Root and Stem Cutting and its impact on Tree Stability

Tom Smiley, Ph.D.
Bartlett Tree Research Laboratories
Charlotte, NC USA
Clemson University, SC

Part 1. Sapwood loss and implications for tree stability

Research project conducted in part at the ISA/TREE Fund Biomechanics Week (2010) with Dr. Brian Kane

Missing wood contributes to tree failures, most research has focused on internal decay

It is generally accepted that up to 2/3 of the interior of the stem can be lost without affecting stability

However, wood can also be absent from the outer portion of the tree

Cutting notches and pulling testing with measured force to determine the effects of sapwood loss on stability

Research Methods

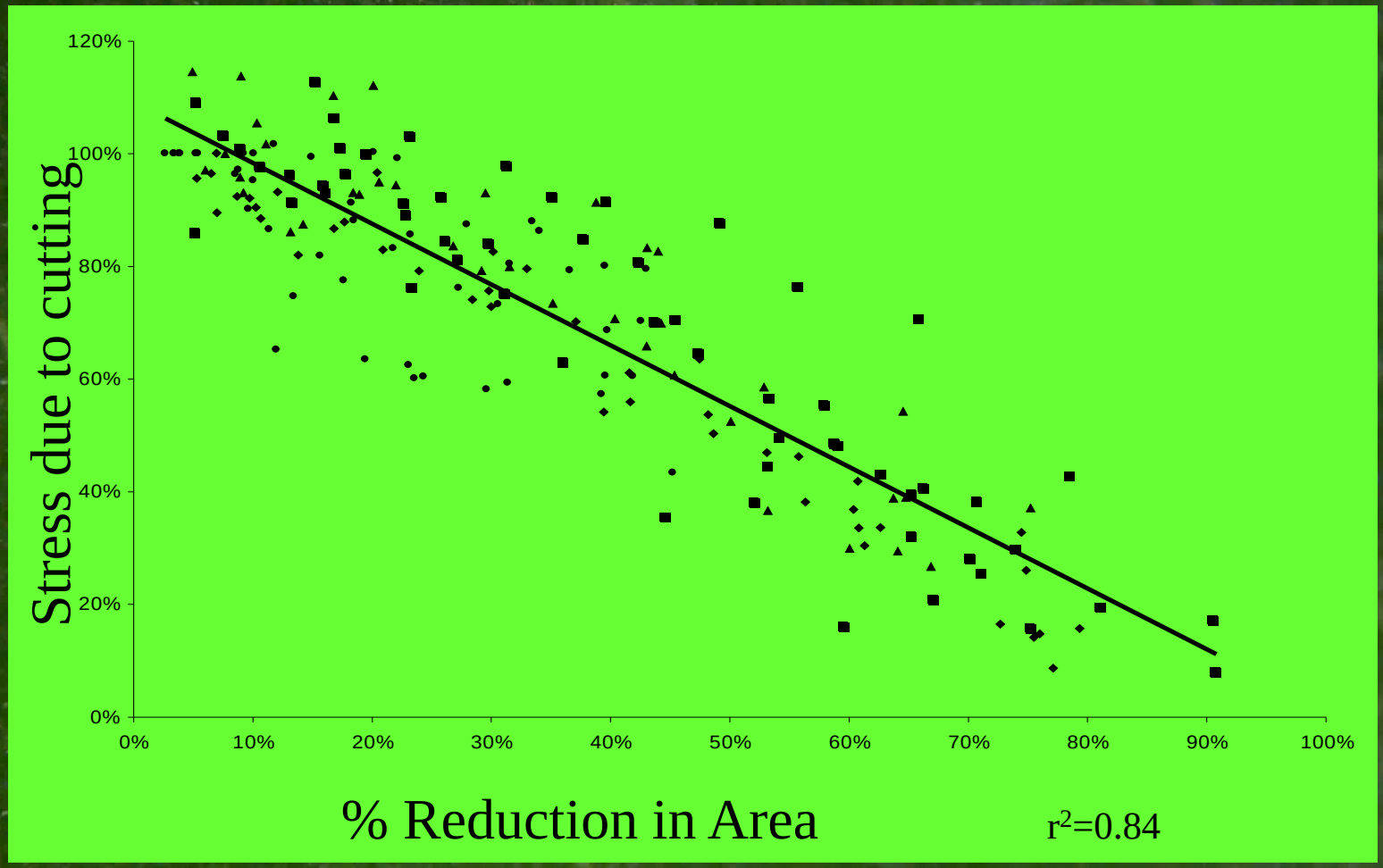
Species: Red maple *(Acer rubrum*)
Sweetgum *(Liquidambar styraciflua)*
Sawtooth oak *(Quercus acutissima)*

Size: 7-25cm (*3 to 10"*) DBH
Number of trees: *45*
Number of cuts: *188*

Stem Cutting

Pull testing cut stems

Relationship between Area of a Sapwood Cut and Stress

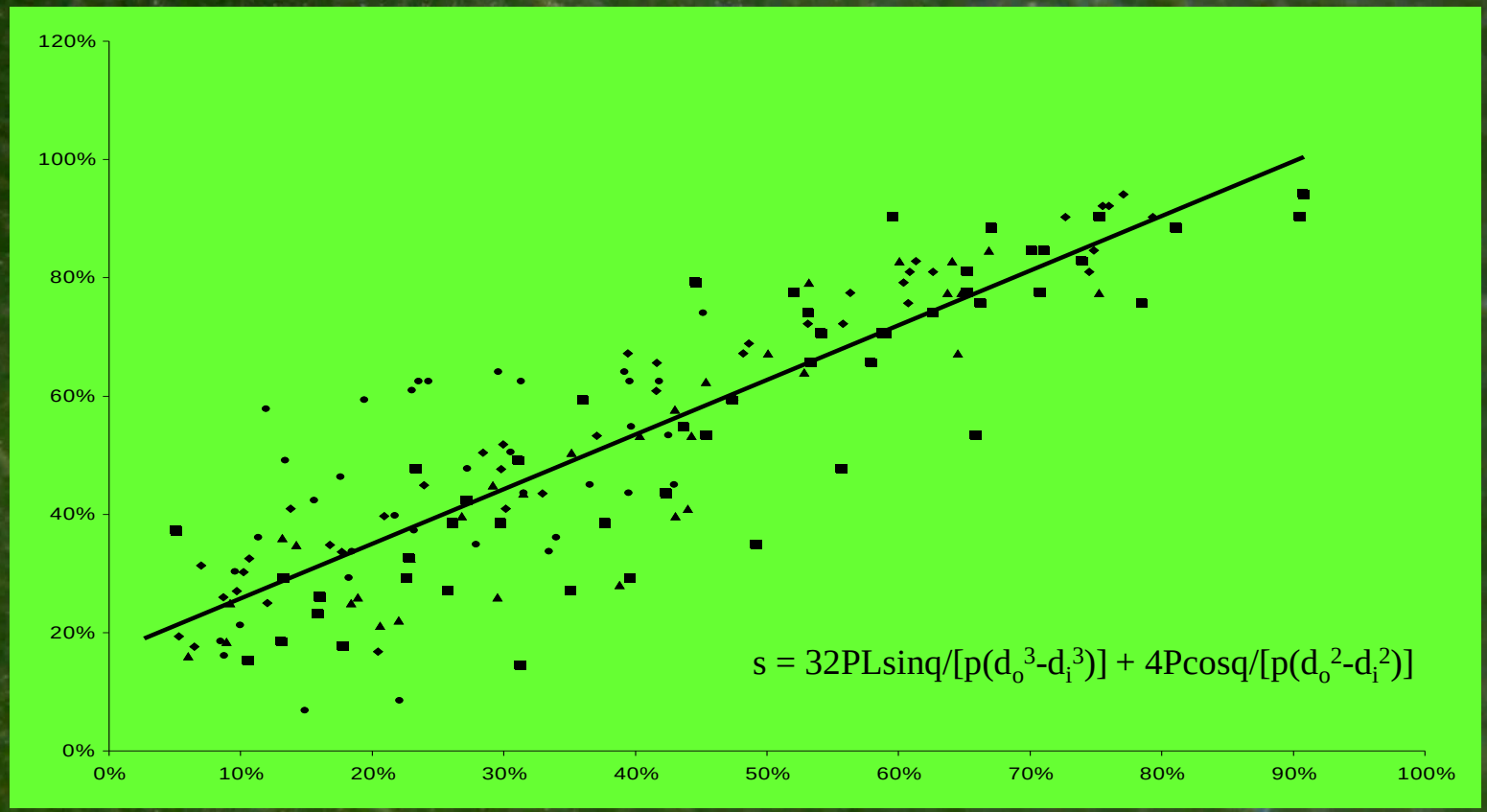


small red maple (■), large red maple (●), sweetgum (▲), and sawtooth oak (♦). The relationship ($\Delta\sigma = 1.10 - 1.08 * \Delta A$) was significant ($p < 0.001$), robust ($r^2 = 0.84$) and similar for all species ($p = 0.258$).

Strong correlations between both cross sectional of cut and stability of the tree.
Minor differences among species.

How much loss is too much?

Relationship between the reduction in sapwood and the heartwood to cause an equivalent magnitude of stress

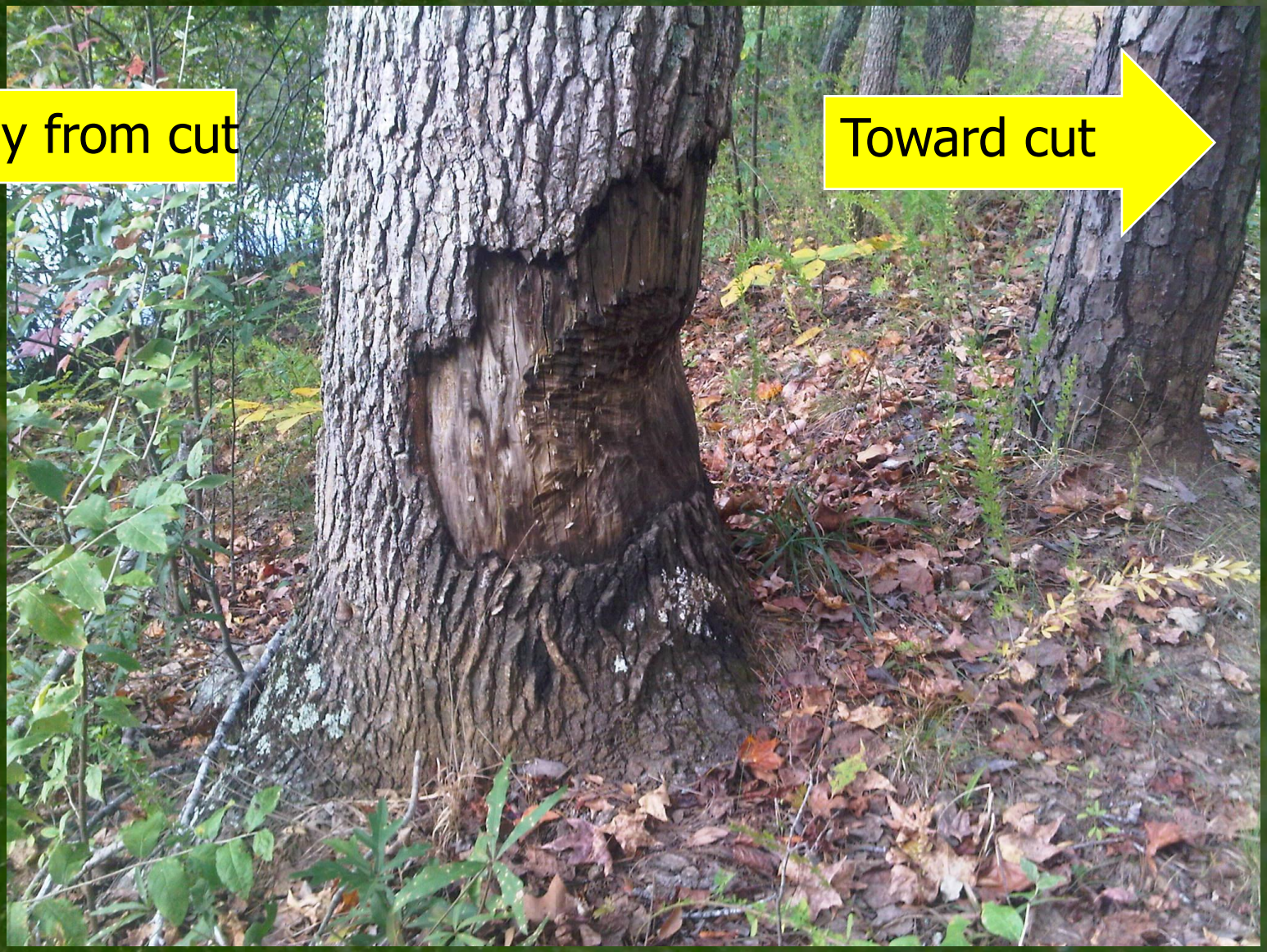


Small red maple (■), large red maple (●), sweetgum (▲), and sawtooth oak (♦). The relationship ($\Delta\sigma_C = 0.17 + 0.92 * \Delta A$) was significant ($p < 0.001$), robust ($r^2 = 0.76$), and similar for all species ($p = 0.740$).

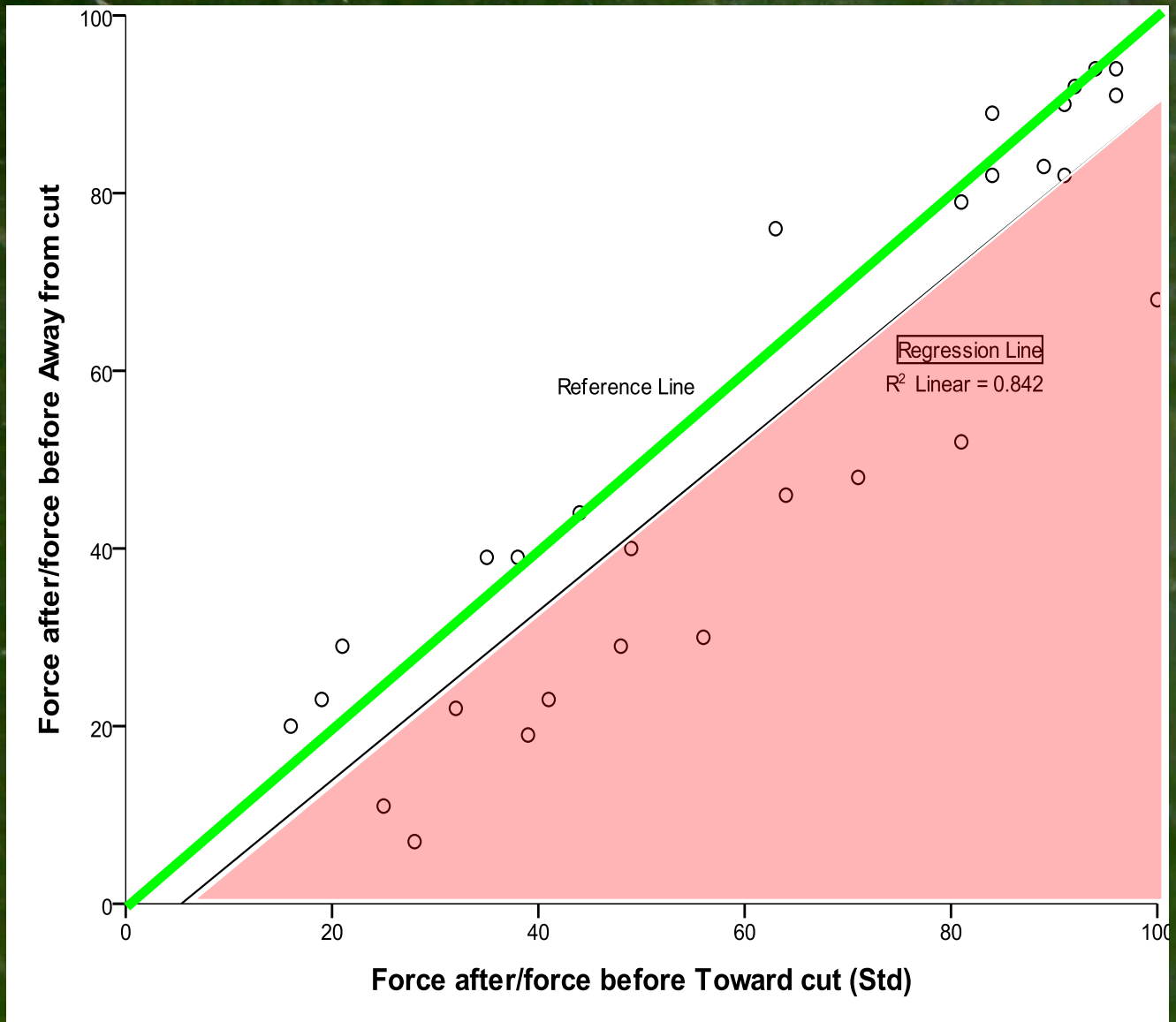
Sapwood loss decreases stress about twice as much as heartwood loss

- The generally accepted maximum amount of allowable concentric heartwood loss is 2/3 of cross section,
- So the maximum amount of sapwood loss is about **1/3**

Likelihood of Impact
Which direction is the tree more likely to fail?



Likelihood of Impact
Which direction is the tree more likely to fail?



Failure is more likely to be in toward the cut.
But wind direction is probably more important

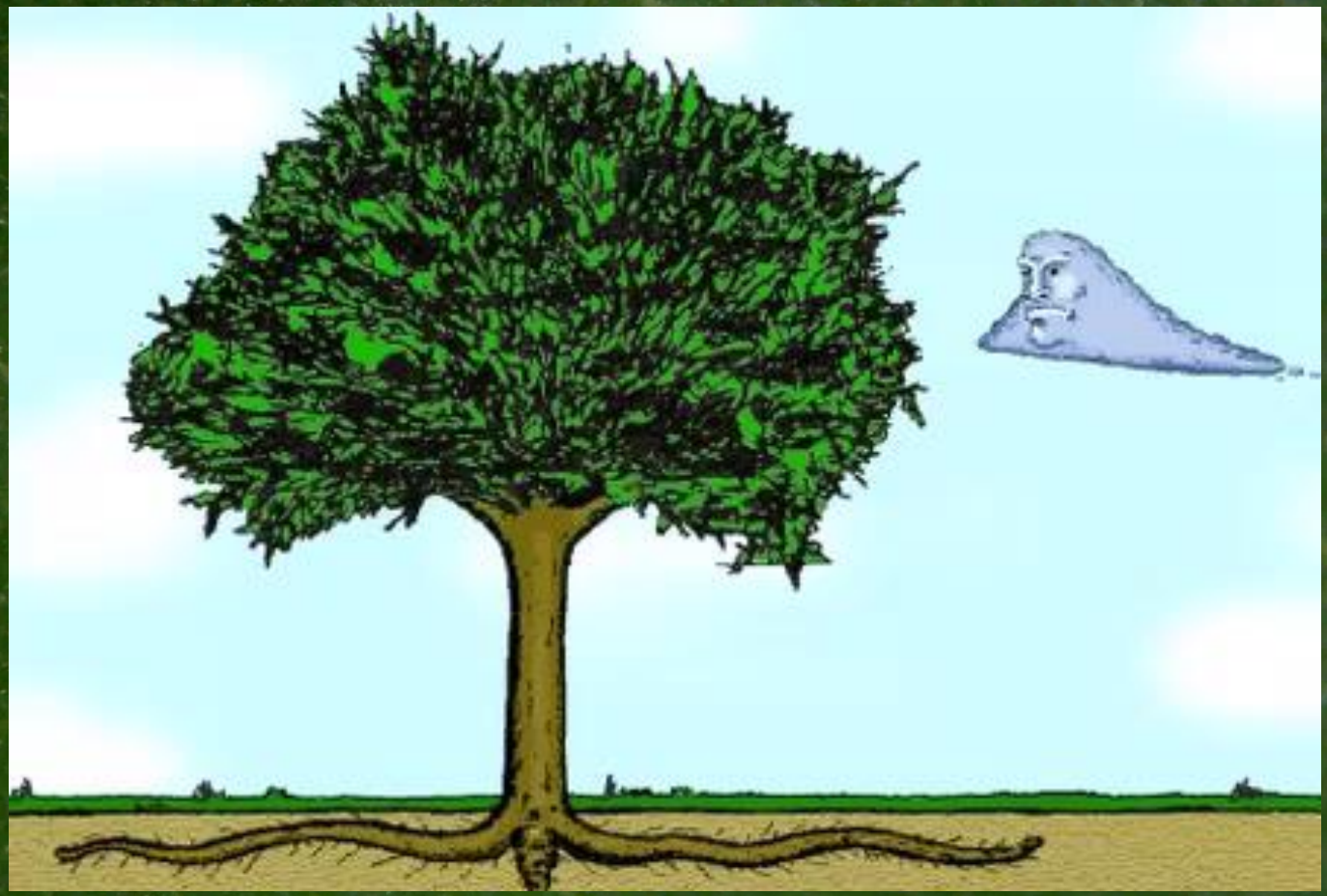
Part 2. Assessing tree roots and root damage

How many failures are Root Related?

% of Failures reported	**Singapore** 10 years	**International Tree Failure Database (ITFD)**	**US Forest Service** 1965-1980	
			Conifers	**Hardwoods**
Branches				
Trunks				
Roots				

How do roots work?

Forces on roots



Leeward

Windward

Tension Compression Tension

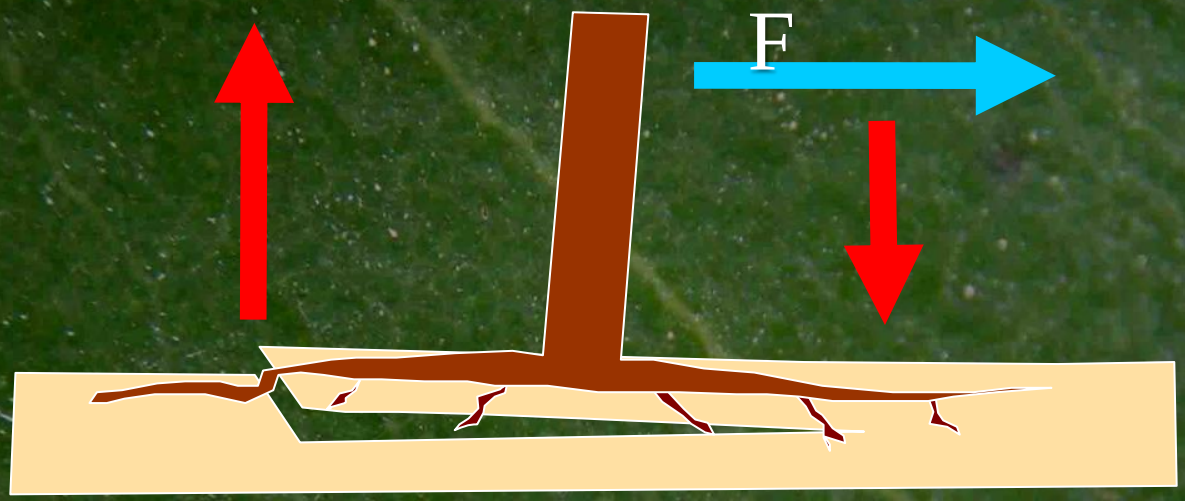
Types of Failures

Root Failures

Soil Failures

Soil Failure

Windthrow resistance due to:



1. Weight of ‘root-plate’;
2. Root strength on windward side;
3. Root strength on leeward side;
4. Frictional properties of soil-
   highly moisture dependant.

From: Tim Newson Univ. of Western Ontario

Root Failure

Test your knowledge of tree roots

What is a typical number of buttress roots on a mature tree?

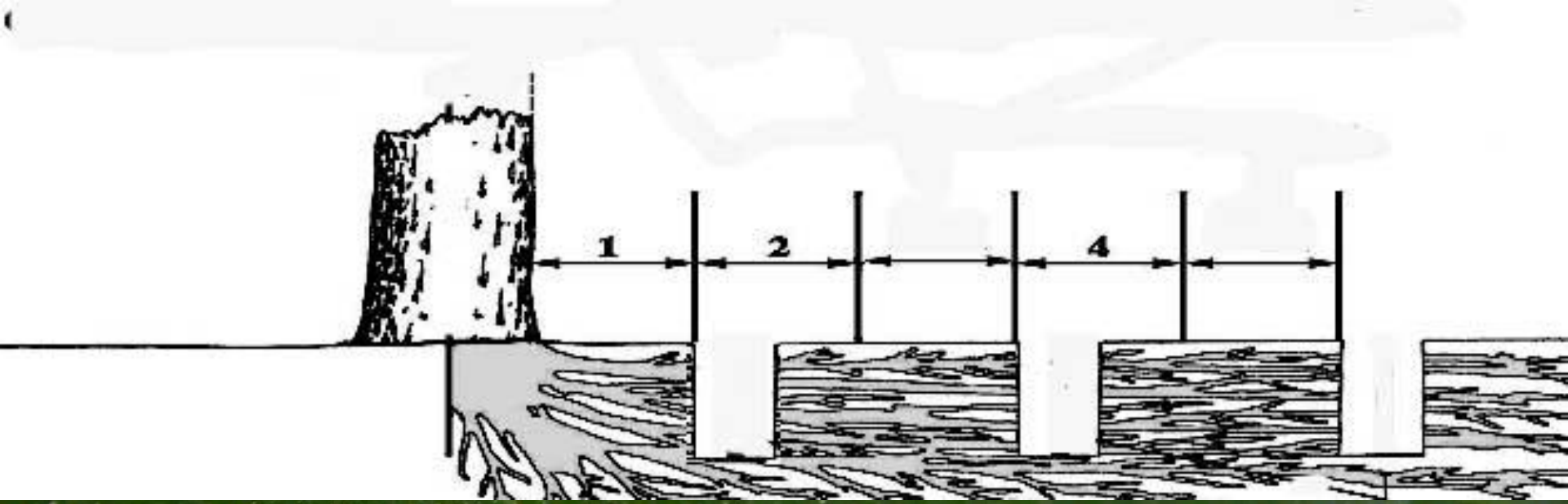
7-11

Root cutting research at the Bartlett Lab

1) Linear root cuts – how close can we cut without affecting stability?
2) Individual root cuts at the trunk-
   a. how many roots can we cut?
   b. what is the best way to assess root loss?

Root cuts are common in urban areas

Root Cutting: How close should you get?



Many municipalities allow cutting to the trunk. How close is too close?

Using a Stump Cutter to Severe the Root System of each Tree

Linear Cuts

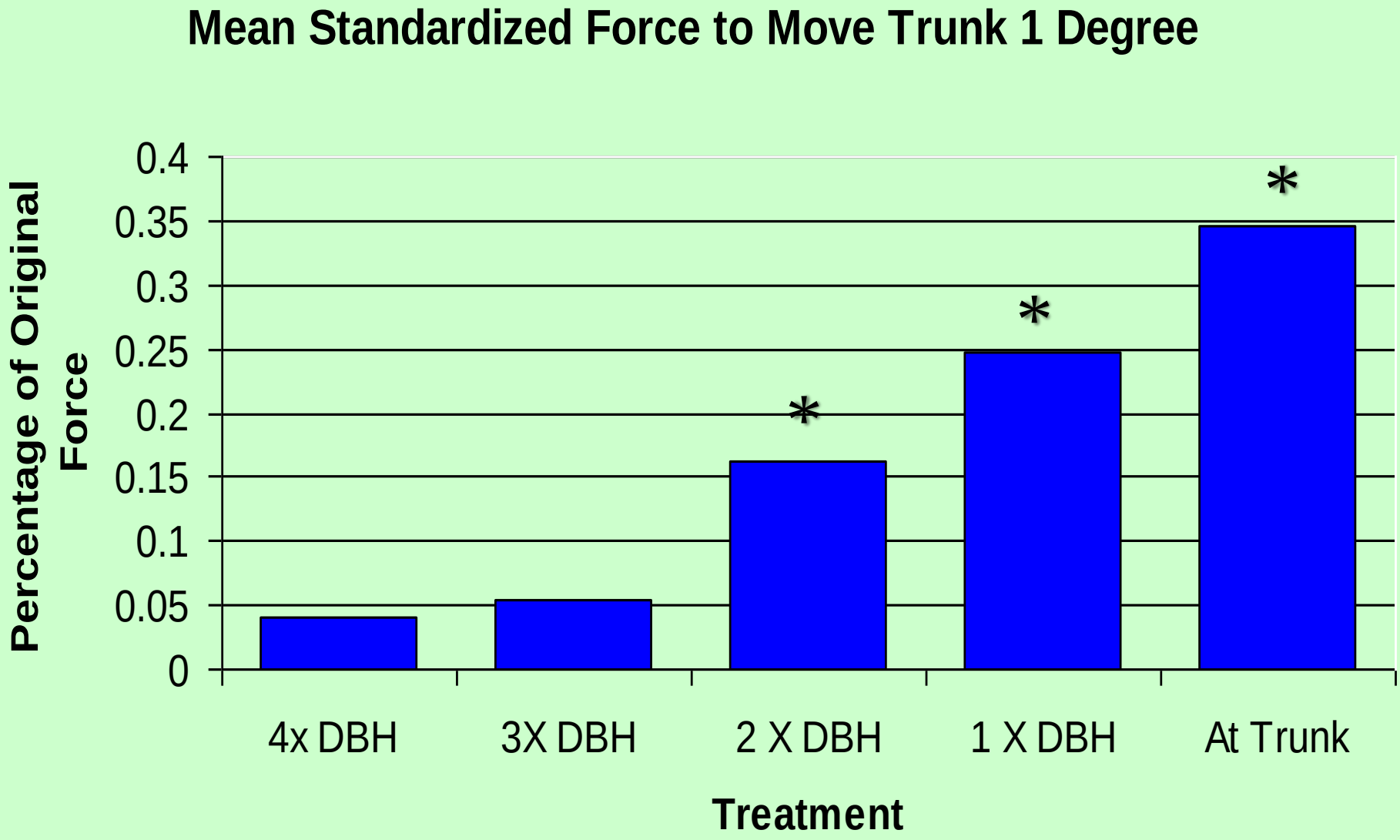
Across the root system

Linear cut close to trunk

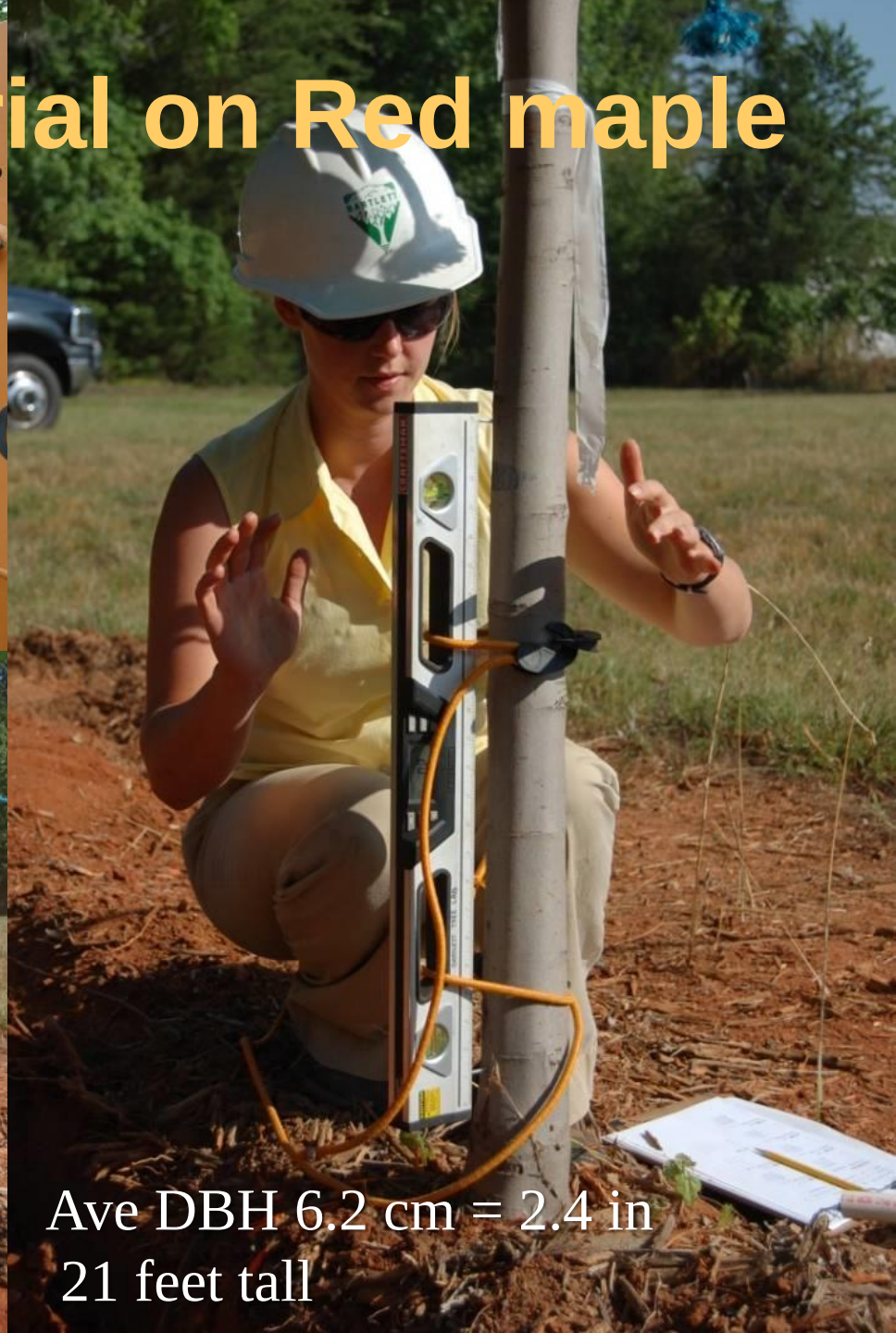
Cut at Trunk

Pull testing

Linear Root Cuts on Willow oak



Repeating the Trial on Red maple



Ave DBH 6.2 cm = 2.4 in

21 feet tall

Red Maple Root Cutting

Reduction in Standardized Force

50
40
30
20
10
0

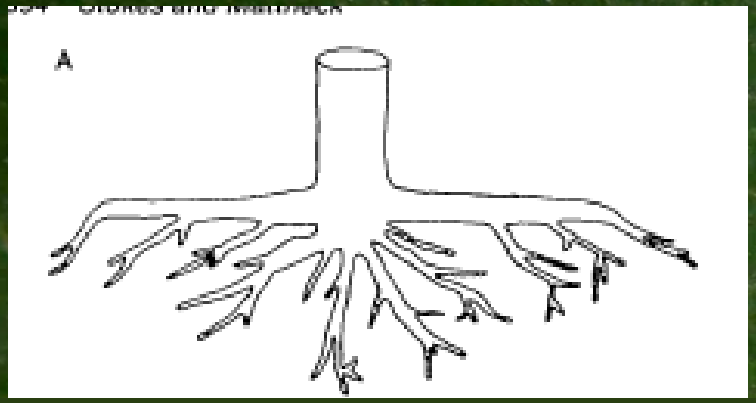
*
*

3 x DBH
2 x DBH
1 x DBH
At Trunk

@ 19 % soil moisture, clay loam soil

Virginia Pine Root Cutting

Are there root system differences among species?



Root System Configurations after Kostler et al. 1968.

A. Deep root or Heart root system

B. Horizontal, lateral or plate root system

C. Tap root system

Likelihood of Impact:

Which way are root cut trees more likely to fall?

Trees Pulled from Two sides

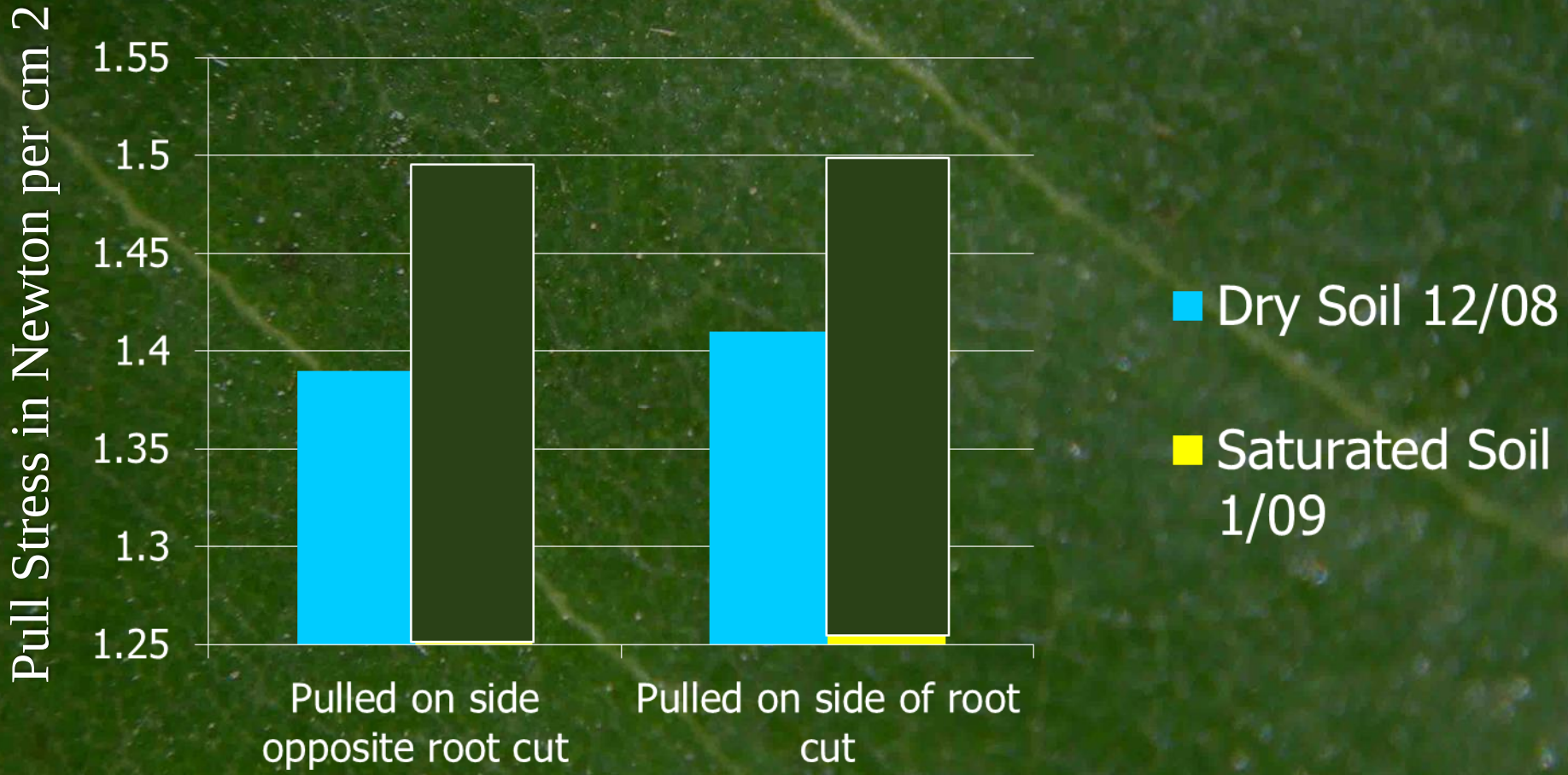
- Pulled away from root cuts
- Pulled toward root cut side
- Pulled trees when the soil was ‘dry’ 19% moisture (w/w)
- Pulled trees with surface soil was saturated, 36% moisture

Pulling Trees in Saturated Soils

Pull (wind) direction does not affect force when the soil is dry.

Force is significantly different when soil is wet.

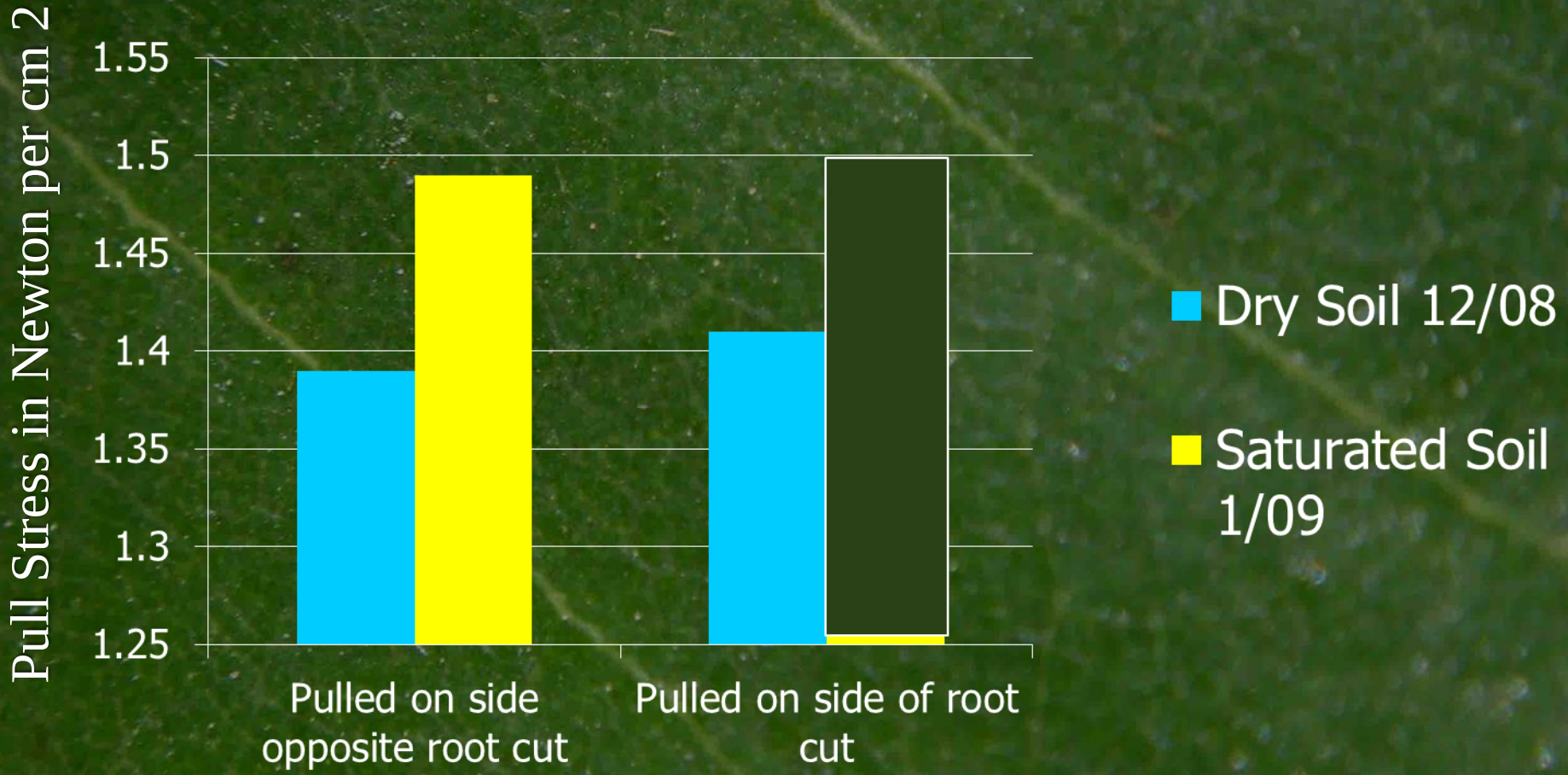
Tree more likely to fail toward root cut when wet.



Pull (wind) direction does not affect force when the soil is dry.

Force is significantly different when soil is wet.

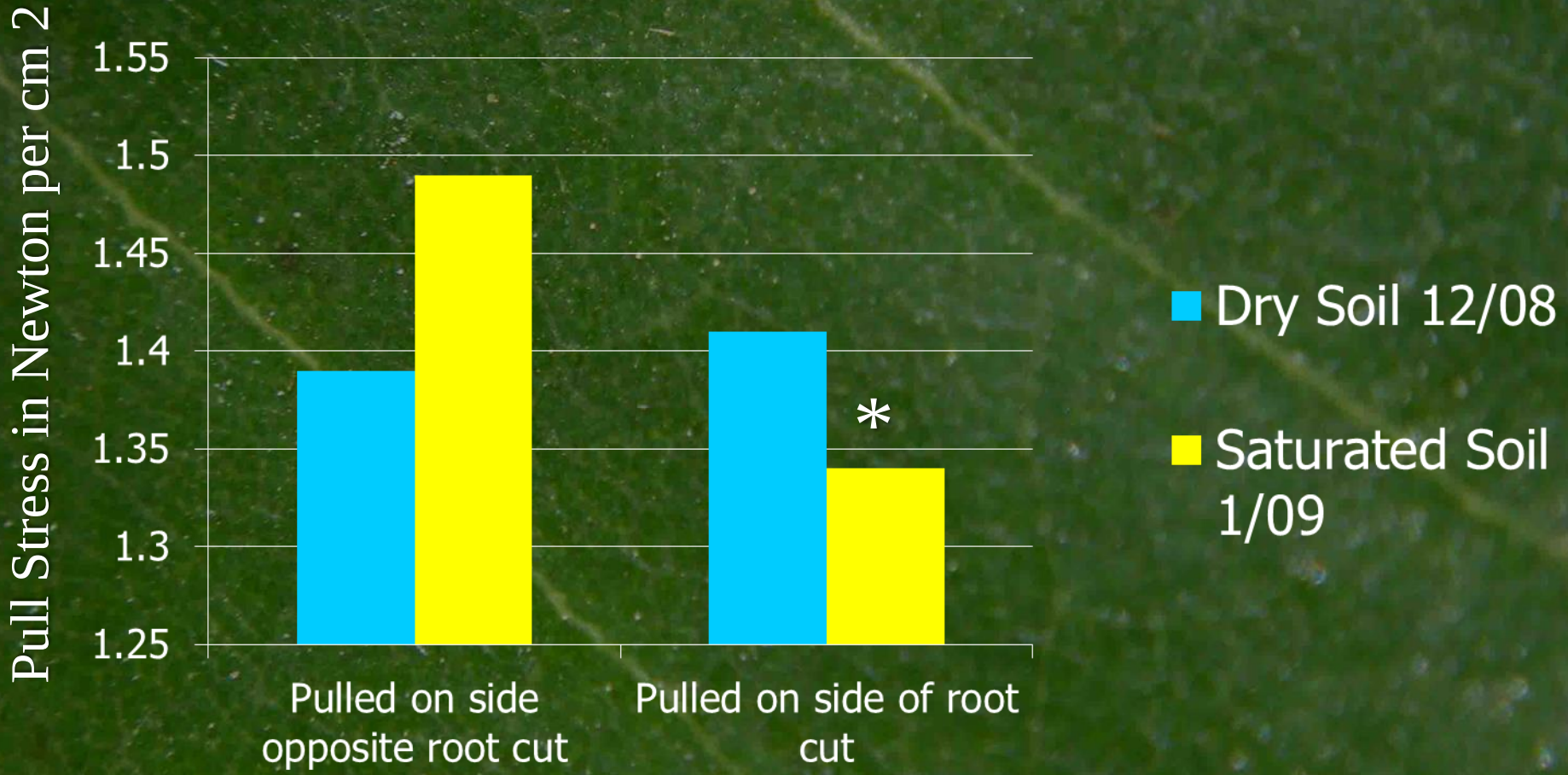
Tree more likely to fail toward root cut when wet.



Pull (wind) direction does not affect force when the soil is dry.

Force is significantly different when soil is wet.

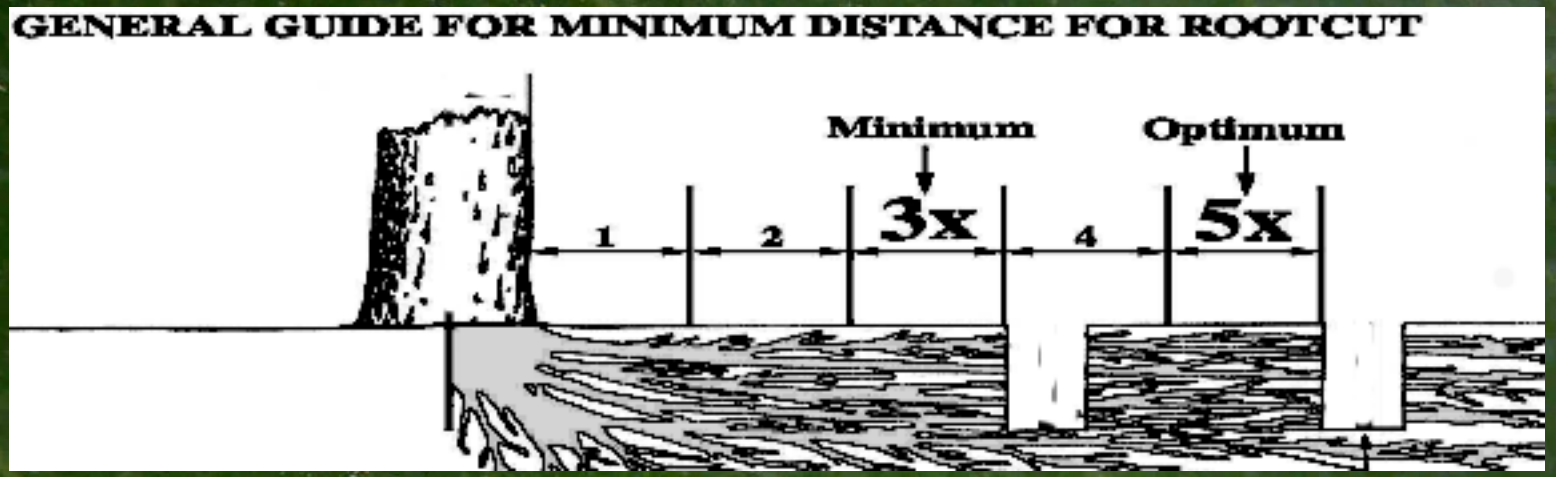
Tree more likely to fail toward root cut when wet.



Does Soil Moisture determine where roots break?

- Ash (*Fraxinus*) trees grown with and without root barriers.
- Pulled to failure.
- Dry soil breaks occur in the lower stem /root collar
- And oblique roots broke in 25-50mm(1–2”) dia.
- In Wet soils All broke in 6-12mm (¼ to ½”)diameter

Root Cutting: One side cuts



It is best to keep all cuts outside dripline.

5X DBH is likely to be a sustainable distance for many species. There are significant species differences.

3 X DBH is as close as you should ever recommend.

Within 1 to 1.5 x DBH consider tree removal

Use greater distances if large tree, leaning trees, trees with root rot etc.

Test your knowledge of tree roots

What is the relation between trunk cross sectional area (CSA) at DBH and the CSA of the buttress roots?

In our studies on eastern hardwood, the root CSA is **three** times the trunk CSA

However, trees also have oblique or tap roots

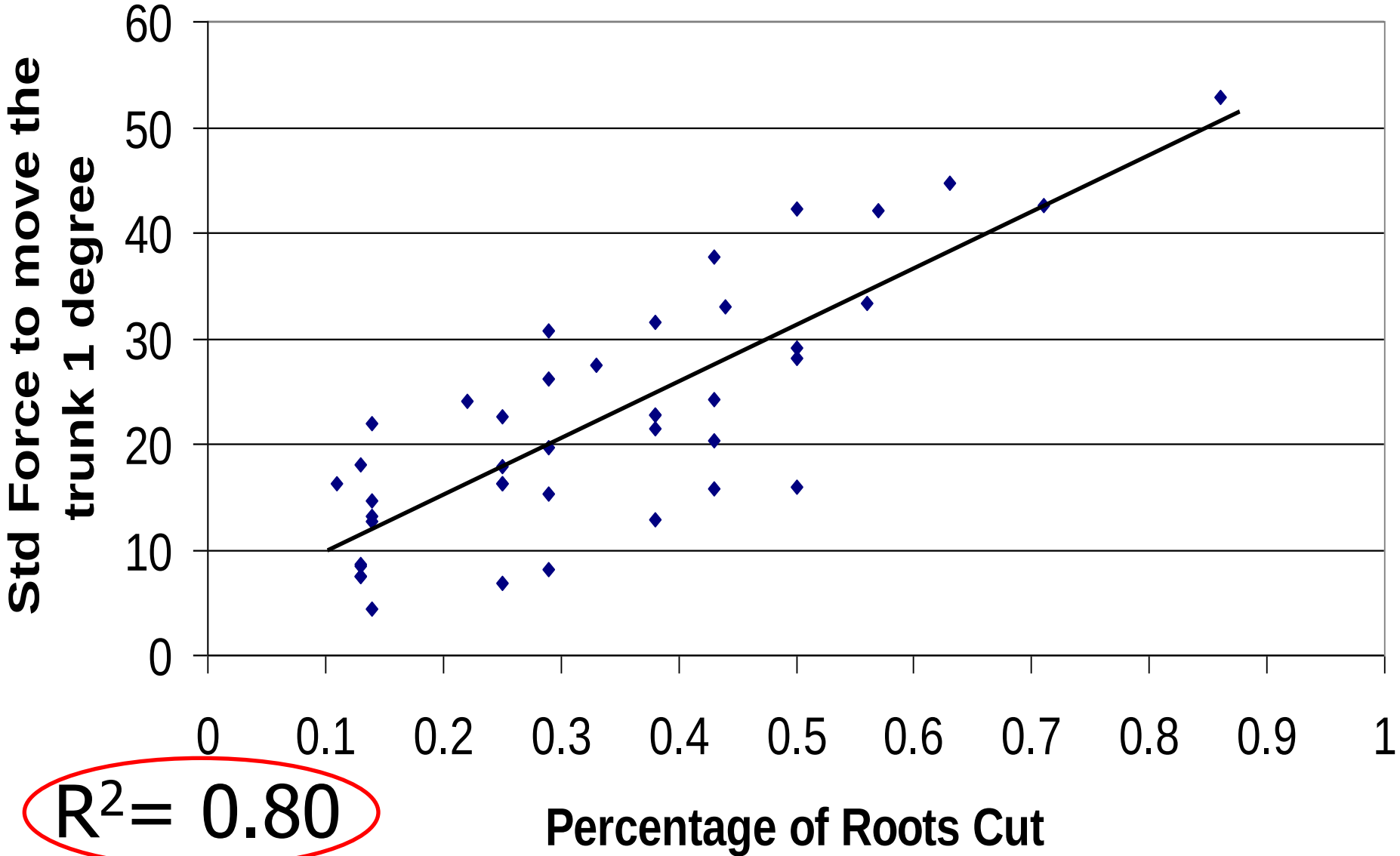
Cutting Individual Roots

Roots cut on the side opposite of the pull force (tension side)

Roots were cut one at a time until roots were severed from 50% of the trunk circumference

Red Maple with 50% of trunk circumference with roots cut

Individual Root Cuts on small Willow oak as a percentage of **number of roots**

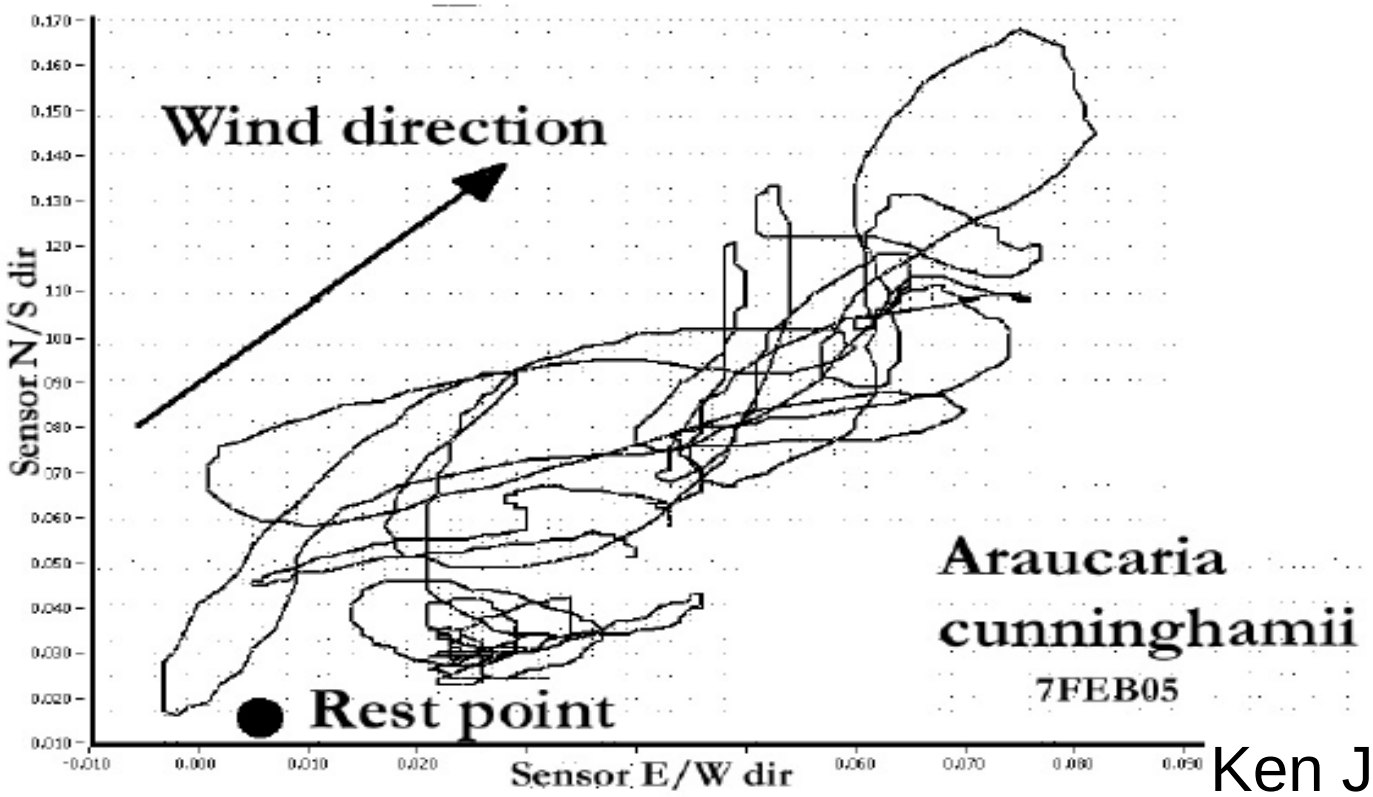


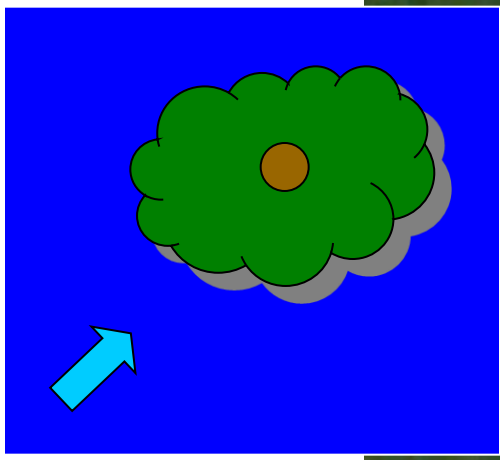
$R^2 = 0.80$

Individual Root Cuts

- Results are highly variable, one root cut can have 5 to 25% change
- Best not to cut any roots at the trunk
- More than 1/3 will significantly increase likelihood of failure

Limitations: 1) We tested with static loads. However, trees experience dynamic loads





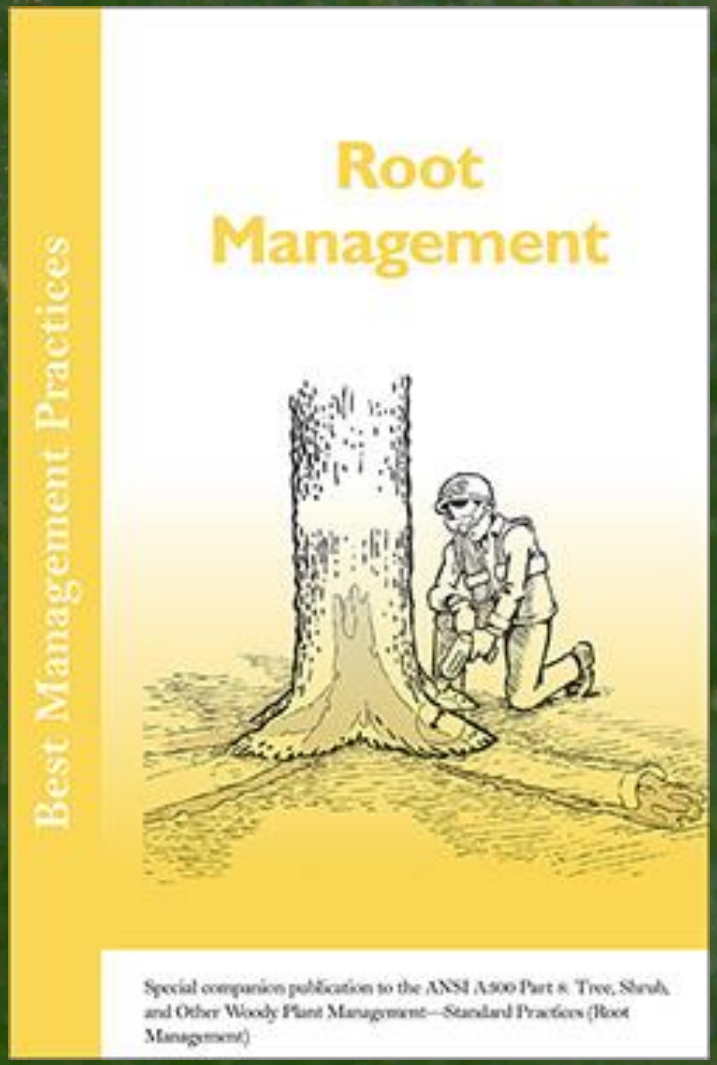
Ken James, 2005

Figure 5 Wind Forces on Hoop Pine (*Araucaria cunninghamii*) for a 2 min period

2) Trees will compensate for strength loss with response growth over time.
We tested immediately after damage.

As with all tree risk assessment, Response growth and Load should be considered in addition to root loss

Want more information on Root Management?



Root Assessment

Measure DBH

Count all significant buttress roots

Determine depth to decay in each

If less than DBH X 0.15 –Decayed

Determine % of roots with Decay or roots that are severed or missing

Likelihood of Failure General Guidelines

Imminent- > 50% of roots with significant decay, or if decay is uphill or opposite lean

Probable- > 33% of roots with significant decay, or is uphill or opposite lean roots are significantly decayed

Possible- < 33% of roots with Some decay

Improbable - no significant decay or cut roots, not in low or wet site etc

For more information:

Arboriculture & Urban Forestry 2008. 34(2):123–128.

Root Pruning and Stability of Young Willow Oak

E. Thomas Smiley

Abstract. Two root-pruning methods simulated construction-related trenching and individual root cuts such as from decay after root pruning. Tree trunks were pulled to an angle of 1° from vertical using measured force. A third of the study trees were pulled to failure to determine the relationship between the 1° pull force and the pull-to-failure force. The regression had correlation with r^2 equal to 0.76. Utility trenching was simulated with linear cuts across the root zone. Measurable decreases in force applied occurred when cuts were within three times the trunk diameter from the trunk. Force decreased by 35% when a tangential cut was

tsmiley@bartlettlab.com