
58°F	2X
76°F	4X
94°F	8X
112°F	16X
130°F	32X

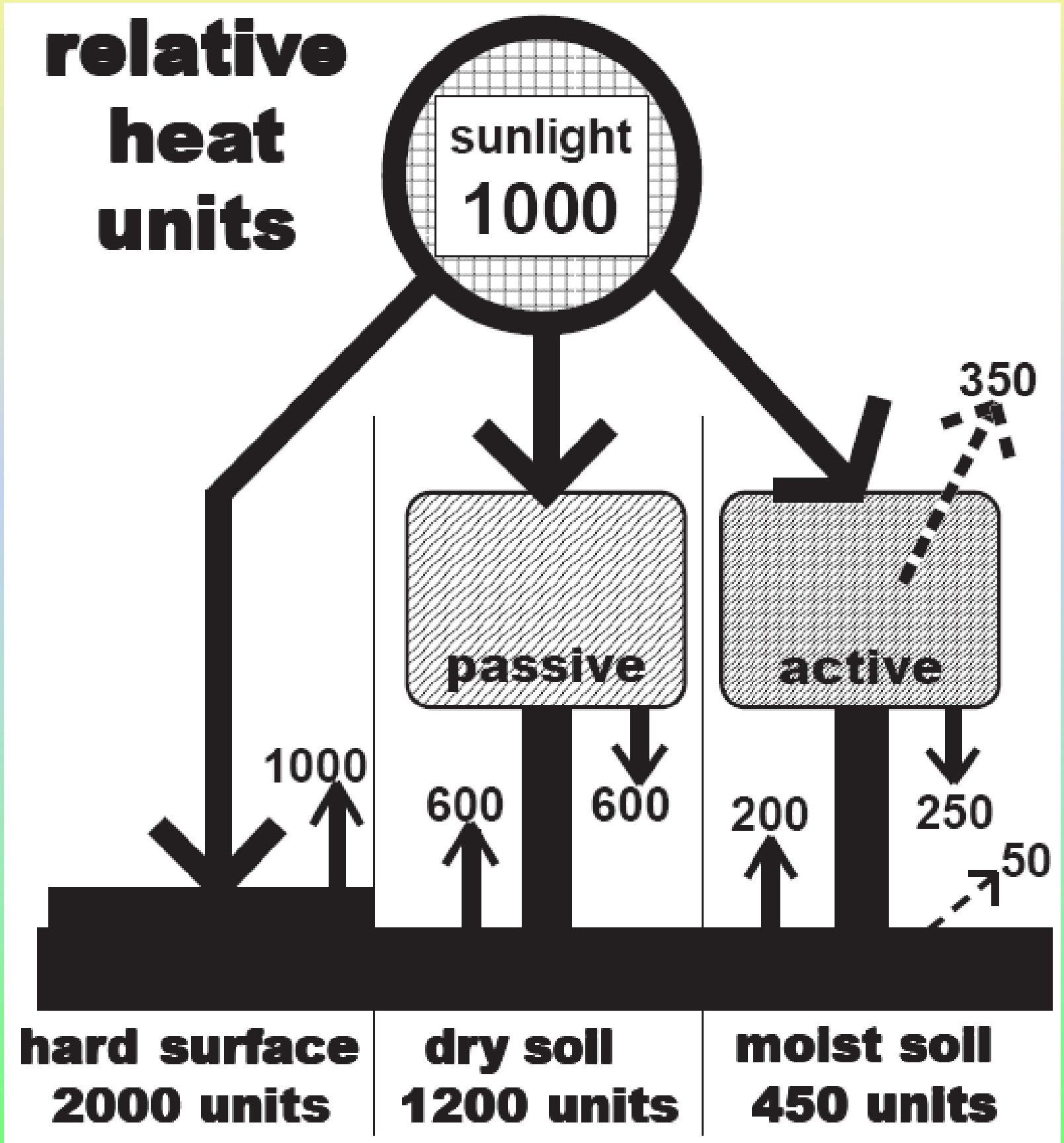
ESTIMATING HEAT LOADING:

COUNT HARDSCAPE VIEWS



viewfactor (%) of non-evaporative, dense, heat loading surfaces facing tree / site	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

HEAT LOADS:
ACTIVE & PASSIVE SHADE



SHADE STRUCTURES

(in addition to trees)

trellis / arbors
walls / gazebos
pergolas

+ wood / low density materials

+ block advected heat

berms & walls

+ active shade

(plants !) shaded low vines

shaded ground covers

pleach / espalier / pollard

SUSTAINABLE ECOPLEX GOALS

=

shade >67% of hardscapes with active shade

+

shade >25% of hardscapes with passive shade

Prevent / Minimize Injury & Damage

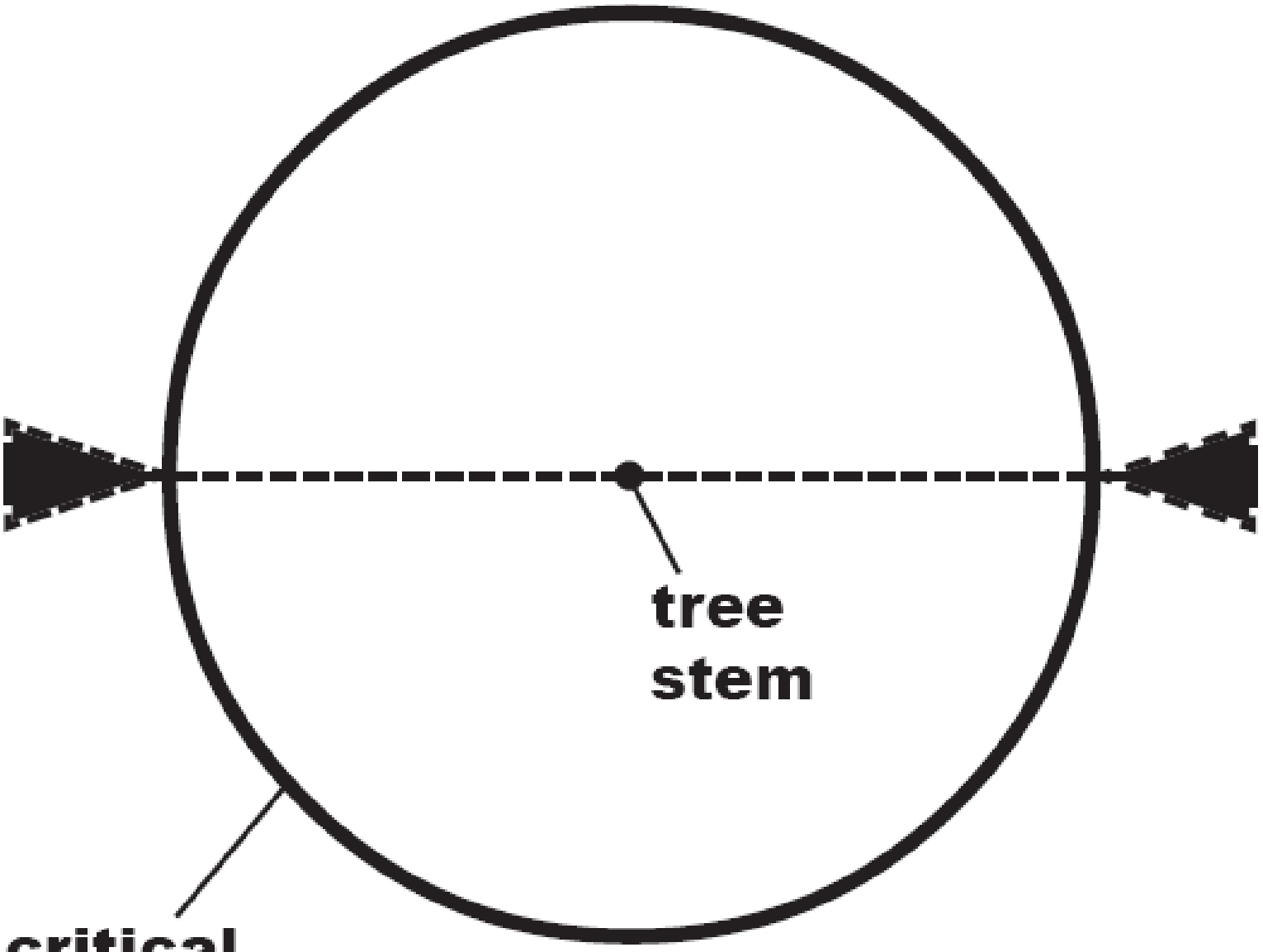
TREE MASS CONTROL

limit reach & extent
(pruning / reduction)

limit emergent height
(pruning / reduction)

limit excessive movement
(cable / brace / prop)

hold weakened confluences & creep
(cable / brace / prop)



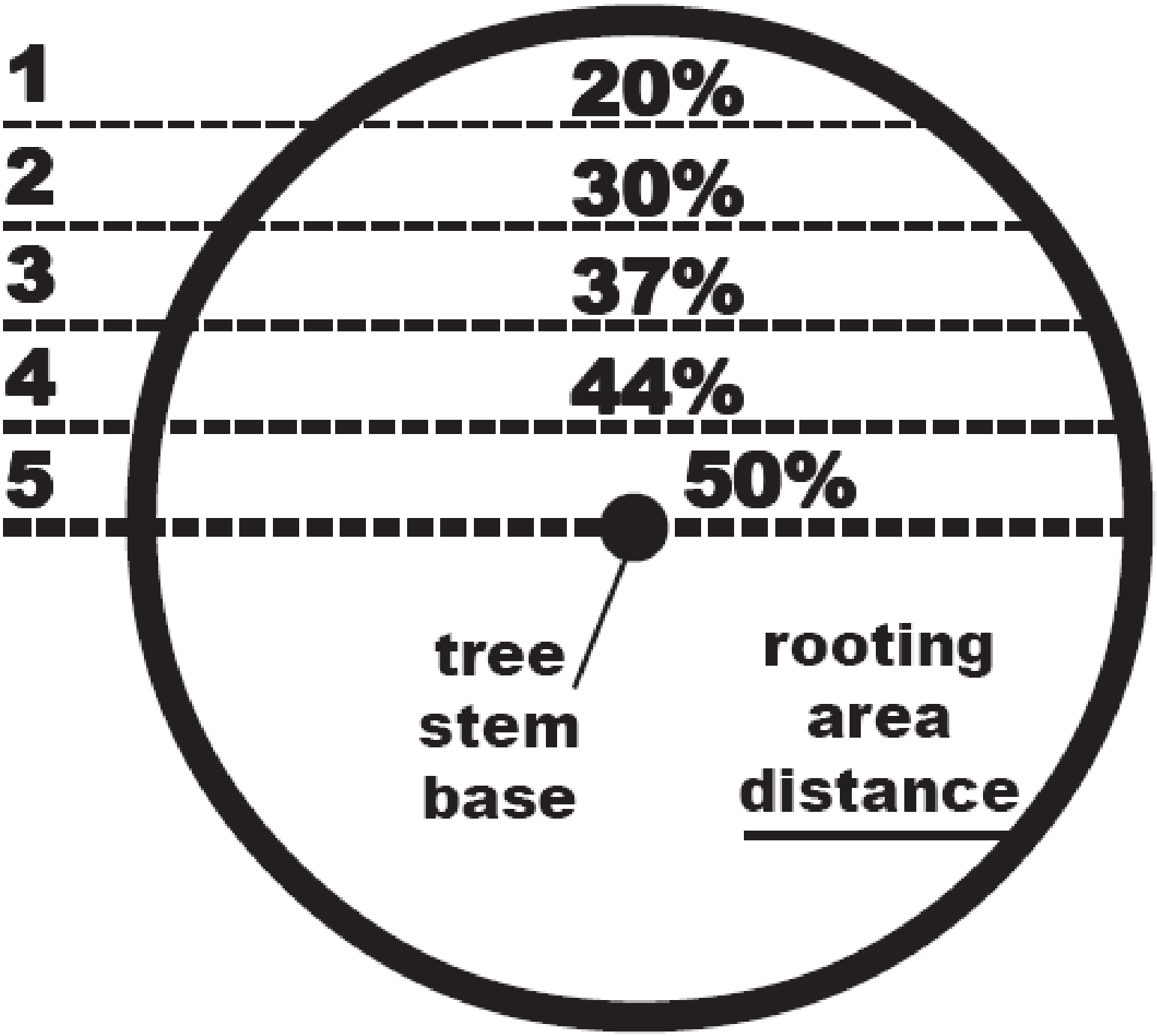
2.5 X DIAMETER OF TREE (DBH in inches)

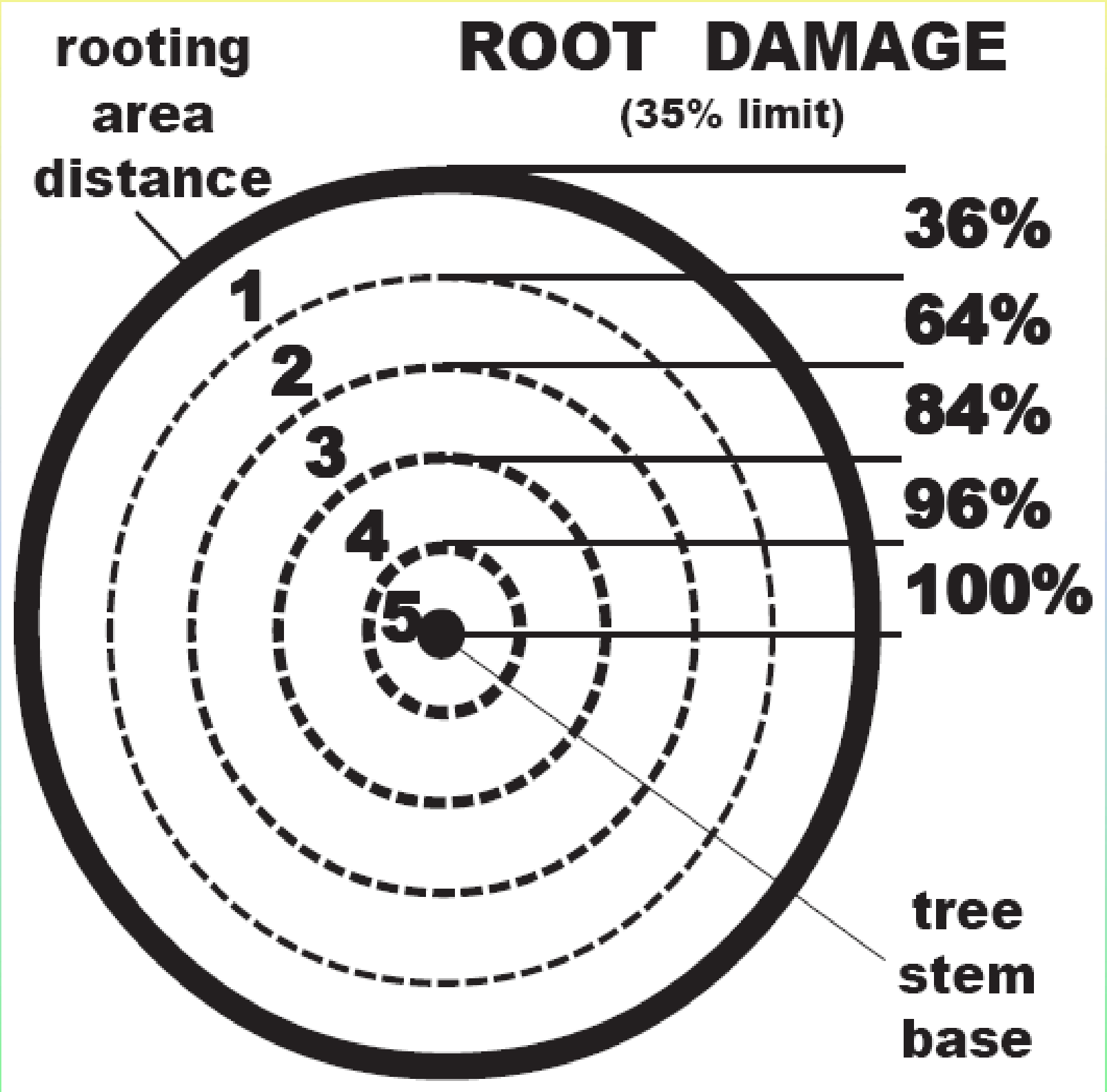
=

CRITICAL ROOTING AREA DIAMETER (in feet)

ROOT DAMAGE

(35% limit)




ROOT DAMAGE
(35% limit)
rooting
area
distance
1
2
3
4
5
36%
64%
84%
96%
100%
tree
stem
base

DEFEND / CONSERVE PERIDERM !

NO

cuts, abrasions,
burns (rope or fire),
bruising, or scrapes

SUSTAINABLE TREES

Proximity / Access

KEEP AWAY

KEEP OFF

KEEP OUT

(defend resource space !)

establish

DEFENSIBLE SPACE

separate combatants
(people, hardscapes,
animals, & ***interfering plants***)

fence / guards / shield

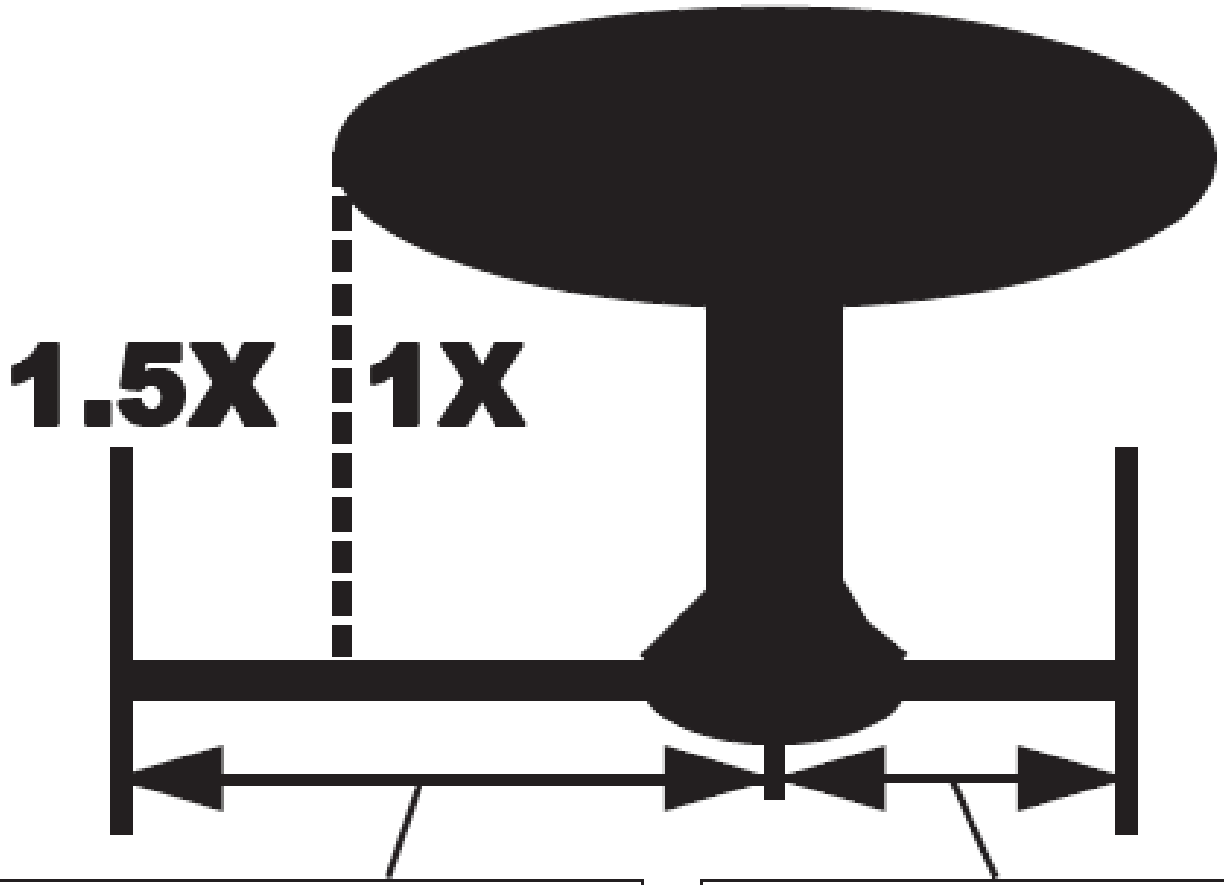
open soil surface
protected with mulch

keep machines away

Soil Resource Enrichment

(N - OM - Mulch)

USE SMALLER AREA OF TWO



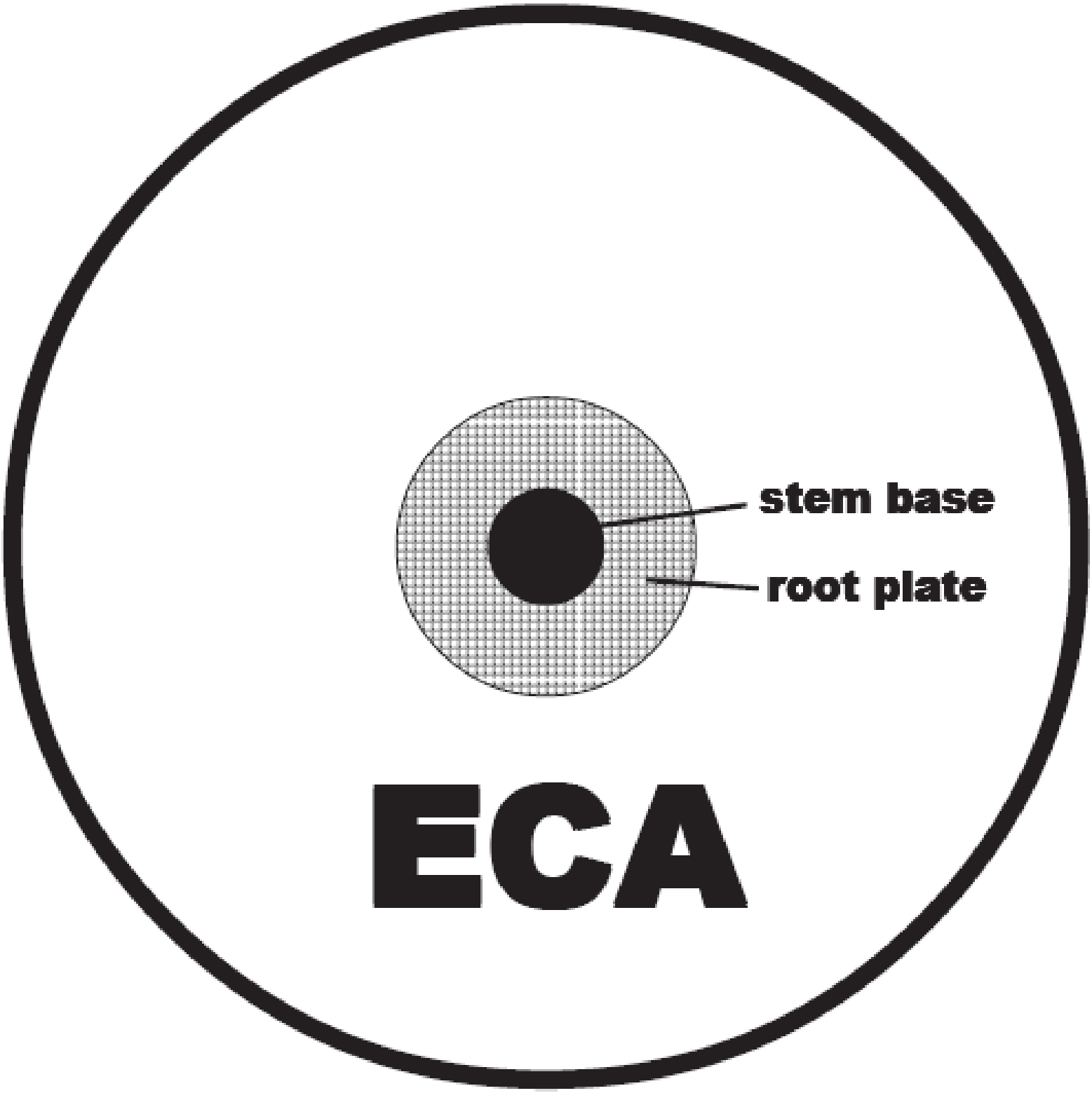
ECA

(area In ft^2 derived from a crown radius measure in feet)

FROSSA

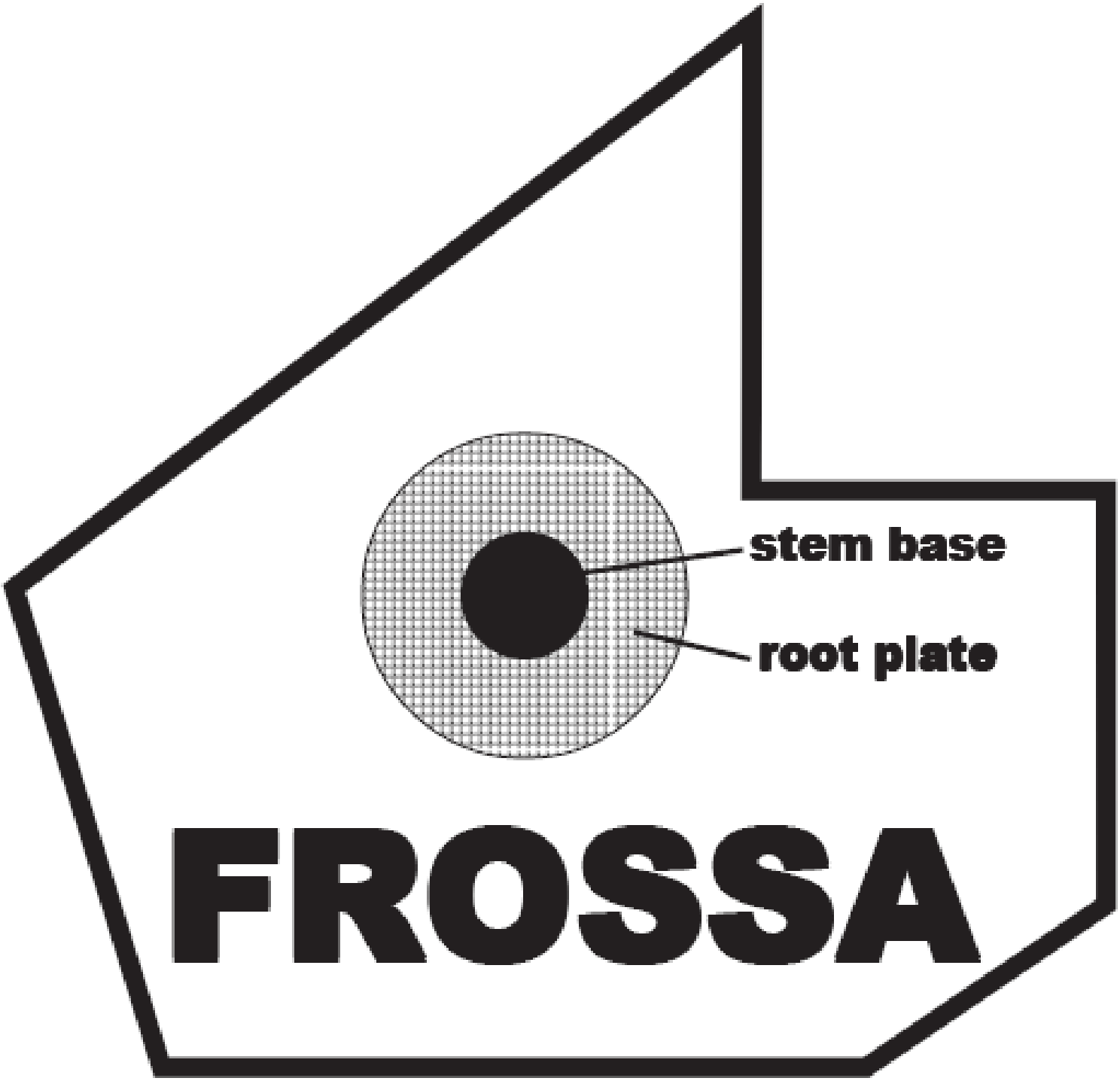
(area In ft^2 derived from actual free-to-root open soil surface)

Element Enrichment Area



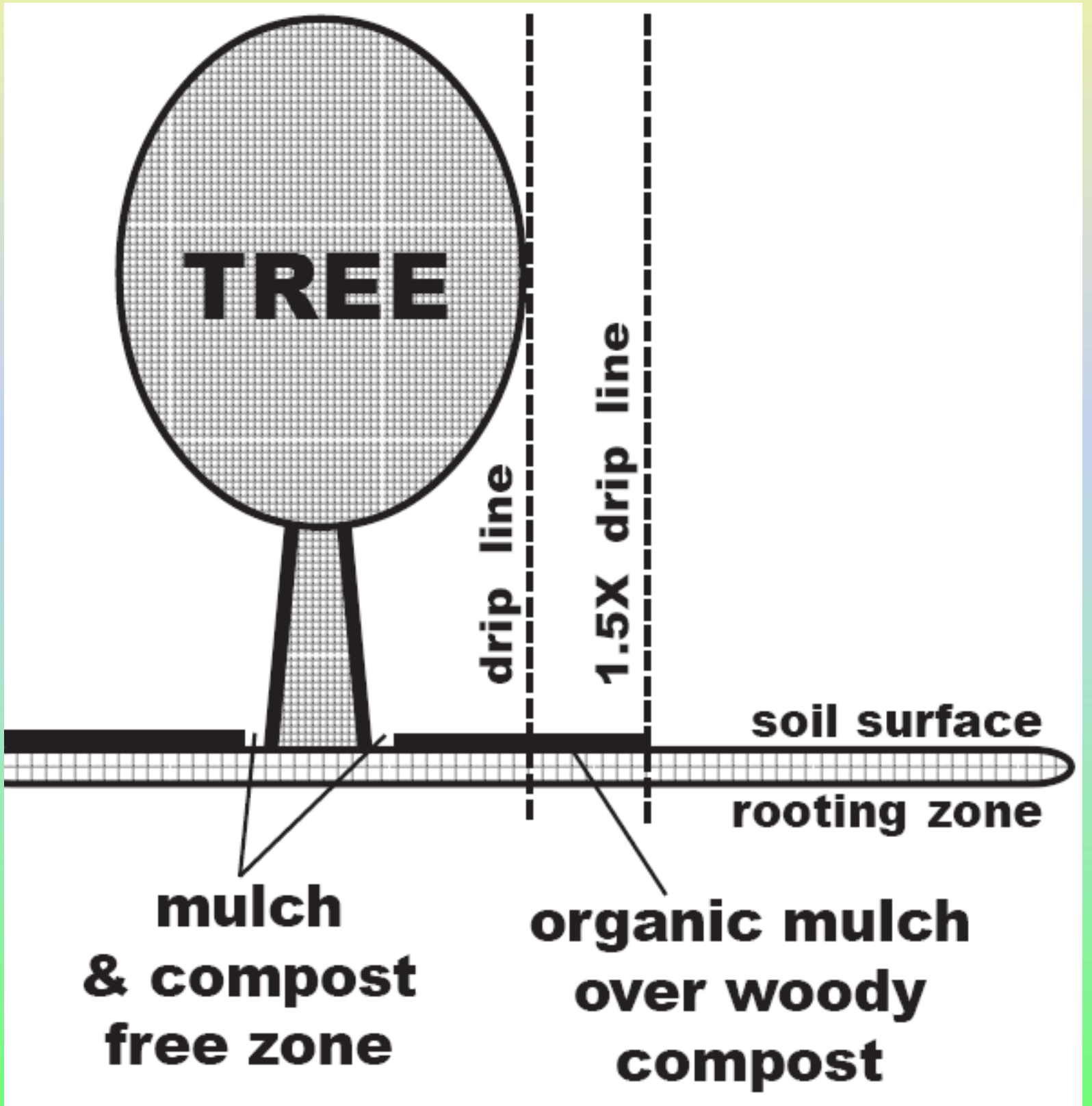
(exempt root plate area around stem base)

Element Enrichment Area



(exempt root plate area around stem base)

ORGANIC MATTER FUEL



Minimum Mulch Distance

(radius$_{ft}$ from tree)

=

[0.5 X

(tree diameter$_{in}$)]

+ 4

SUSTAINABLE TREE SITES

re-insert OM into system

(major energy / element resource)

use matured woody compost for tree sites

protect compost with low density organic mulch covering

Con-clu-sions

SUSTAINABLE TREES

1. Ecologically Viable Space
2. Quantify Water Availability

3. Soil Aeration & Drainage
4. Soil Compaction

5. Light Impacts & Heat Load
6. Structural Architecture

7. Injury & Damage
8. Soil Resource Enrichment

Sustainable Understandings I

-know what you really have

(discard what you think you have)

-note largest interactions first

(not trivial pursuit or chaotic minutia)

-slow tree / site drive toward environment equilibrium

(ecoplex thermodynamics)

Sustainable Understandings II

-manage resource density

(concentrate essentials at ecopixel)

-leave better than found

(do no harm)

-do not accept wasteland of infrastructures for infrastructures

(not faux-ecodesign)

Sustainable Understandings III

-provide future growth space !

-activate life !

(life is fuel for life)

DO NOT

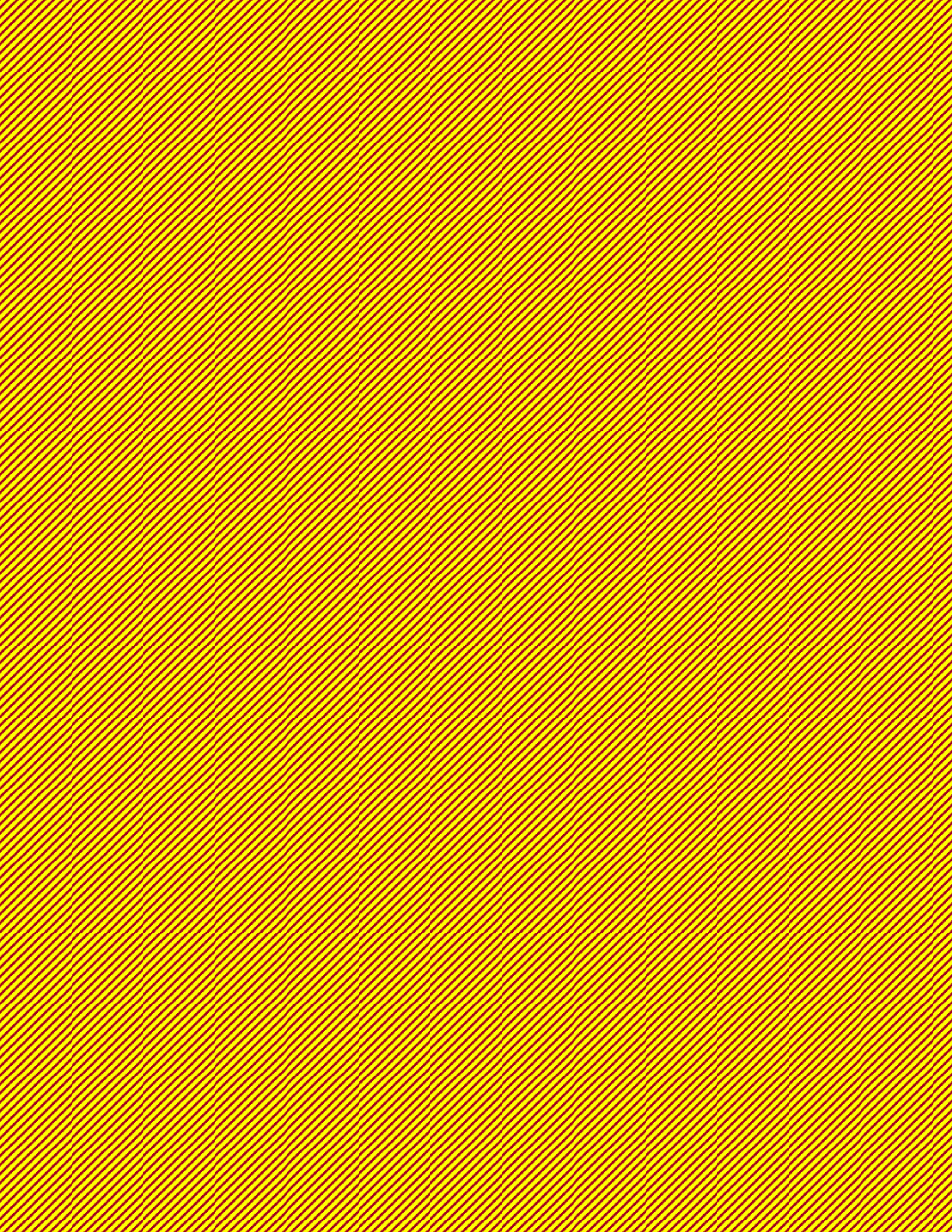
let trees

(or tree parts)

be just

trophies !

(on a wall / in the street)



SPACING & CANOPY COVER ISSUES:

Preventing Overpacking

Key Components Sustaining Trees

1. More Space
2. Resource Enrichment / Site Improvement
3. Manage Living Mass
4. Minimize Stress

MORE
QUALITY SPACE
PER TREE

NOT

MORE TREES

greenspace is not
for jamming trees
together !


More Space
More
Resources
More
Sustainable

STOP

over-crowding

over-stocking

too many trees for resources available

tree huddles / clusters / scrums

Biological Occupancy

a site
(depending upon quality)
holds a given amount
of leaf surface area

leaf surface area
can be concentrated
onto few large trees or
many small trees

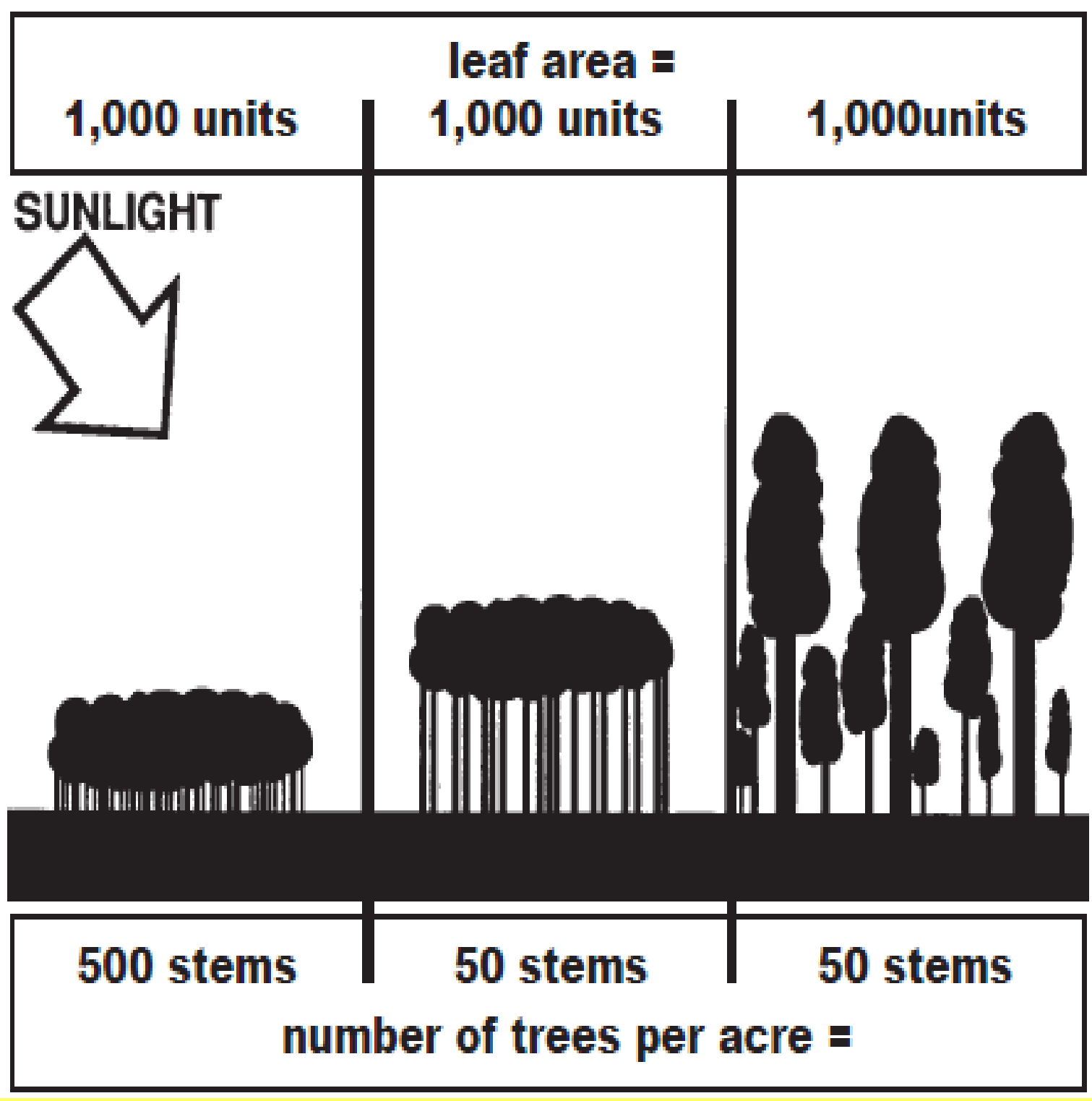
you manage limited light !

Biological Occupancy

600 five-inch trees
150 ten-inch trees
65 fifteen-inch trees
40 twenty-inch trees
= similar total crown volumes

trade-off between numbers of trees & sizes for similar site occupancy

Same Sunlight Spread Over Different Number of Trees



Canopy Measurement Blight

high stem density
&
low stem density
plantings

SAME
Canopy Coverage
(control by site quality)

EASY

estimate site occupancy of area using basal area (BA) factor

use angle gauge or prism (or US 5 cent coin)

BASAL AREA MEASURES

count number of trees wider than nickel

overstocked / prone to decline
> 7.5 trees

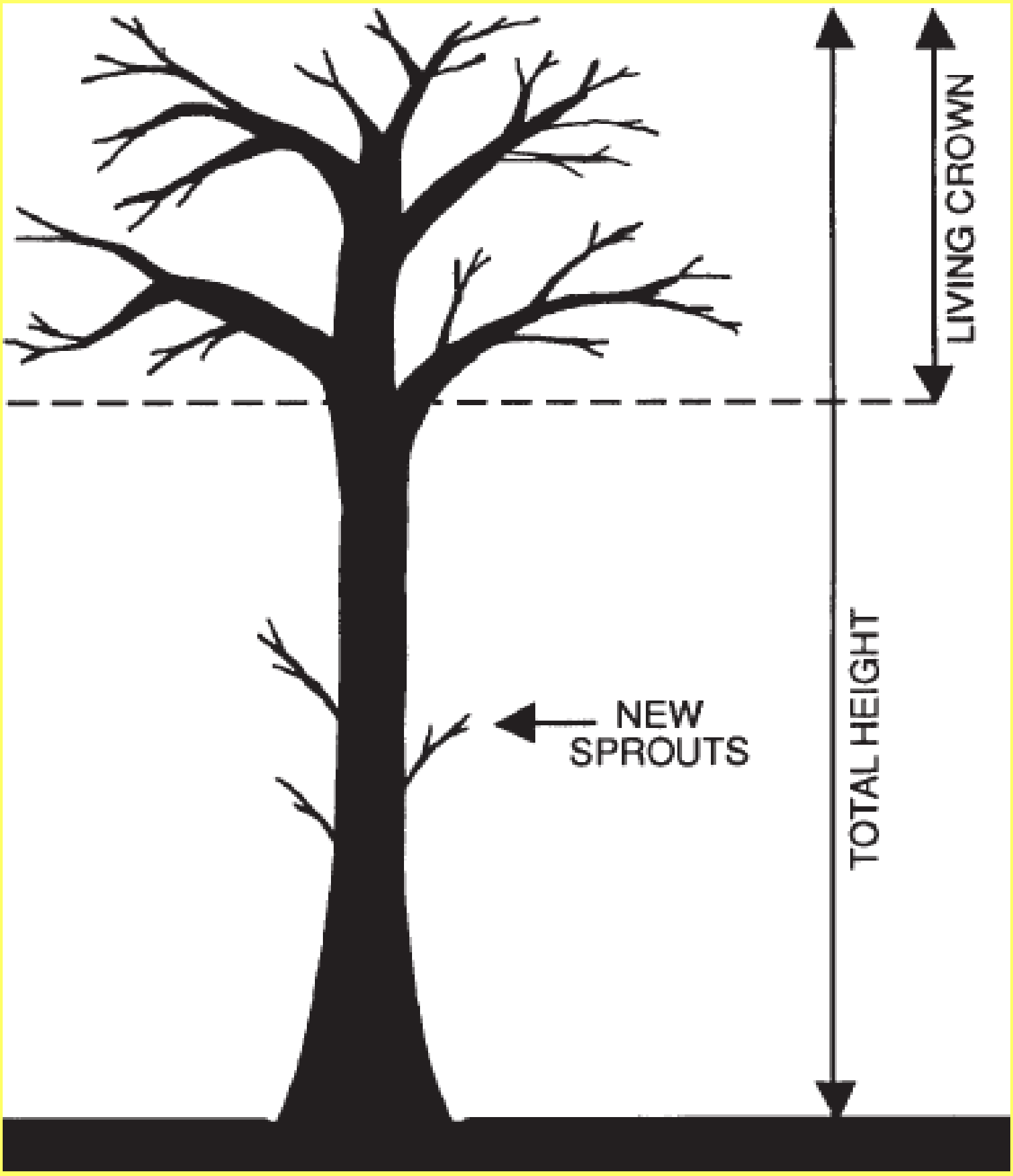
adequate
2.0 – 3.5 trees

TOO DENSE ?

TOO MANY STEMS
TOO CLOSE TOGETHER

SMALL LIVE CROWN RATIO

LIVE CROWN RATIO



LIVE CROWN RATIOS

large live crown ratios react to changes well

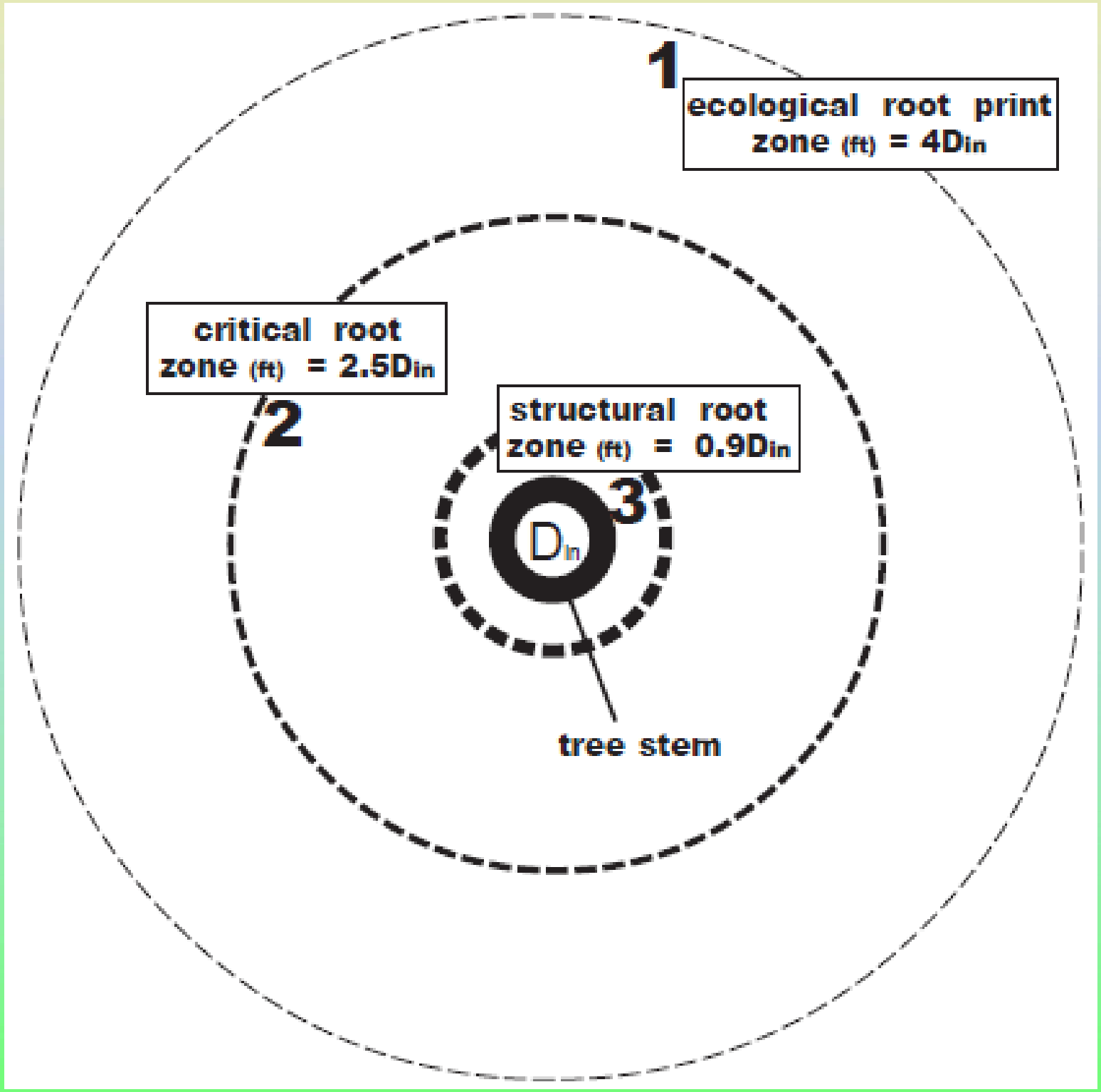
ideal =
>66% live crown ratio

majority =
>35% live crown ratio

decline =
<20% live crown ratio

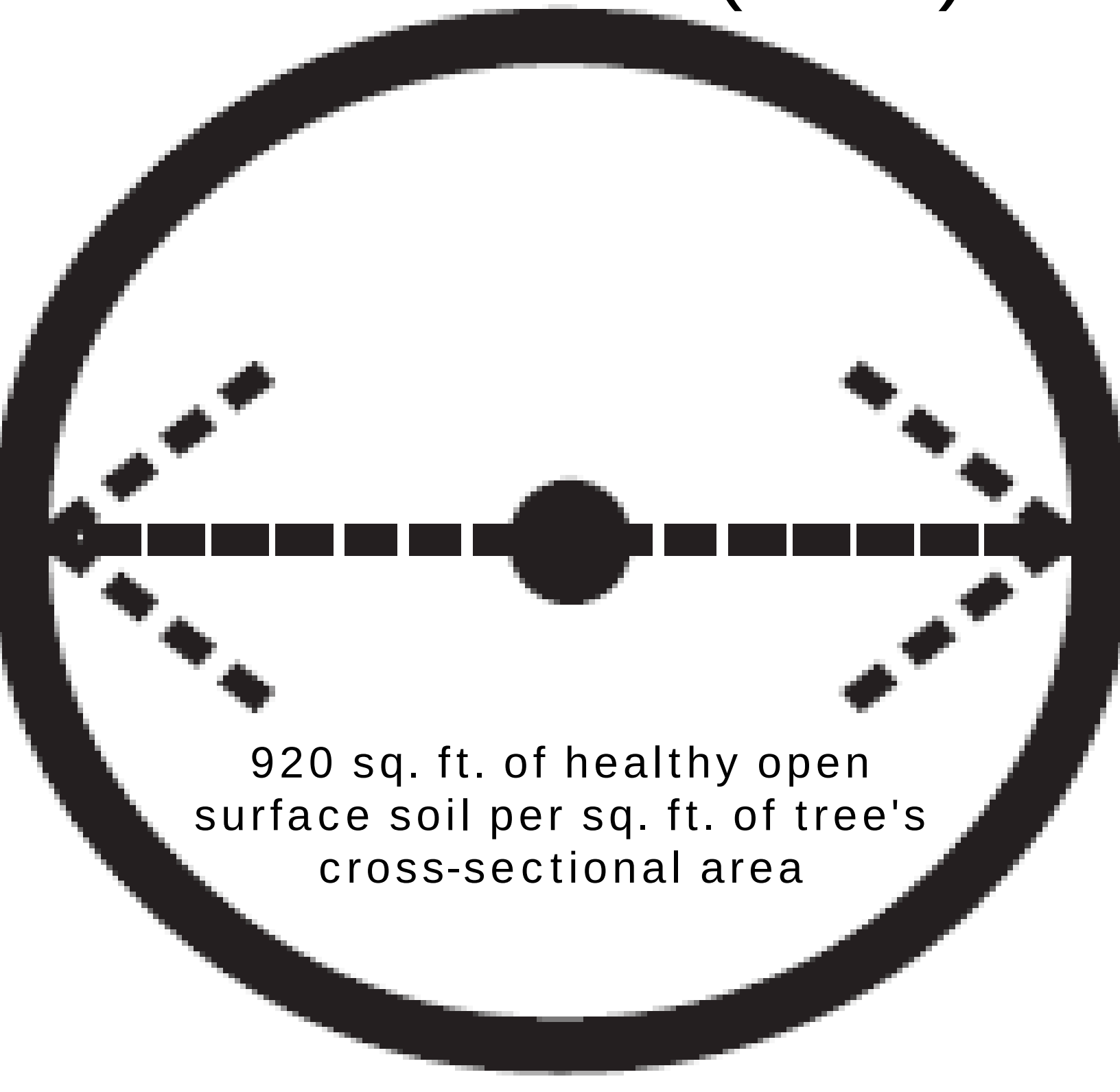
removal =
<10% live crown ratio

ROOT ZONE CALCULATIONS



2.5 X DIAMETER OF TREE (inches) =

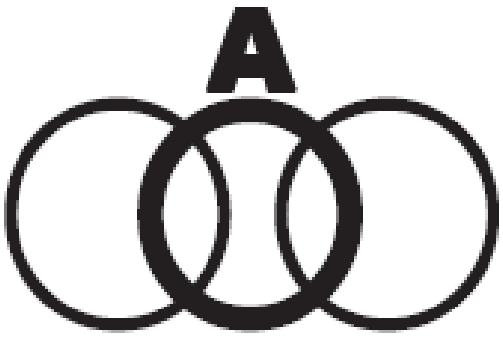
CRITICAL ROOTING DISTANCE (feet)



920 sq. ft. of healthy open surface soil per sq. ft. of tree's cross-sectional area

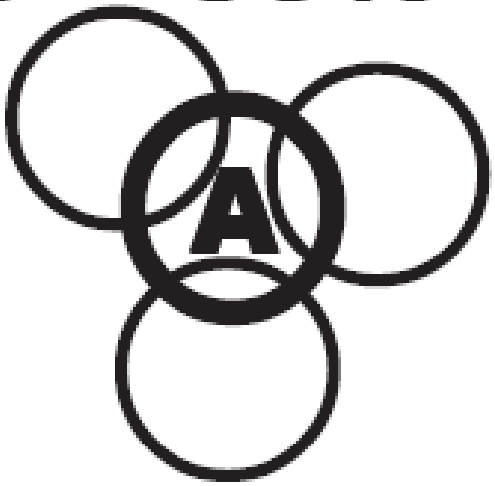
CRITICAL ROOTING AREA OVERLAP

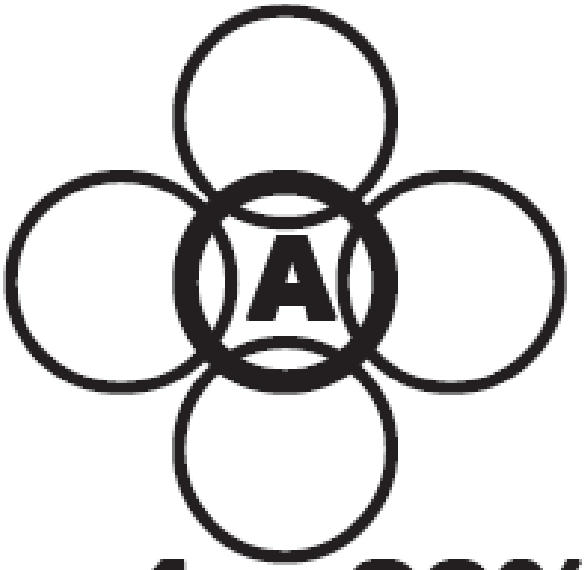
number of trees neighboring tree A	allowed critical rooting area overlap with tree A
1	50%
2	40%
3	30%
4	20%
5	10%
>6	0%



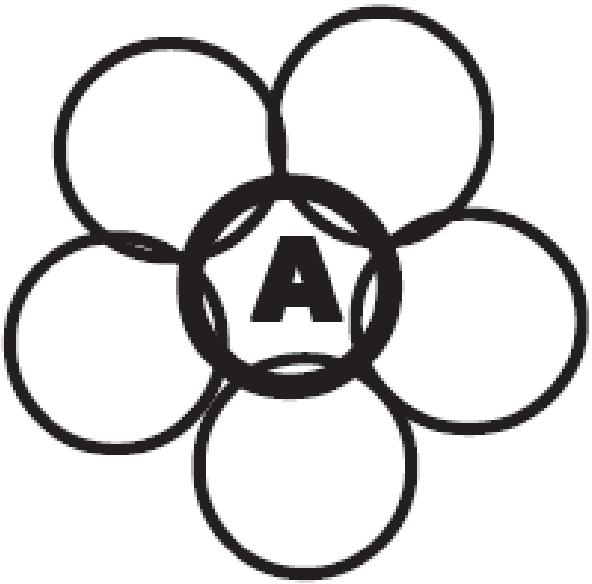
2 = 40%

3 = 30%





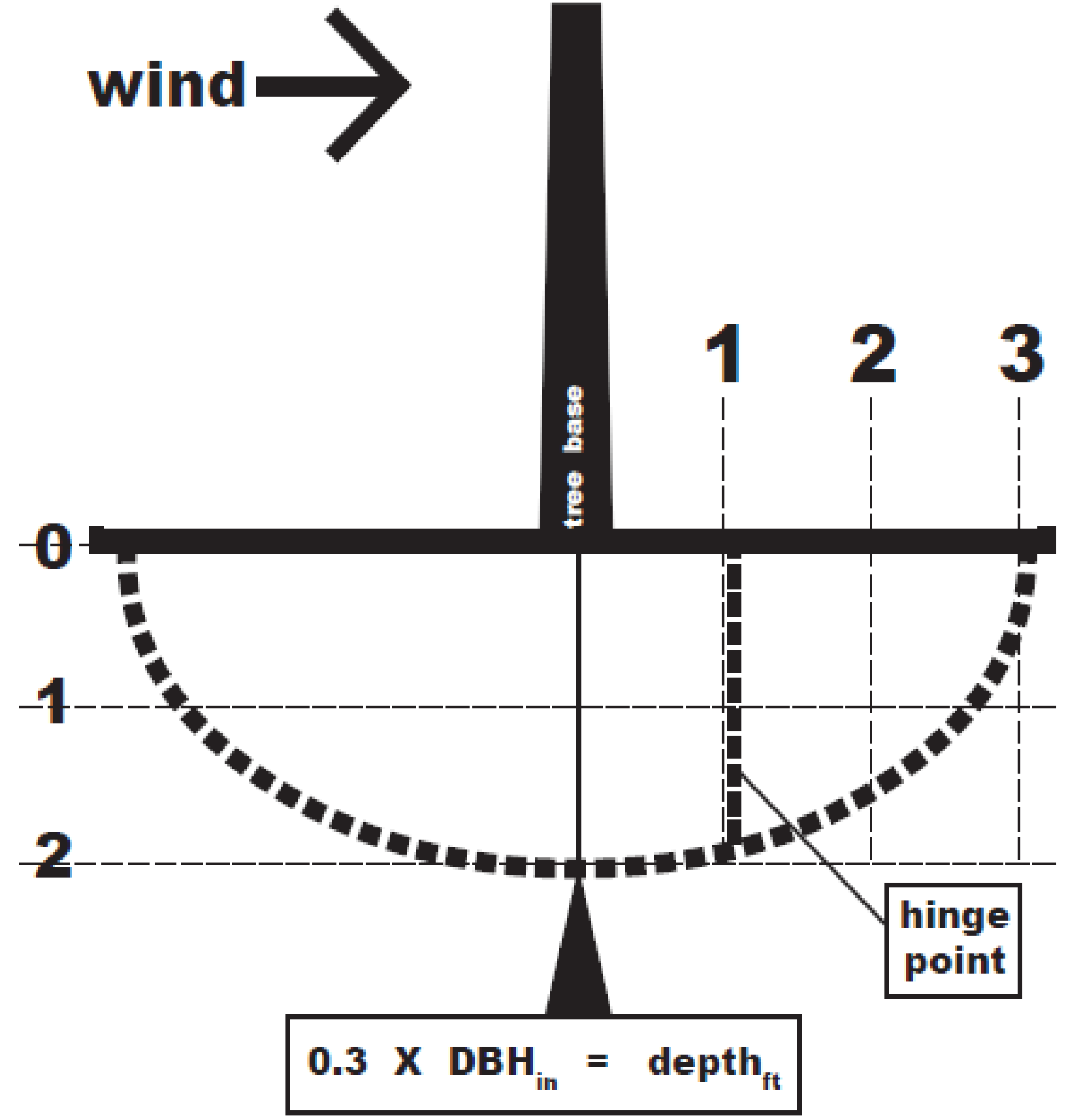
4 = 20%



5 = 10%

6 = 0% OVERLAP

ROOT PLATE



UNLIMITED VOLUME

2 X

ROOT PLATE DIAMETER

=

AVOID ALL DAMAGE

IN THIS AREA

$0.9 \times 2.0 \times DBH_{in}$

=

$TREE\ SAFETY\ AREA_{ft}$

(Koeser et.al. 2013)

(Day et.al. 2010)

ROOT VOLUME

mature
rooting volume

=

3 cubic feet soil
for every square
foot of crown
projection for
mature tree

(sustainable site)

OPEN SOIL SURFACE AREA !!!!!

INCREASE OPEN SURFACE AREA DIAMETER BY 5X

INCREASE LONG-TERM SURVIVAL BY 2.5X

(Koeser et.al. 2013)

Eventual TREE Size

(canopy, height, stem)

Ecological Viable Space

Trees On Site !

PRESERVE**

VS.

DESIGN,
PRESCRIBE,
& PLANT

TREE LIFE

quality
habitat loss

NOT

fragmentation

AVOID

tree homogeny

(genetics to family)
(no even-age classes)

Tree Diversity

improves ecosystem stability

distributes risks of tree loss among many species / sites

increases resilience to neglect & abuse

TREE REPLACEMENT ?

diameter inch X 1.05
(not 1:1)

(basal area in^2)$^{2.05}$
(not 1:1)

NOT PLANTING ENOUGH BACK TO BREAK EVEN !

TREE REPLACEMENT ?

do NOT use diameter inches !

loss of $(BENEFITS)^2$

(use basal area basis)

PERCEPTION IS THE PAST

DIFFICULT TO SEE ACCELERATING TREE DECLINE & DEATH

Current canopy ?
Canopy added ?
Canopy lost ?

Measure Effective Tree Canopy Coverage Change

3 tree species size classes

small = 10-20 feet tall at 20 years
medium = 21-50 ft tall at 30 years
large = >50 ft tall at 40 years

3 tree stress zones

(Coder, 2011 -- WSFNR11-35)

ZONE 1: High Tree Stress Sites

size class	number of stems planted this year		area factor		crown canopy area
SMALL TREES	= _____	X	0.02	=	_____
MEDIUM TREES	= _____	X	0.2	=	_____
LARGE TREES	= _____	X	0.4	=	_____

total zone 1 canopy area value = _____

Zone 1 Canopy = total zone 1 canopy area value / acres of zone 1 = _____

ZONE 2: Moderate Tree Stress Sites

size class	number of stems planted this year		area factor		crown canopy area
SMALL TREES	= _____	X	0.006	=	_____
MEDIUM TREES	= _____	X	0.05	=	_____
LARGE TREES	= _____	X	0.2	=	_____

total zone 2 canopy area value = _____

Zone 2 Canopy = total zone 2 canopy area value / acres of zone 2 = _____

ZONE 3: Low Tree Stress Sites

size class	number of stems planted this year		area factor		crown canopy area
SMALL TREES	= _____	X	0.002	=	_____
MEDIUM TREES	= _____	X	0.02	=	_____
LARGE TREES	= _____	X	0.06	=	_____

total zone 3 canopy area value = _____

Zone 3 Canopy = total zone 3 canopy area value / acres of zone 3 = _____

STEP #1:
TOTAL TREE CANOPY COVERAGE OF COMMUNITY (%)

= _____% (tree canopy area / total community area)

STEP #2:
ANNUAL NEW COMMUNITY TREE CANOPY FROM PLANTING (%)

= _____% (tree canopy area gained / total tree canopy area)

STEP #3:
ANNUAL COMMUNITY TREE CANOPY COVERAGE LOSS (%)

= _____% (tree canopy area loss / total tree canopy area)

[#1 / (#2 - #3)]

=

Effective Tree Canopy Coverage Change

" - " years until complete canopy loss
" + " increasing canopy values
" 0 " balance of gain & loss

conclusions
conclusions
conclusions

TREE BENEFITS

geometrically increase with large, long-lived trees on high quality sites

TOO MANY TREES FOR LIMITED ECOLOGICALLY VIABLE SPACE?

less trees
better sites

WORKING DOGS (trees)

VS.

LAP DOGS (shrubs)

(do you want nothing but toy poodles ?)