WATER AND NUTRIENT INTERPLAY AND FOREST PRODUCTIVITY IN THE TROPICS

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WATER AND NUTRIENT INTERPLAY AND FOREST PRODUCTIVITY IN THE TROPICS

International Symposium
"Forest Soils under Global and Local Changes: from Research to Practice"

PROBLEM

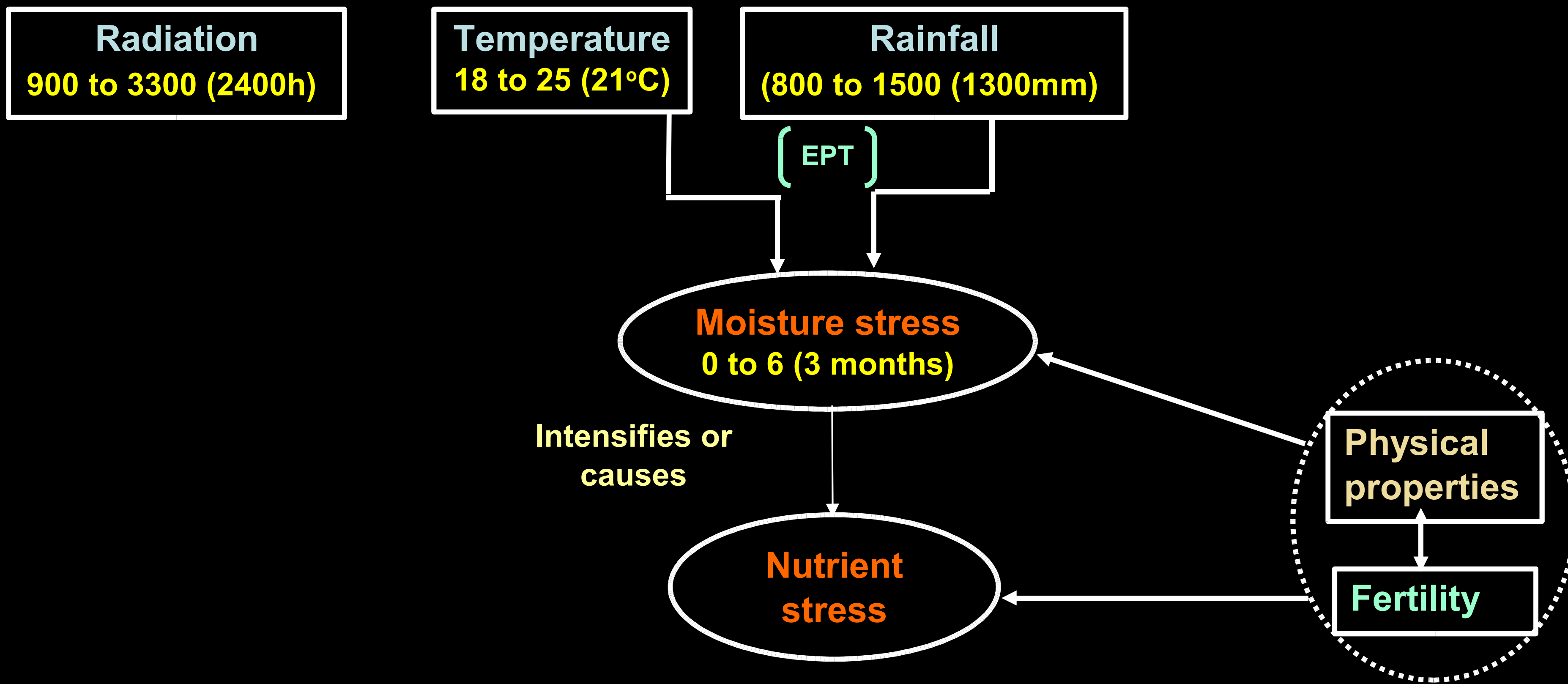
Tropical e subtropical environment

- **Large forest plantations established under seasonal moisture stress**

  - ❖ **24% of rainy**
  - ❖ **49% of seasonal**
  - ❖ **27% of dry and desert climate**

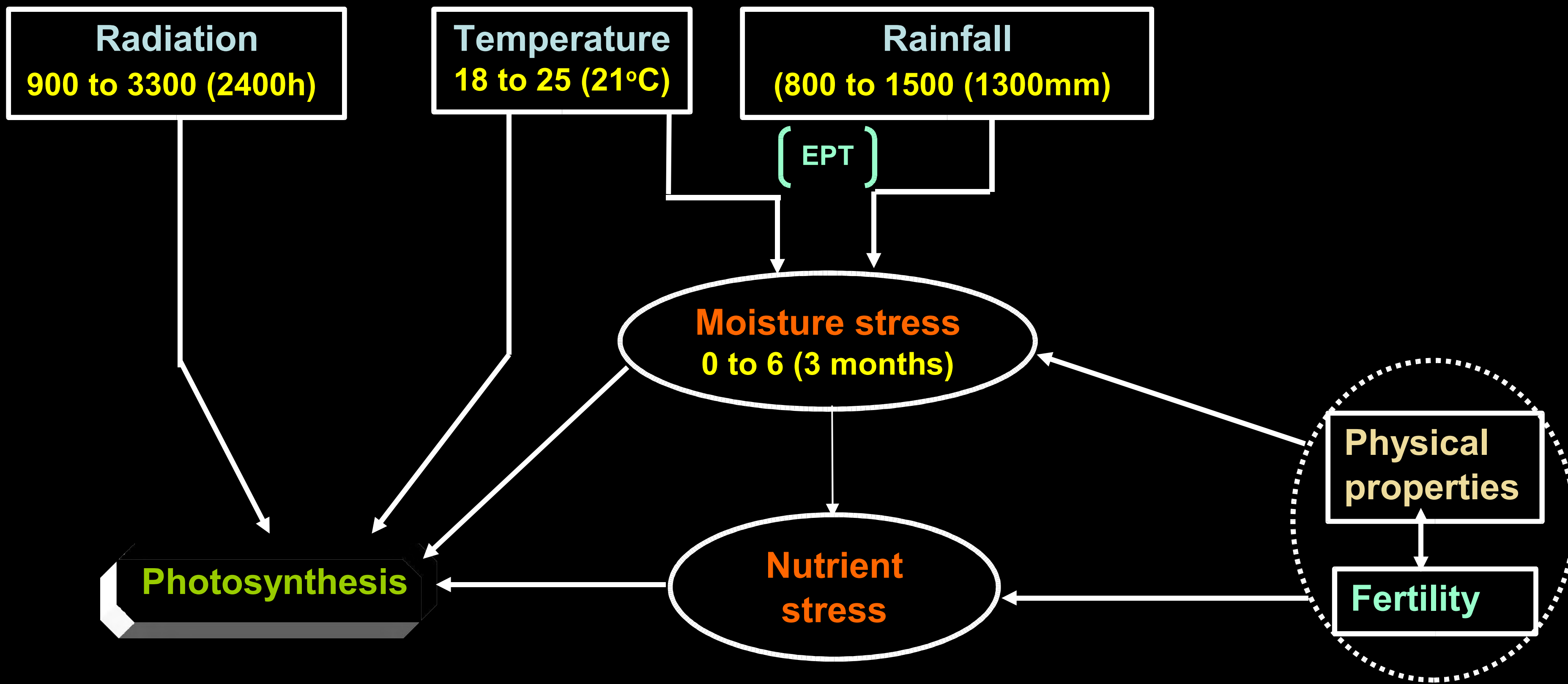
Sánchez (1976)

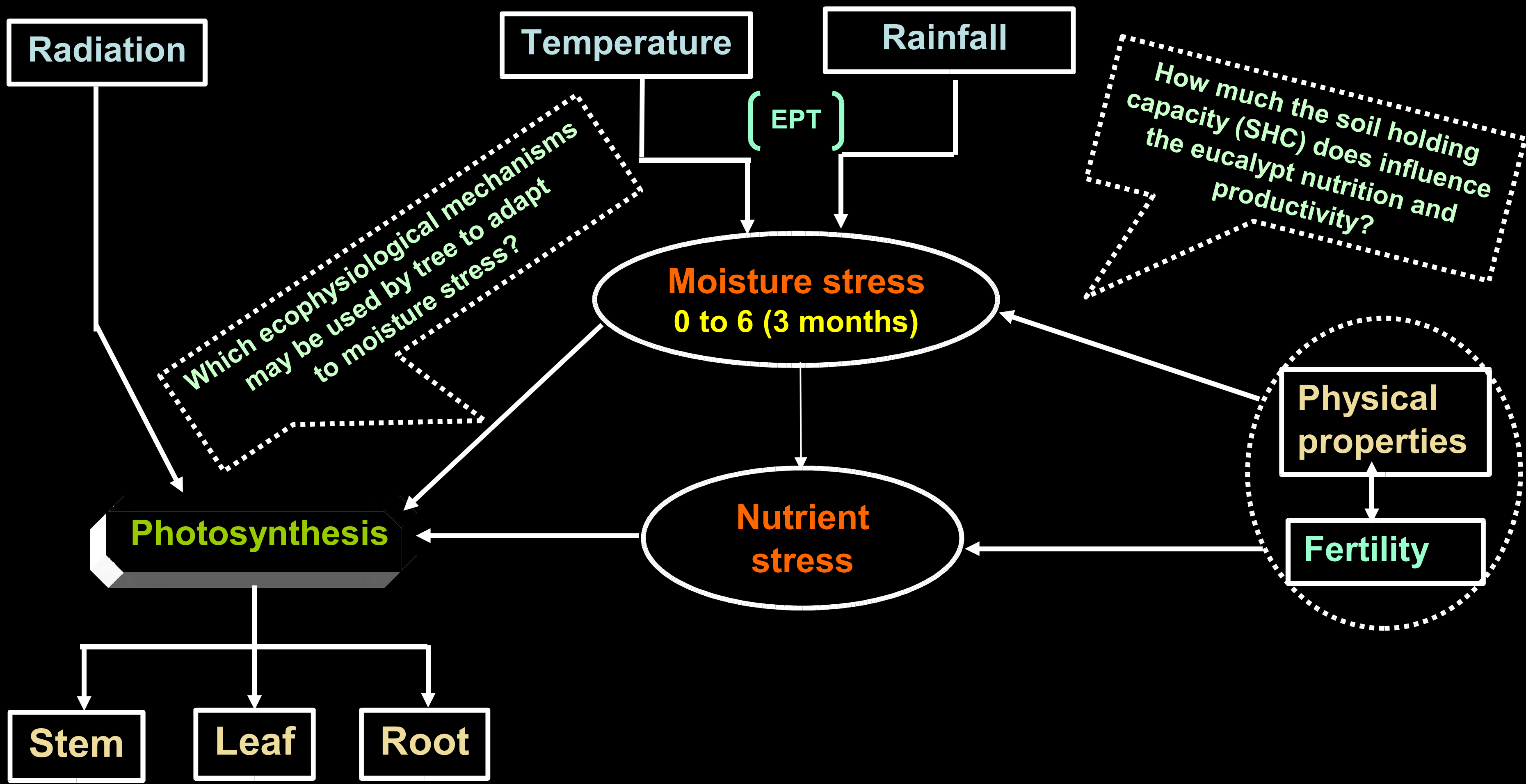
Increase or maintenance of productivity has narrows relationship with efficiency of use of rainfall and soil fertility (natural and modified)



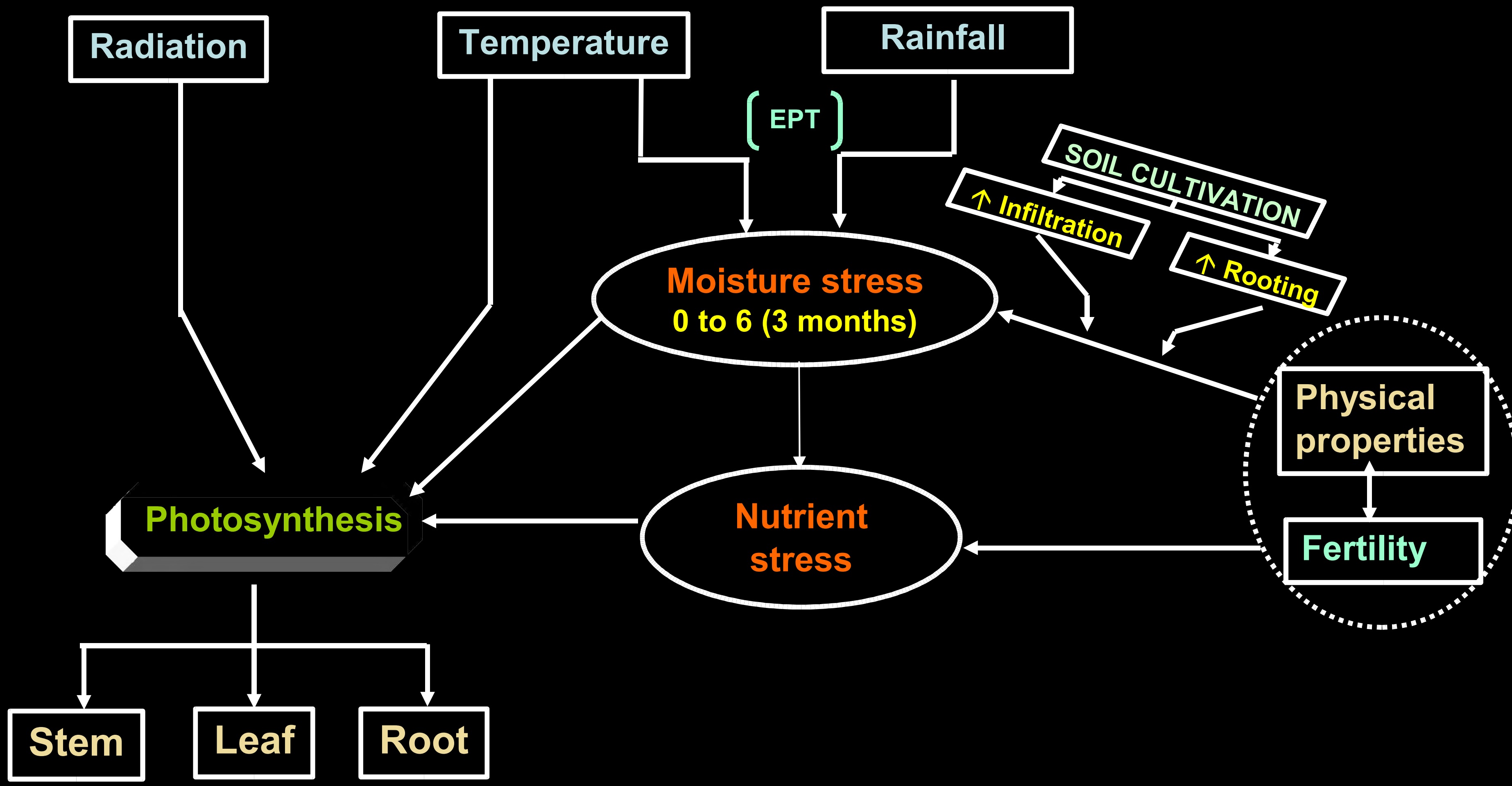
Radiation
900 to 3300 (2400h)
Temperature
18 to 25 (21°C)
Rainfall
(800 to 1500 (1300mm)
EPT
Moisture stress
0 to 6 (3 months)
Intensifies or causes
Nutrient stress
Physical properties
Fertility

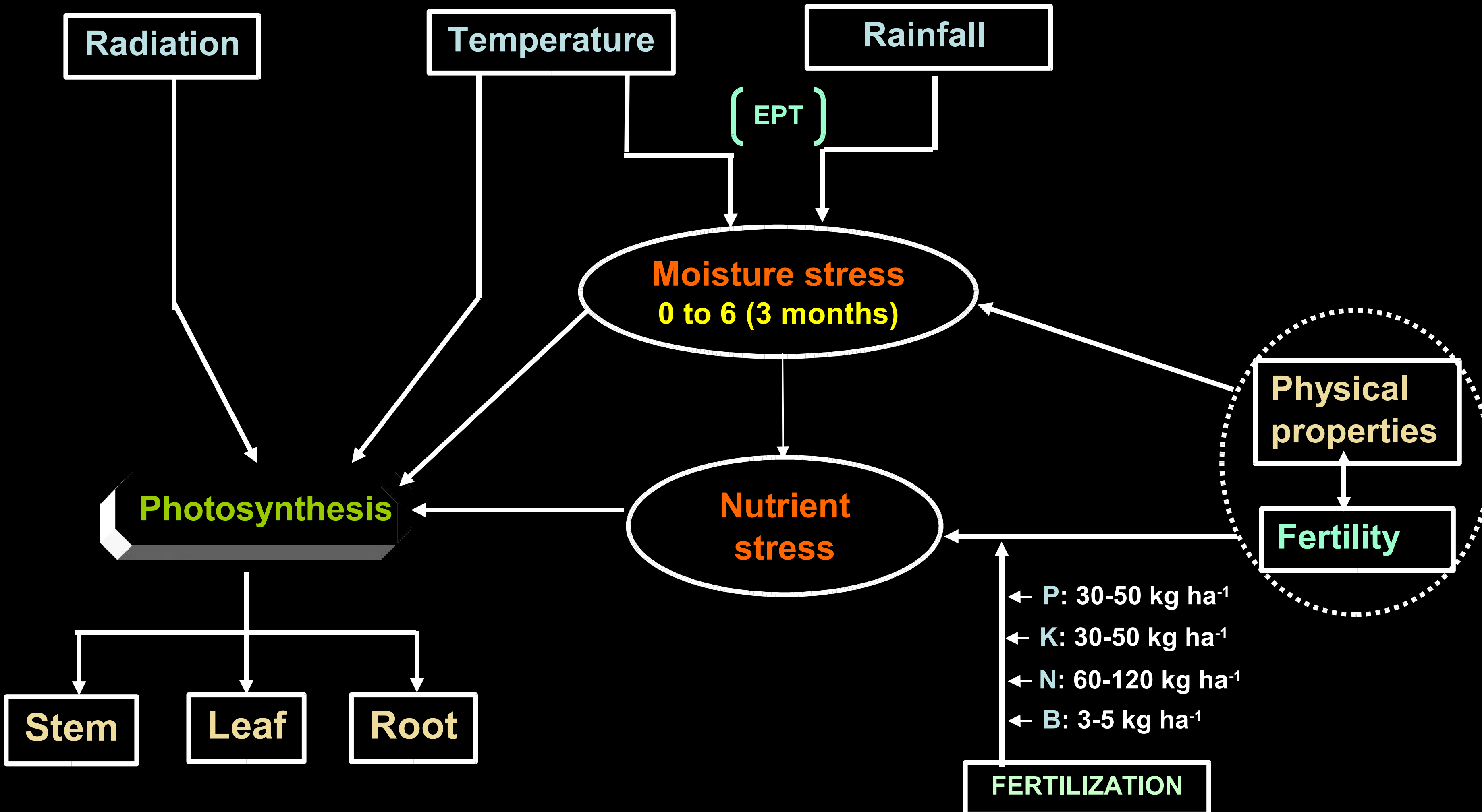

Seasonal P deficiency
Fertilized with 50 kg P ha-1
2004 8 20

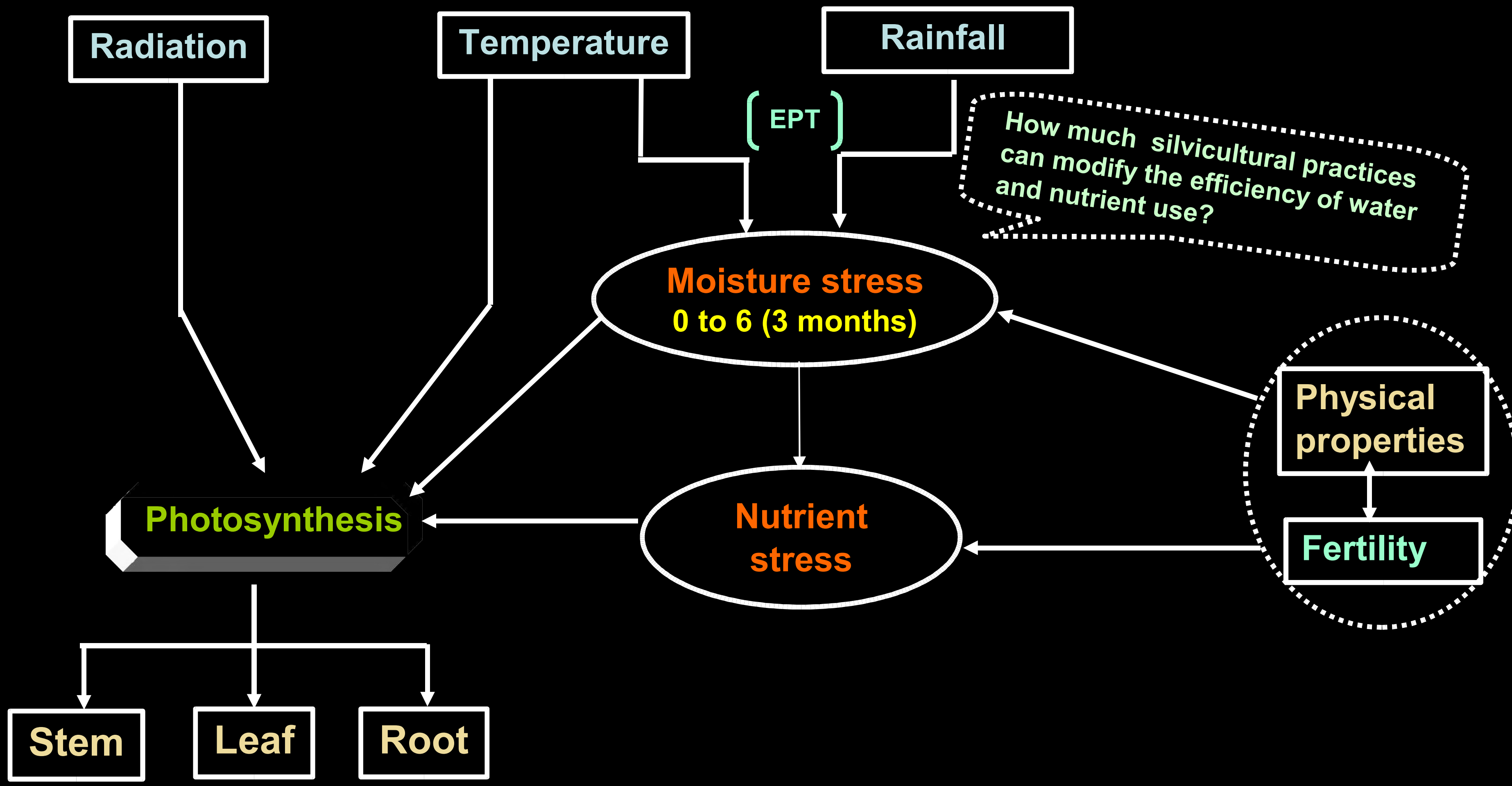

Radiation
900 to 3300 (2400h)
Temperature
18 to 25 (21°C)
Rainfall
(800 to 1500 (1300mm)
EPT
Moisture stress
0 to 6 (3 months)
Photosynthesis
Nutrient stress
Physical properties
Fertility

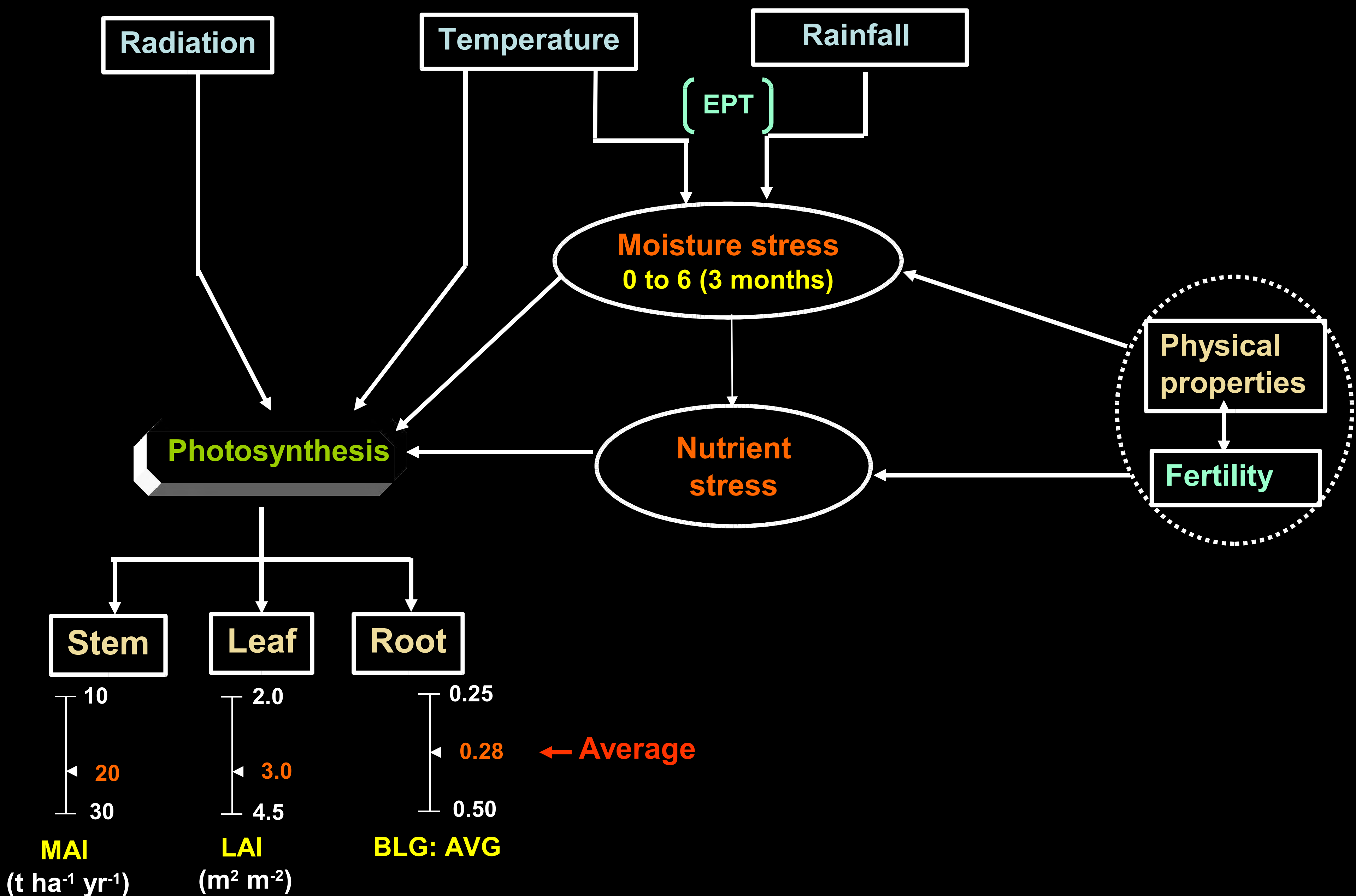


Radiation
Temperature
Rainfall
EPT
How much the soil holding capacity (SHC) does influence the eucalypt nutrition and productivity?
Which ecophysiological mechanisms may be used by tree to adapt to moisture stress?
Moisture stress
0 to 6 (3 months)
Physical properties
Fertility
Nutrient stress
Photosynthesis
Stem
Leaf
Root


Radiation
Temperature
Rainfall
EPT
SOIL CULTIVATION
↑ Infiltration
↑ Rooting
Moisture stress
0 to 6 (3 months)
Photosynthesis
Nutrient stress
Physical properties
Fertility
Stem
Leaf
Root


Radiation
Temperature
Rainfall
EPT
Moisture stress
0 to 6 (3 months)
Photosynthesis
Nutrient stress
Physical properties
Fertility
P: 30-50 kg ha-1
K: 30-50 kg ha-1
N: 60-120 kg ha-1
B: 3-5 kg ha-1
FERTILIZATION
Stem
Leaf
Root


Radiation
Temperature
Rainfall
EPT
How much silvicultural practices can modify the efficiency of water and nutrient use?
Moisture stress
0 to 6 (3 months)
Physical properties
Fertility
Nutrient stress
Photosynthesis
Stem
Leaf
Root


Radiation
Temperature
Rainfall
EPT
Moisture stress
0 to 6 (3 months)
Physical properties
Fertility
Photosynthesis
Nutrient stress
Stem
Leaf
Root
10
20
30
MAI
(t ha-1 yr-1)
2.0
3.0
4.5
LAI
(m2 m-2)
0.25
0.28
0.50
BLG: AVG
Average

STUDY OF CASE

Selected sites established with *Eucalyptus grandis* with seasonal moisture stress

PRECONDITIONS

High technological standard

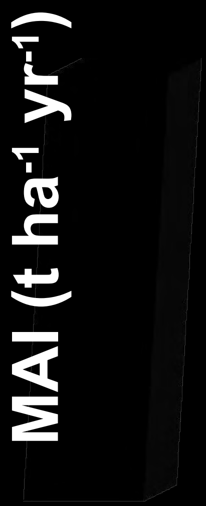
- Without nutrient shortage (adequately supplied by fertilizes)
- Without weed competition
- Without limiting soil structure

Eucalyptus grandis (seedlings)

6 years old

Same climate and relief conditions

Increasing clay content: 12 to 60% (0-40cm)



Fertilization (kg ha^{-1})

N: 80

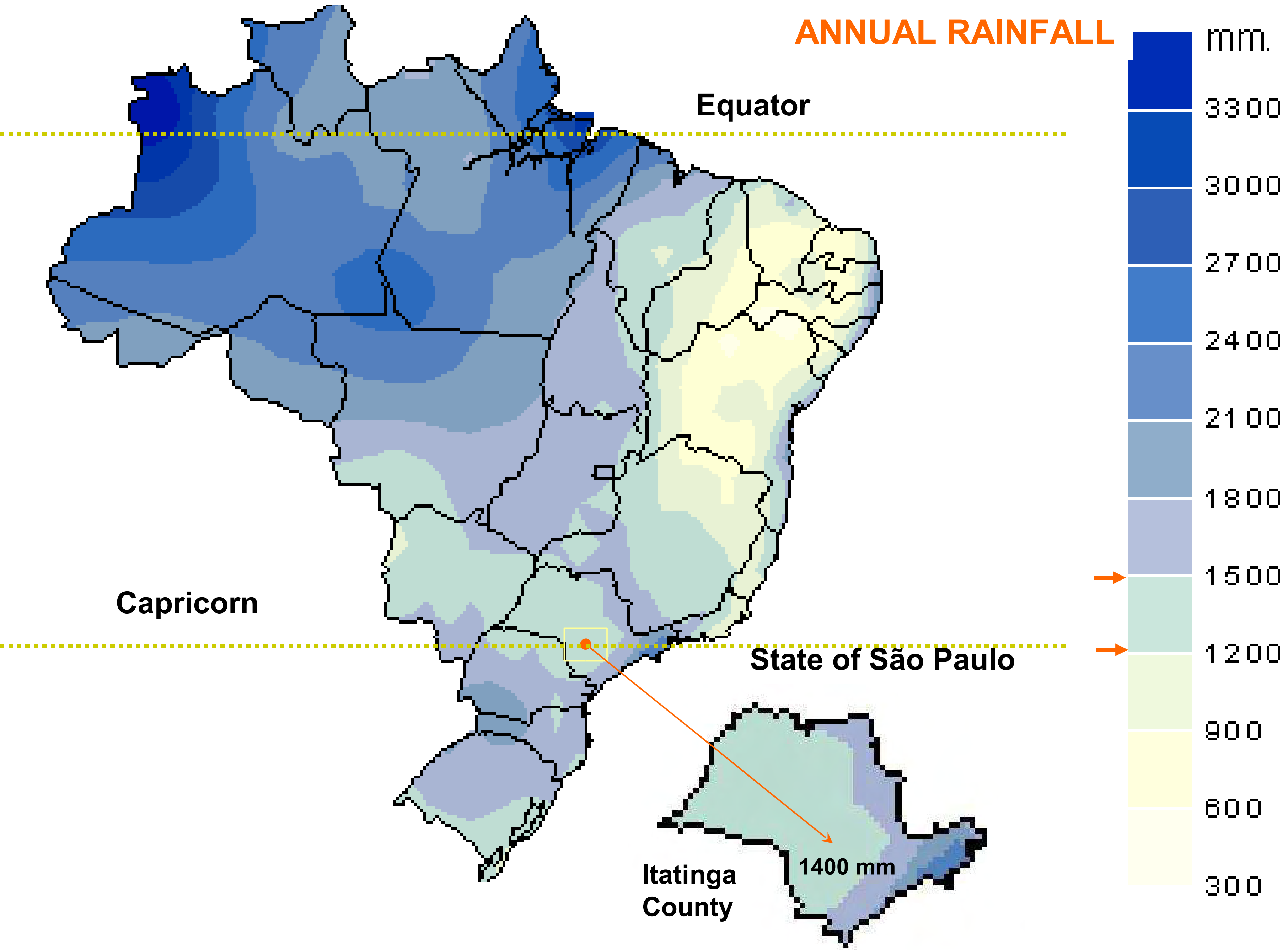
P: 50

K: 100

B: 3

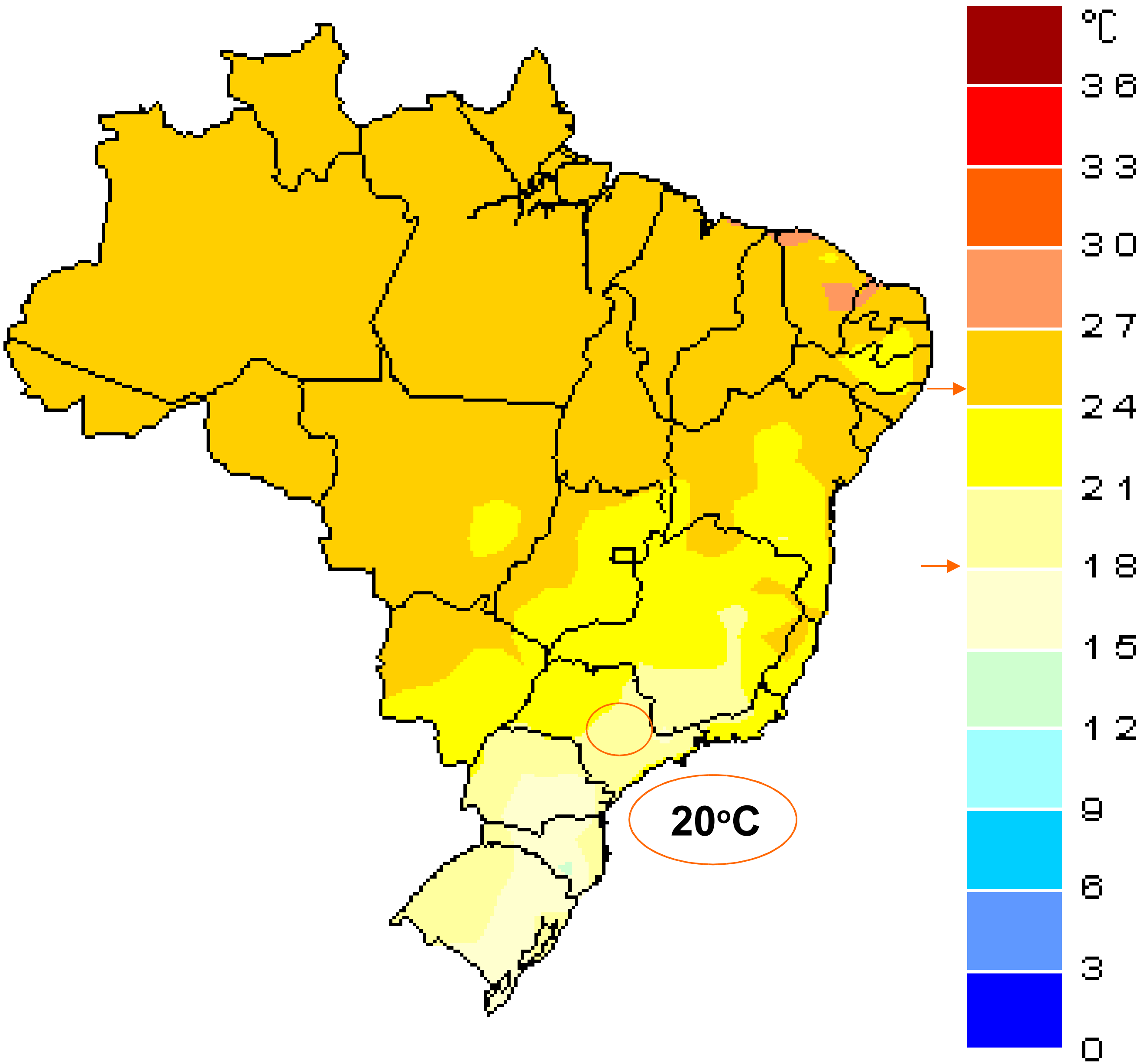
2 t ha^{-1} lime

25 plots



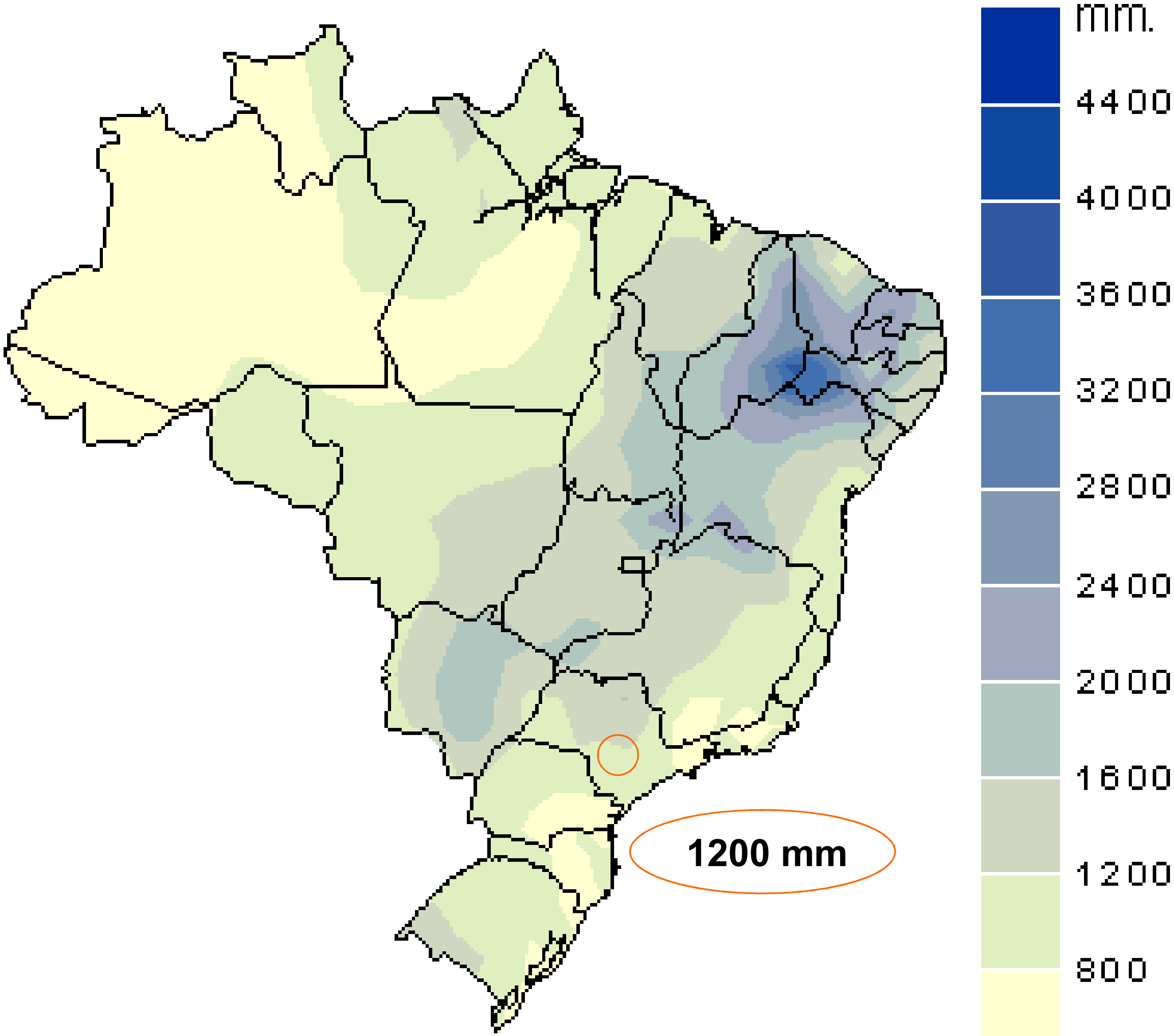
ANNUAL RAINFALL
mm.
3300
3000
2700
2400
2100
1800
1500
1200
900
600
300
Equator
Capricorn
State of São Paulo
Itatinga County
1400 mm

ANNUAL AVERAGE TEMPERATURE



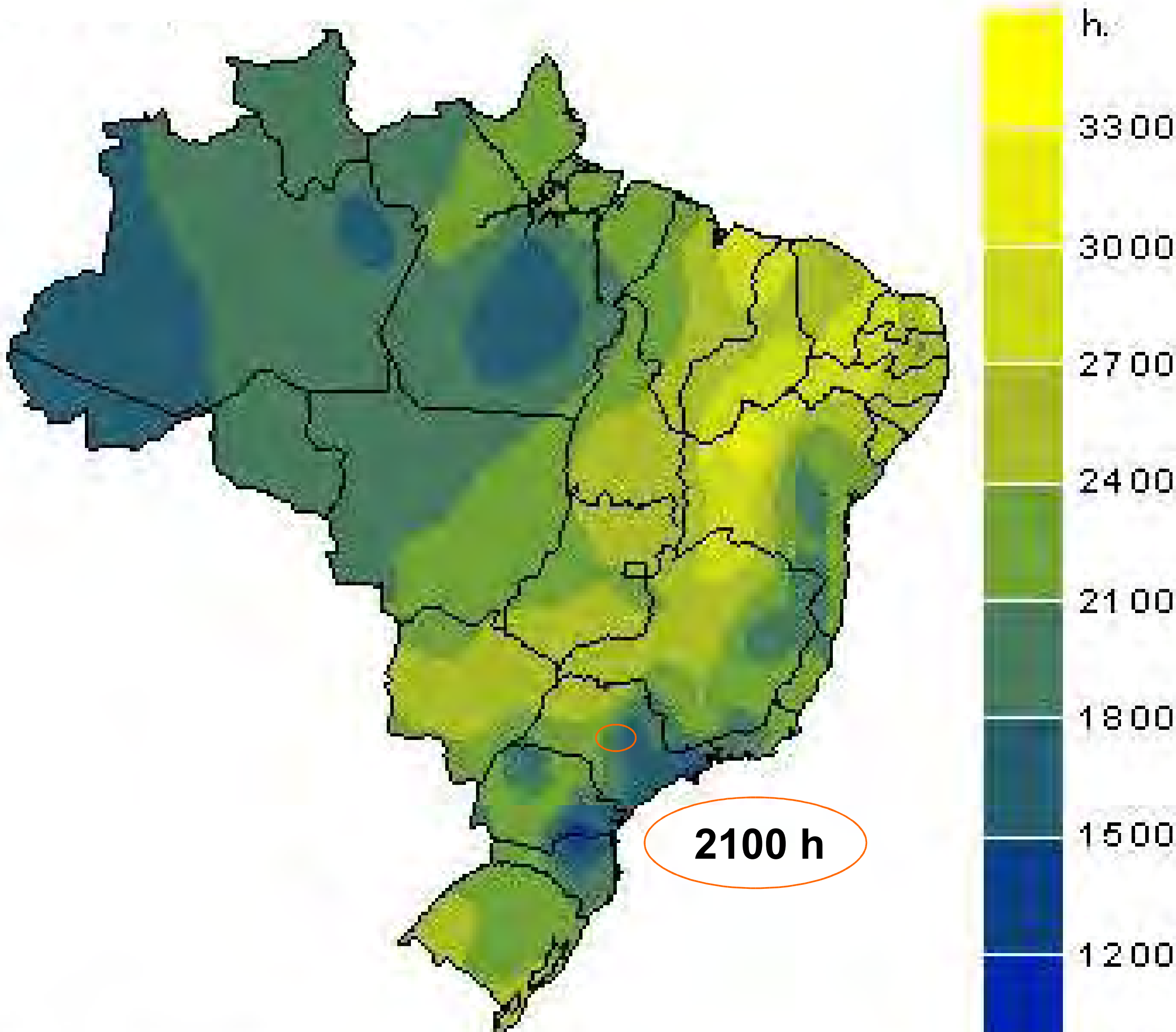
Source: INMET 1931/1990

ANNUAL EVAPORATION

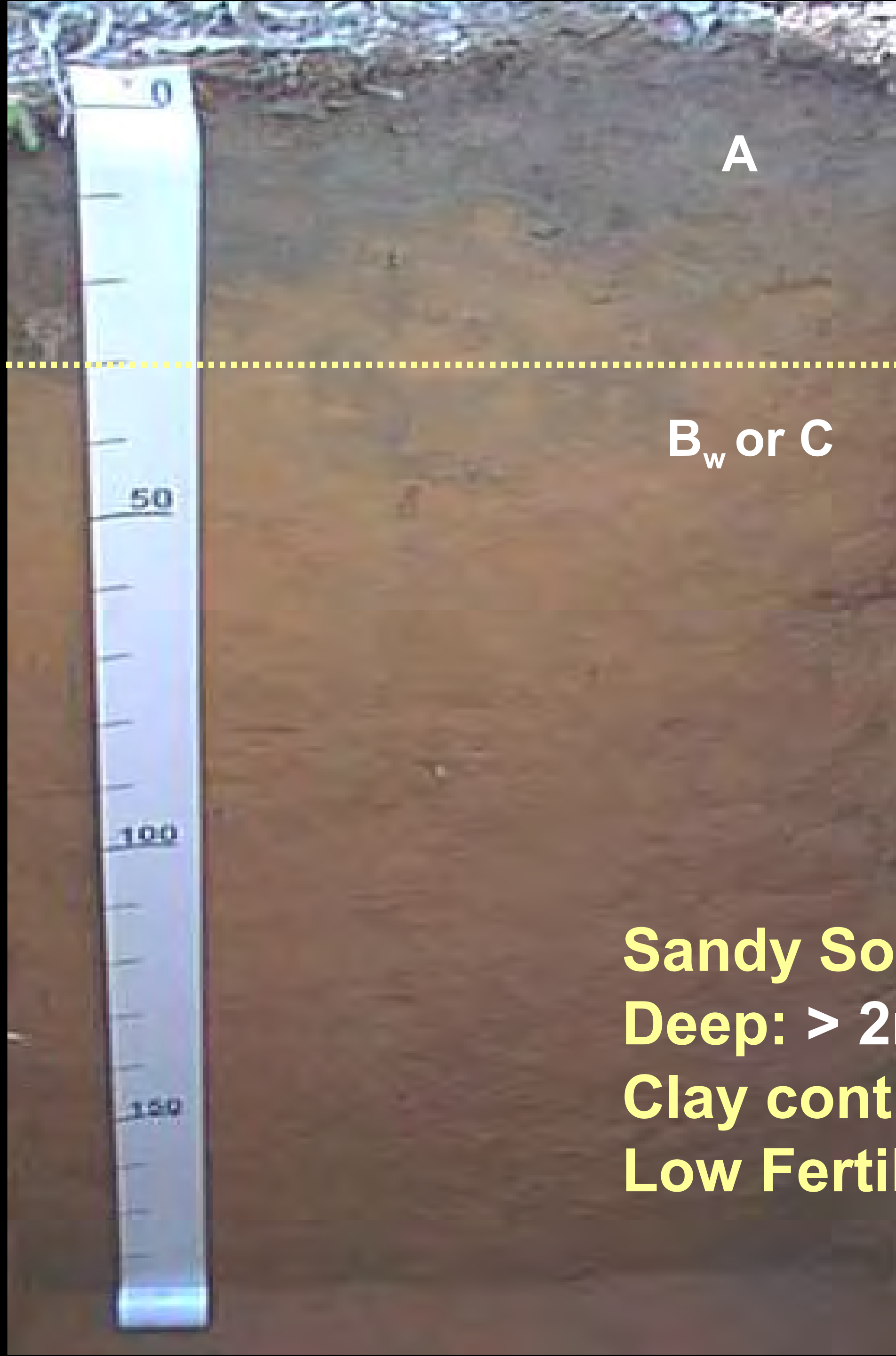


Source: INMET 1931/1990

ANNUAL RADIATION



Source: INMET 1931/1990

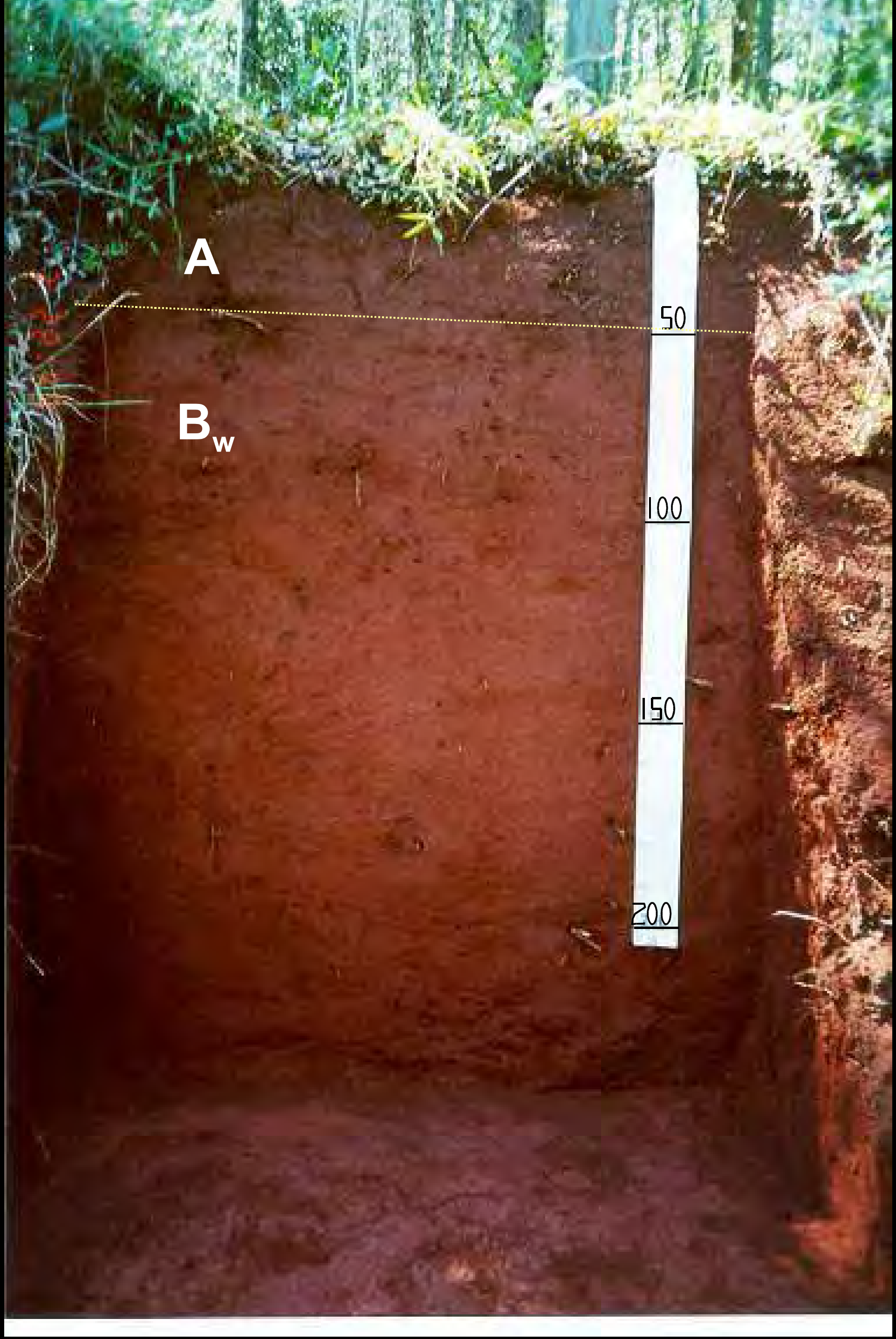


Sandy Soil and Loam Oxisol

Deep: > 2m

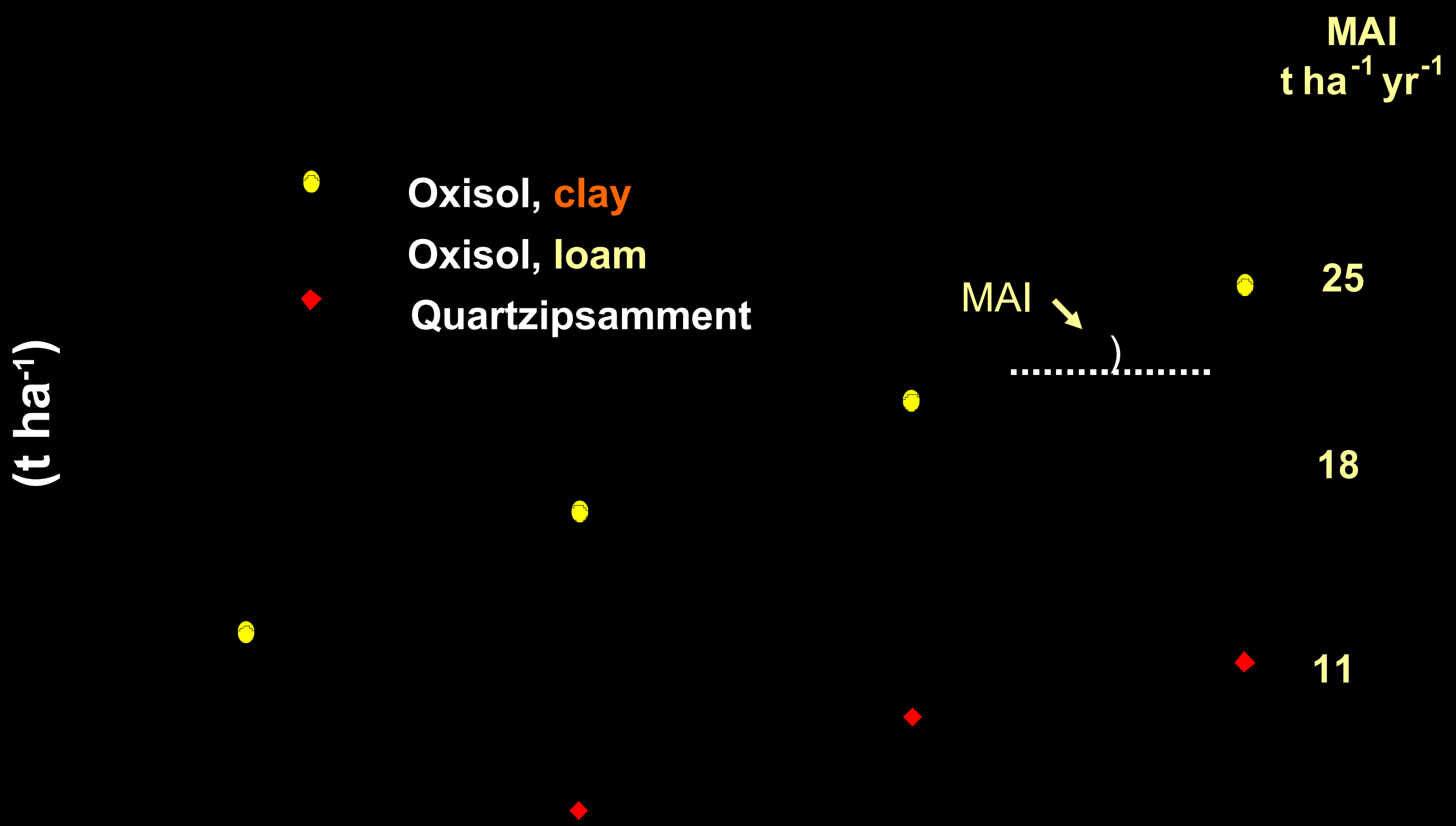
Clay cont.: 10 to 35%

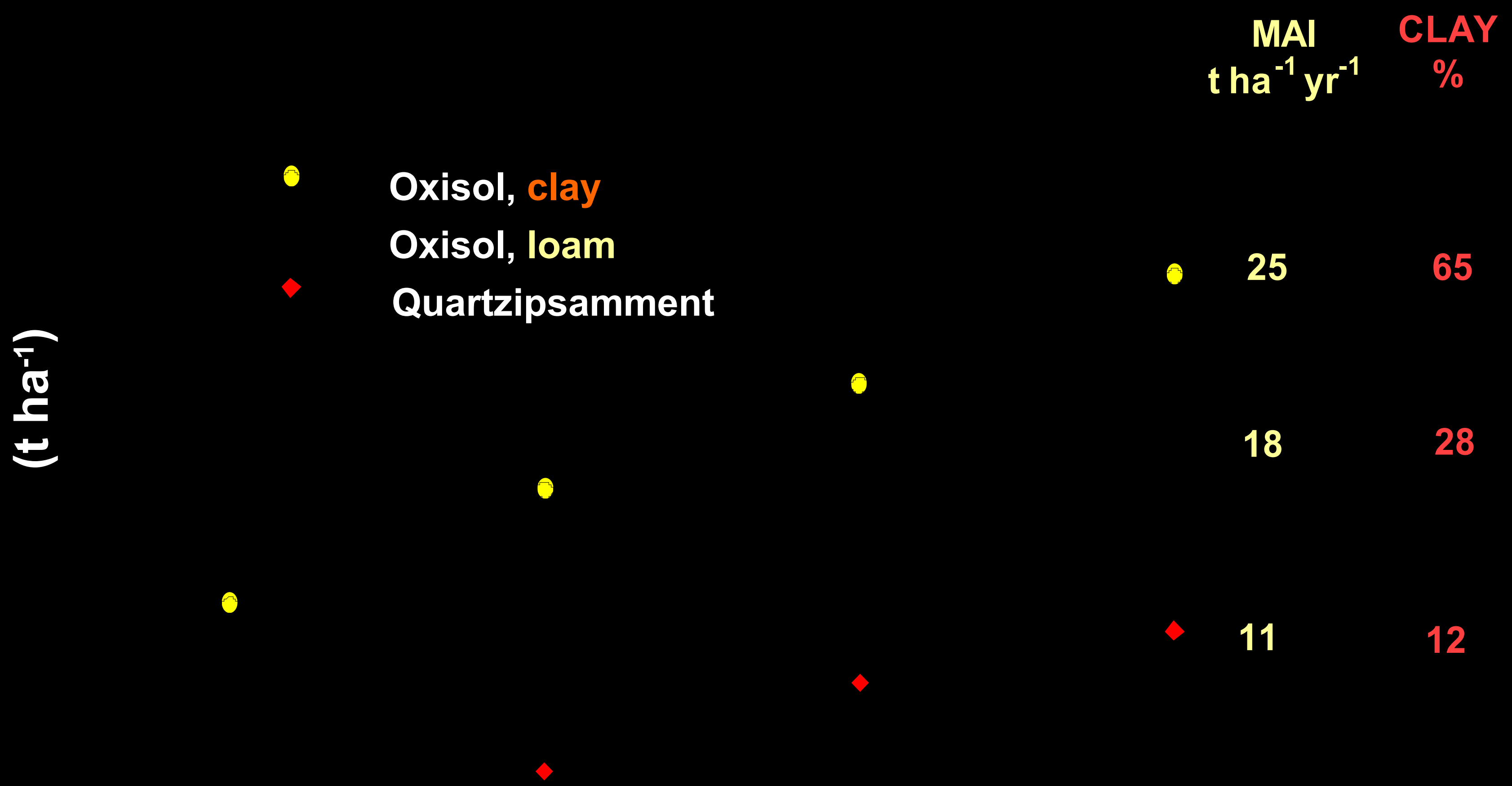
Low Fertility

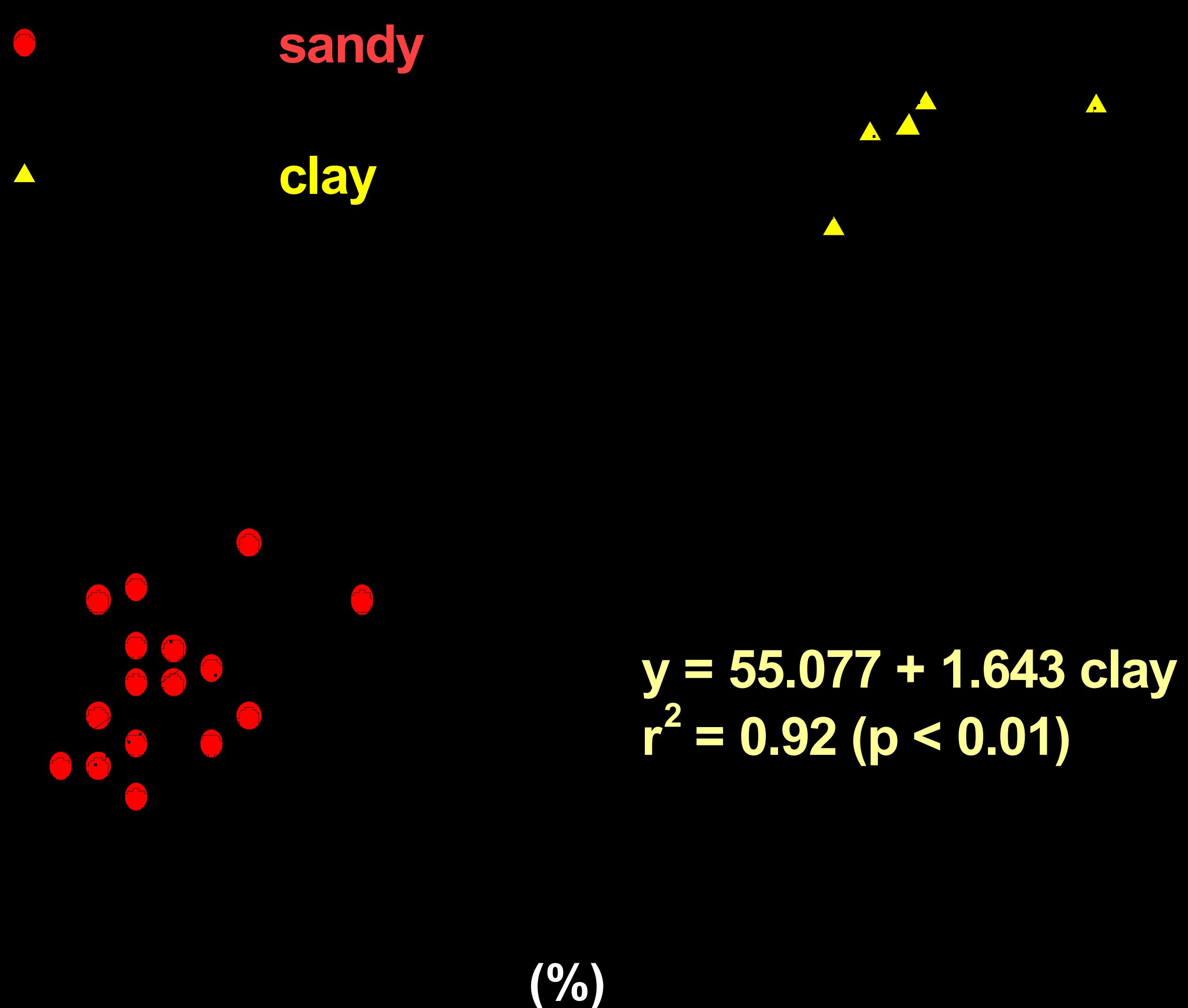


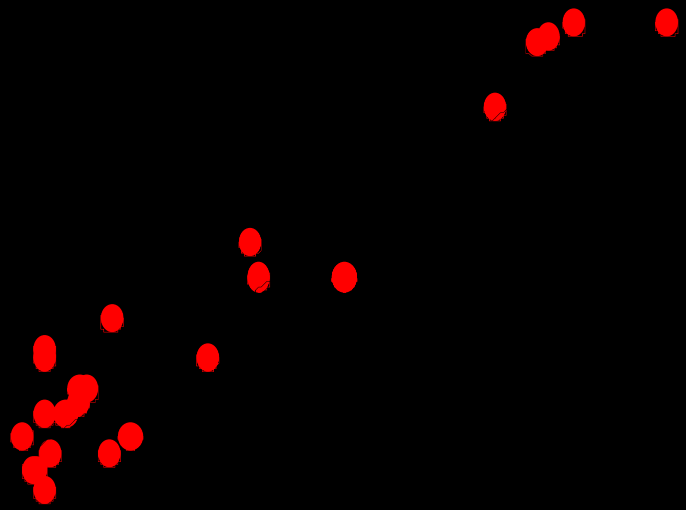
Oxisol
Deep: > 2m
Clay: 35 to 60%
Low Fertility

Eucalyptus grandis



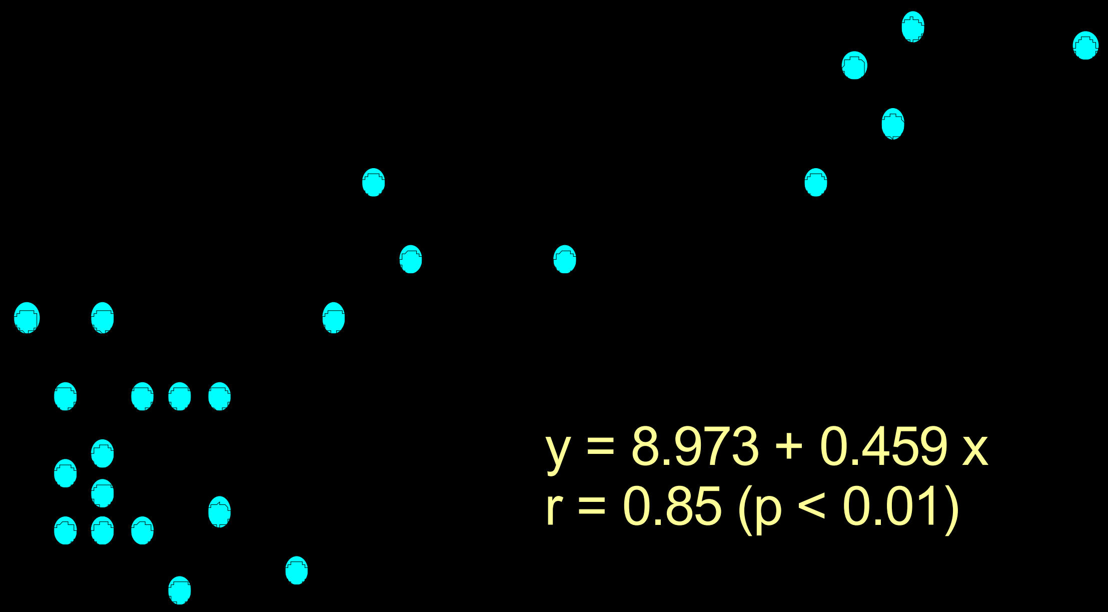

MAI
t ha-1 yr-1
CLAY
%
Oxisol, clay
Oxisol, loam
Quartzipsamment
(t ha-1)
25
65
18
28
11
12


sandy
clay
y = 55.077 + 1.643 clay
r2 = 0.92 (p < 0.01)
(%)



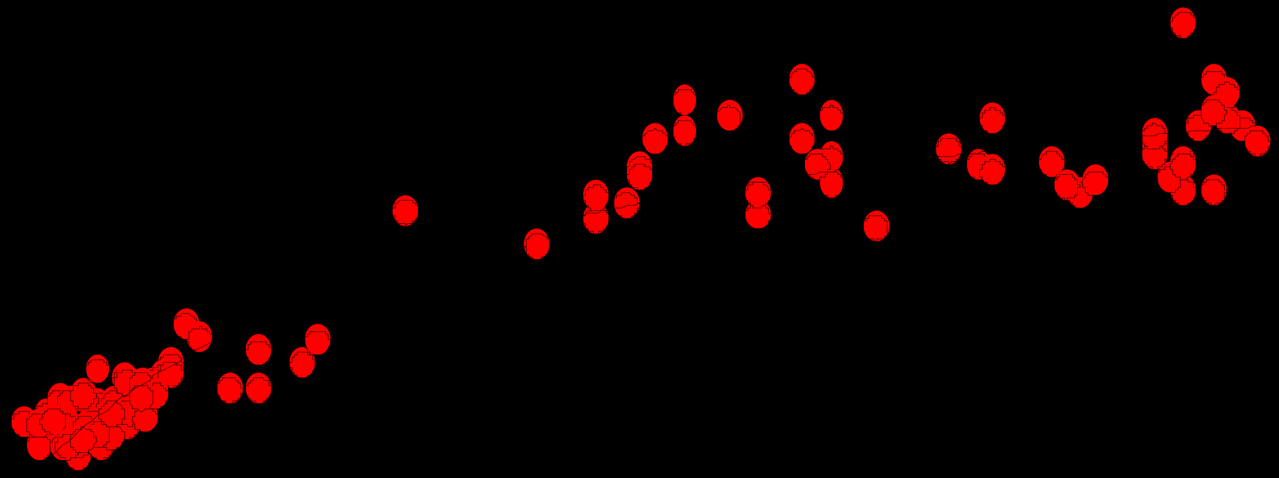
$MAI = 8.510 + 0.240\ Clay + 0.072\ SOM^{ns}$

$R^2 = 0.91$ ($p < 0.01$)


y = 8.973 + 0.459 x
r = 0.85 (p < 0.01)

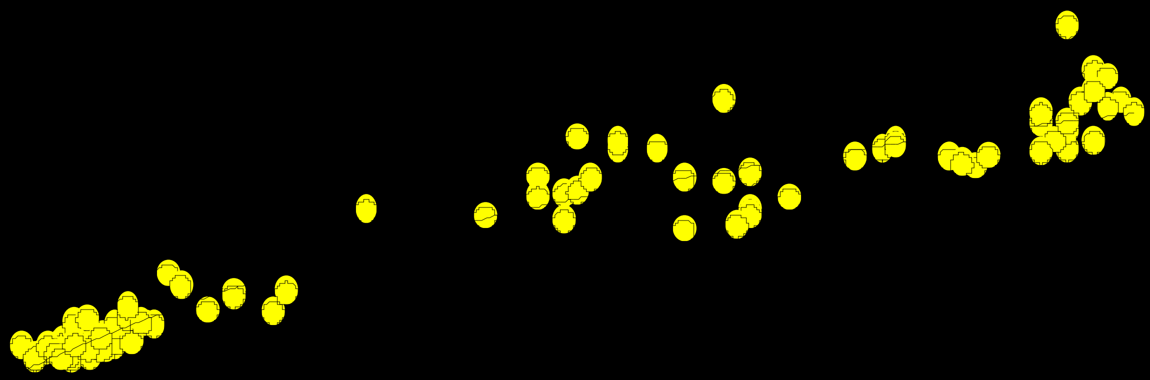
$$FC = \frac{0.533\ CLAY}{(27.865 + CLAY)}$$

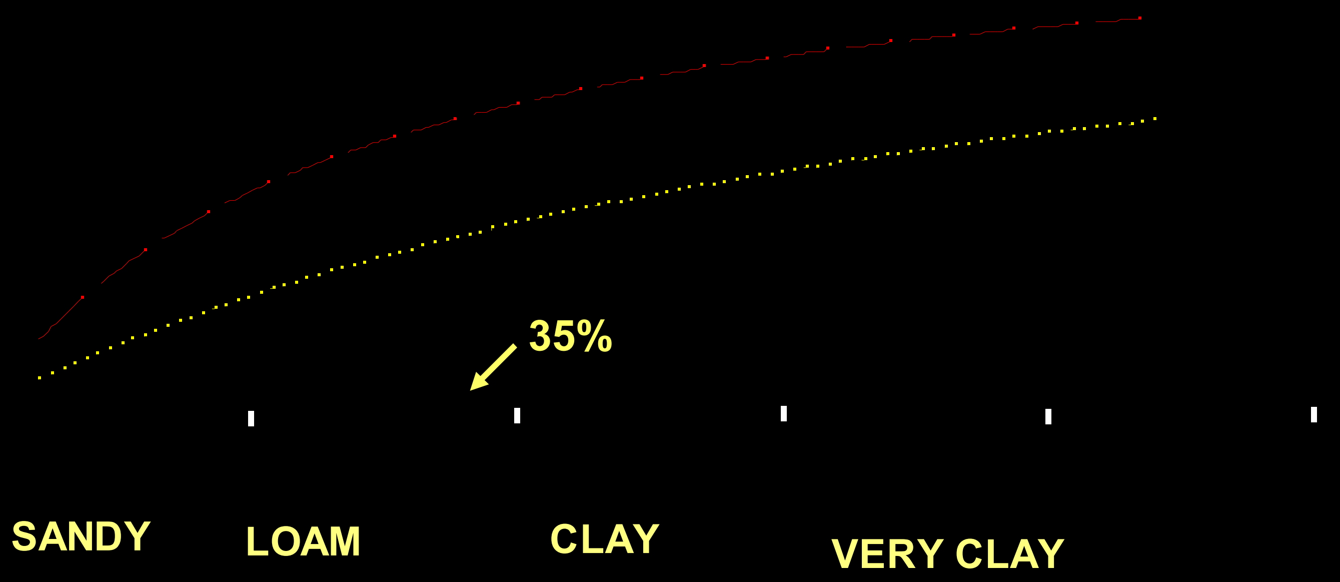
$r^2 = 0.92;\ p < 0.01$

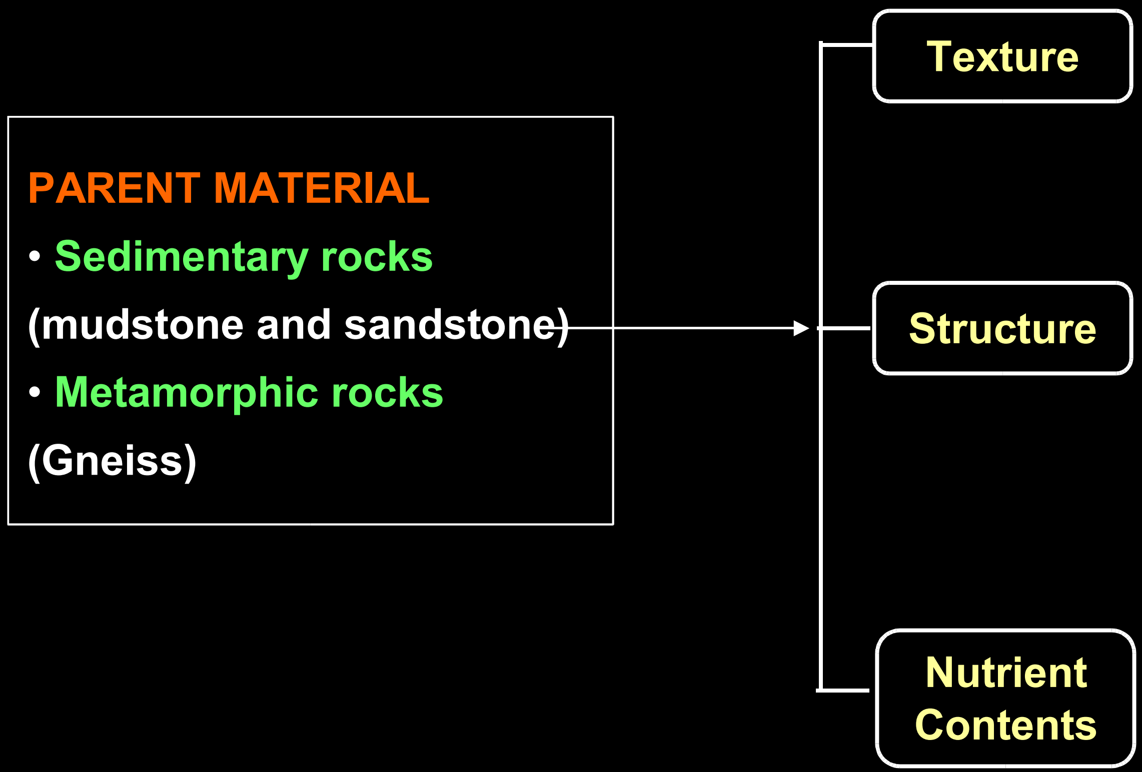


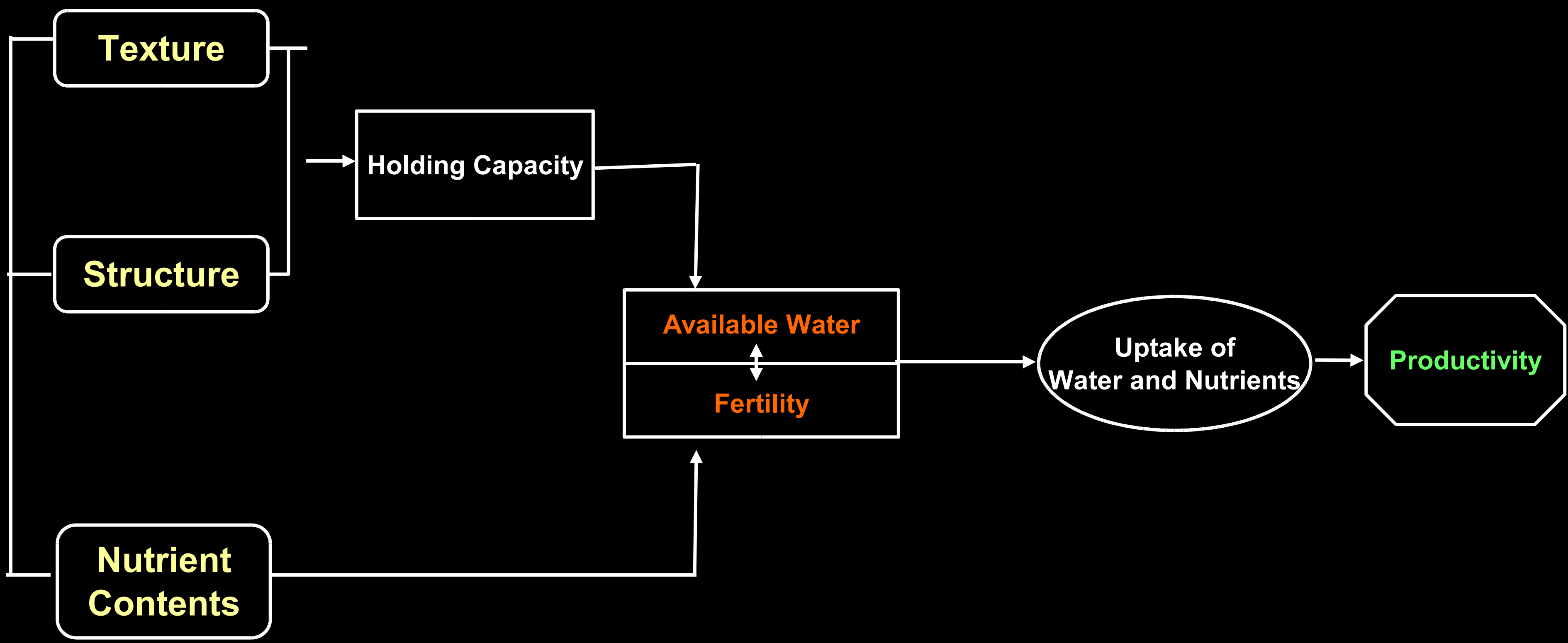
$$WP = \frac{0.559\ CLAY}{(76.859 + CLAY)}$$

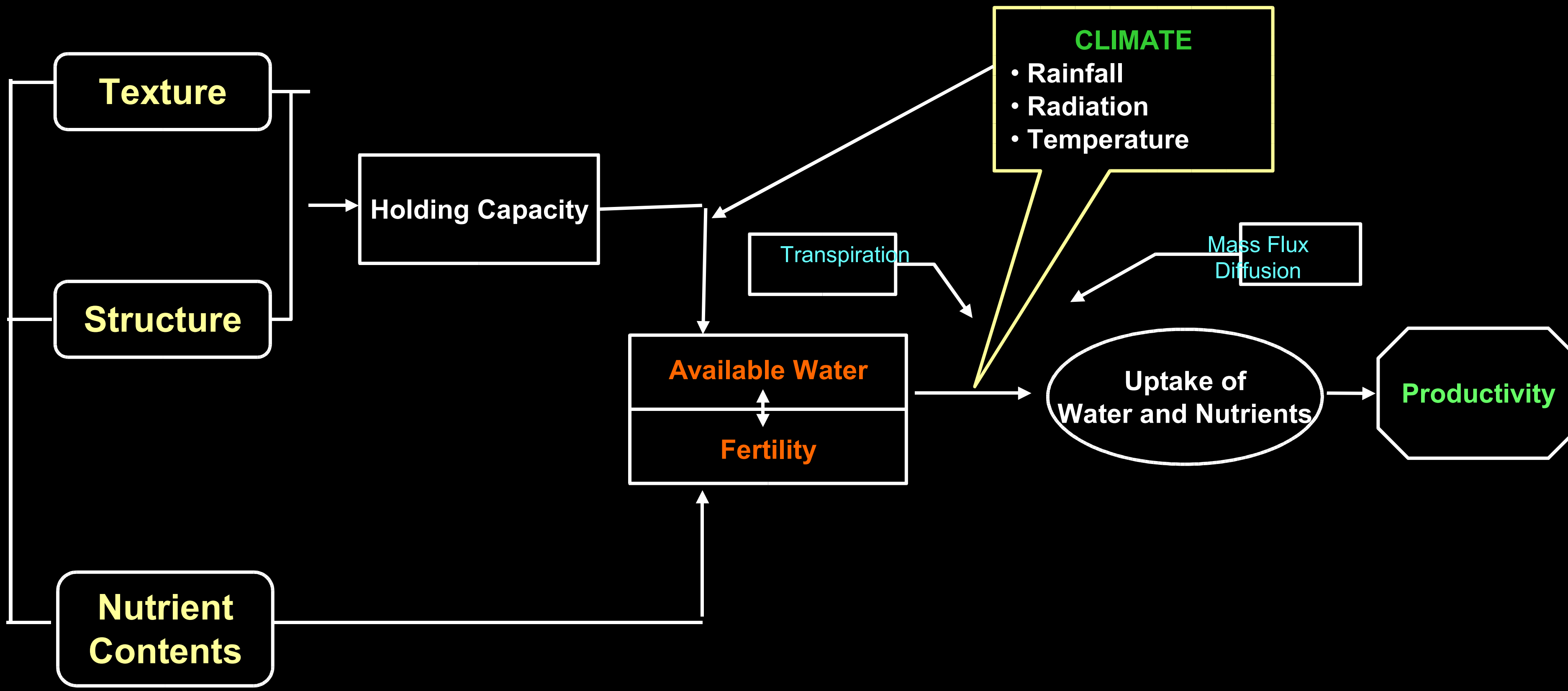
$r^2 = 0.94; p < 0.01$



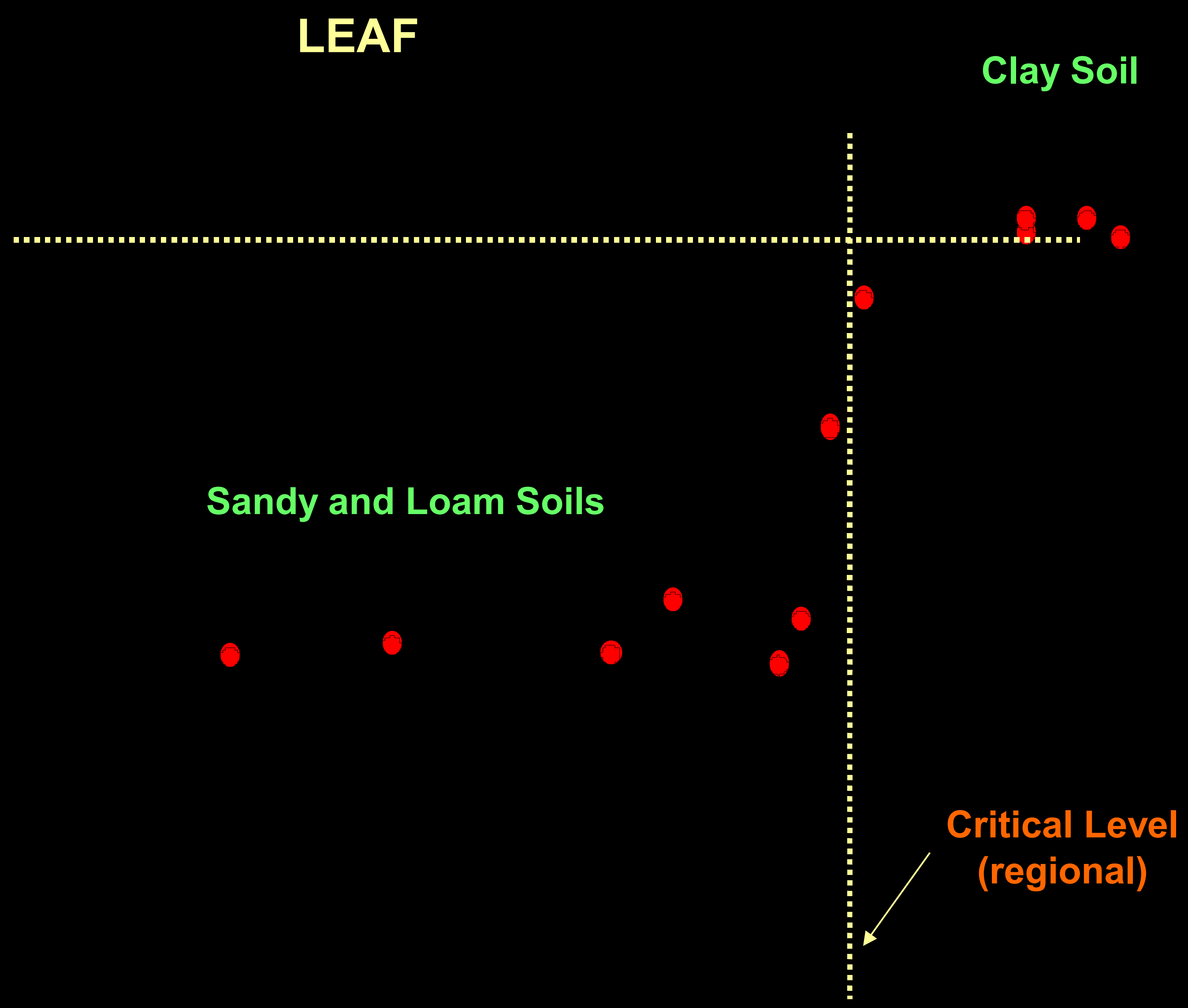

35%
SANDY
LOAM
CLAY
VERY CLAY


PARENT MATERIAL
• Sedimentary rocks
(mudstone and sandstone)
• Metamorphic rocks
(Gneiss)
Texture
Structure
Nutrient Contents


Texture
Structure
Nutrient Contents
Holding Capacity
Available Water
Fertility
Uptake of Water and Nutrients
Productivity

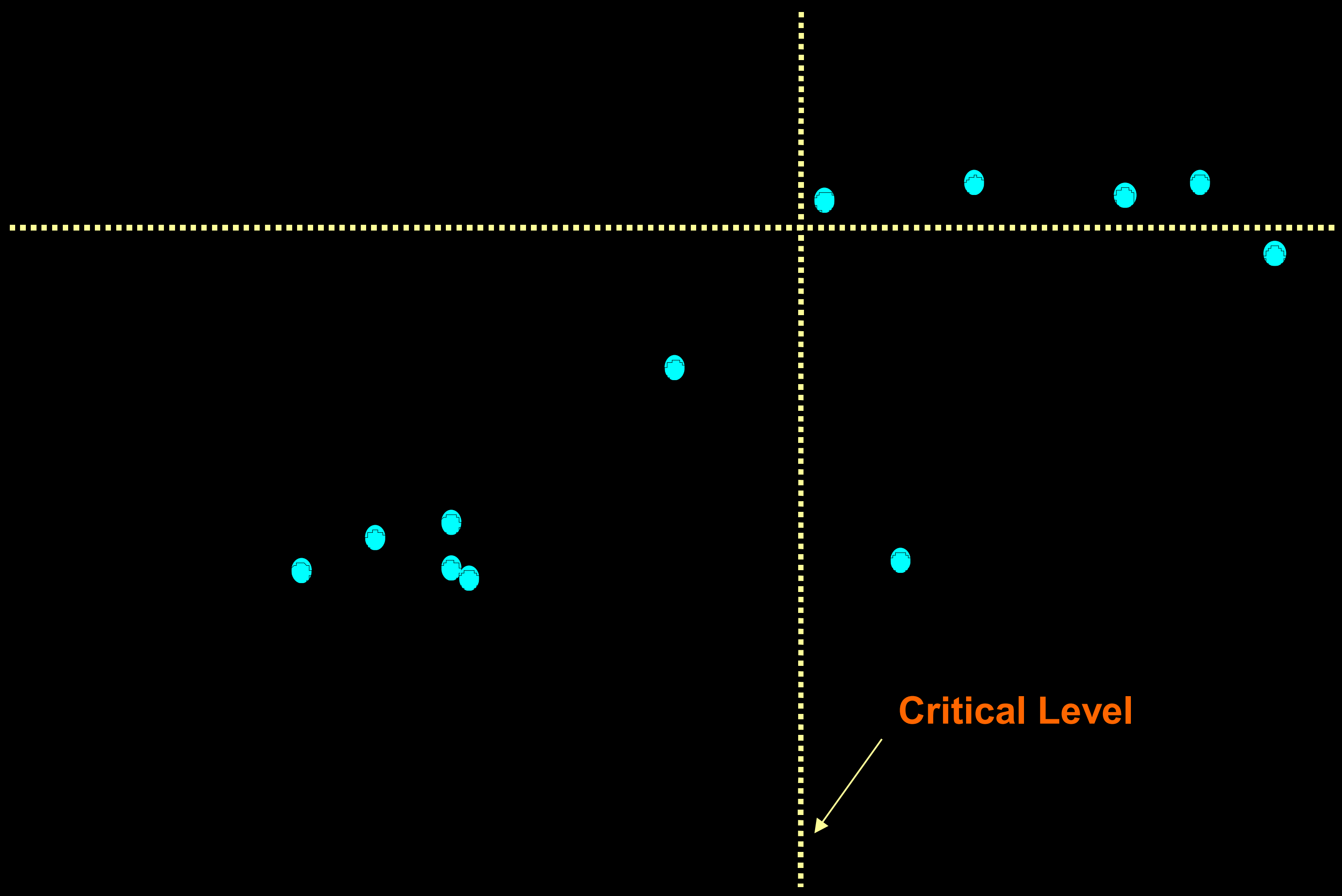


Texture
Structure
Nutrient Contents
Holding Capacity
CLIMATE
• Rainfall
• Radiation
• Temperature
Transpiration
Mass Flux
Diffusion
Available Water
Fertility
Uptake of Water and Nutrients
Productivity


LEAF
Clay Soil
Sandy and Loam Soils
Critical Level
(regional)

LEAF

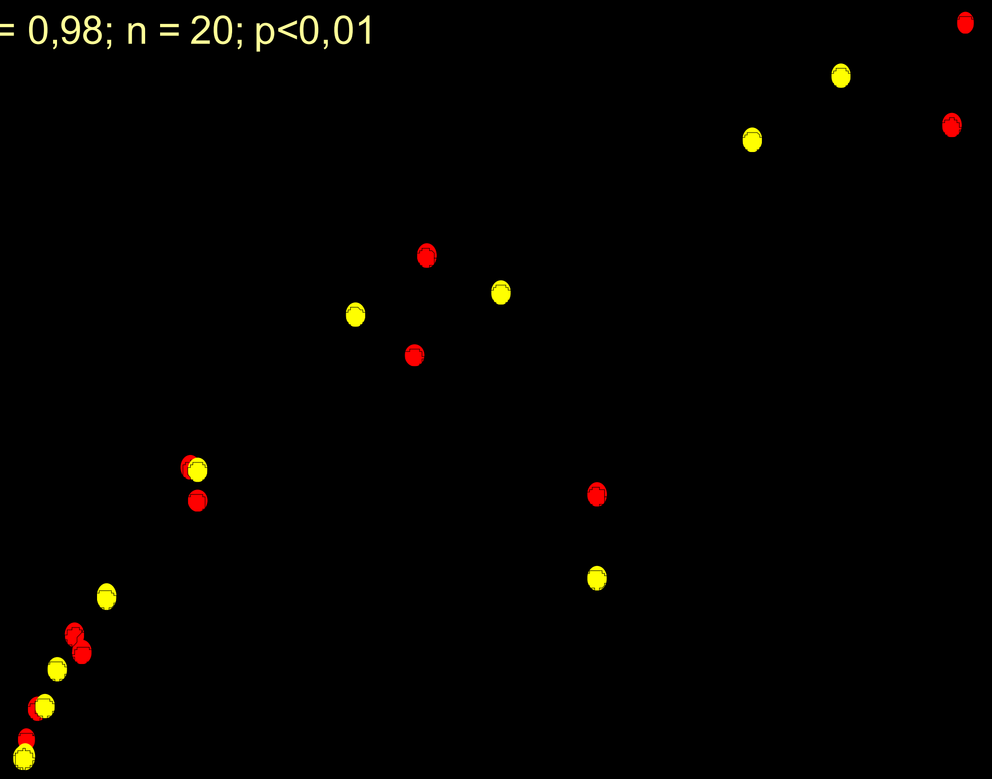
Phosphorus



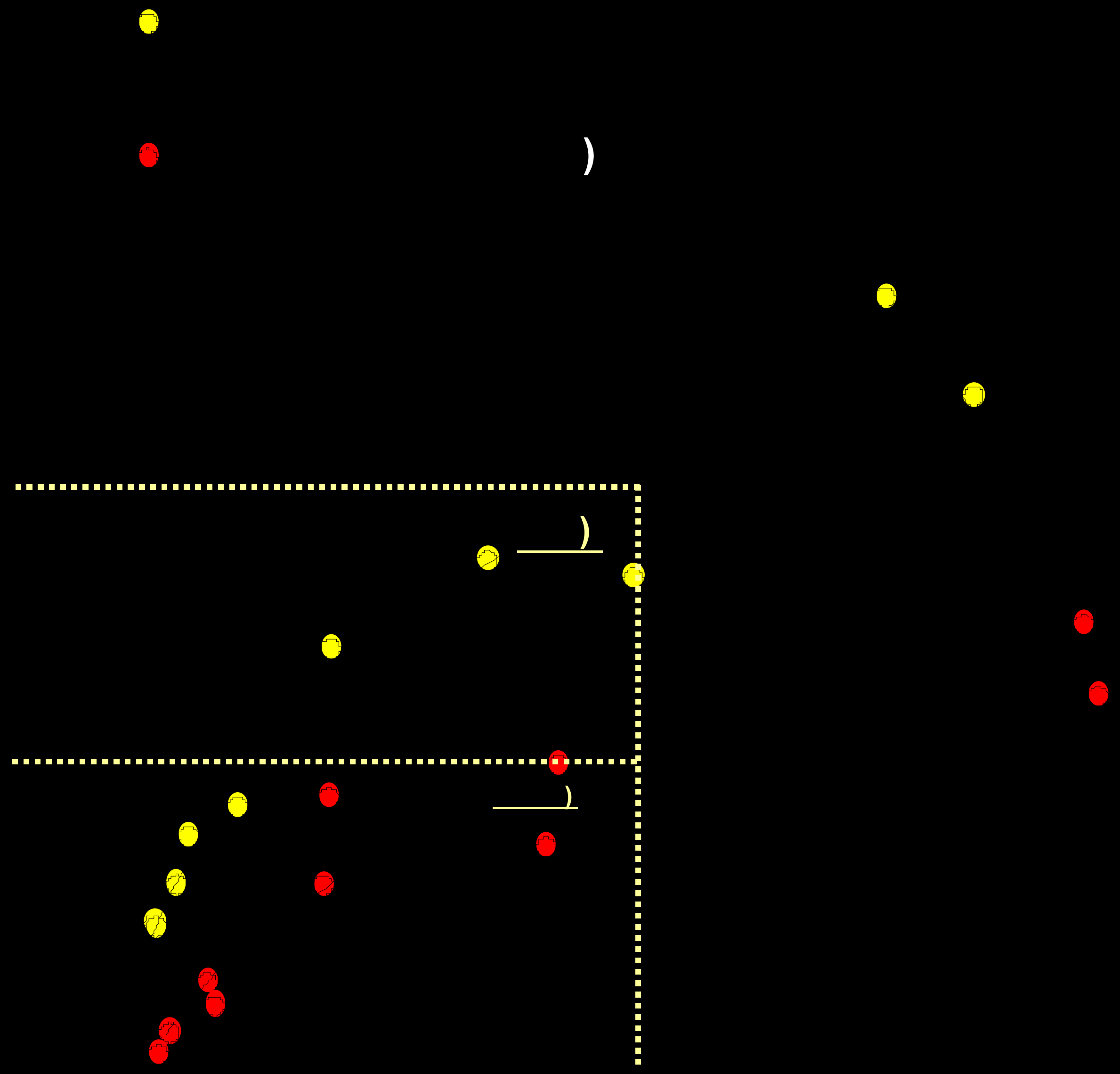
E. grandis (seedlings)
11 years
Rainfall: 1300 mm
Tª: 19ºC
3 months water deficit

$y = -6,738 + 182,283.\exp(DAP^2.H)$

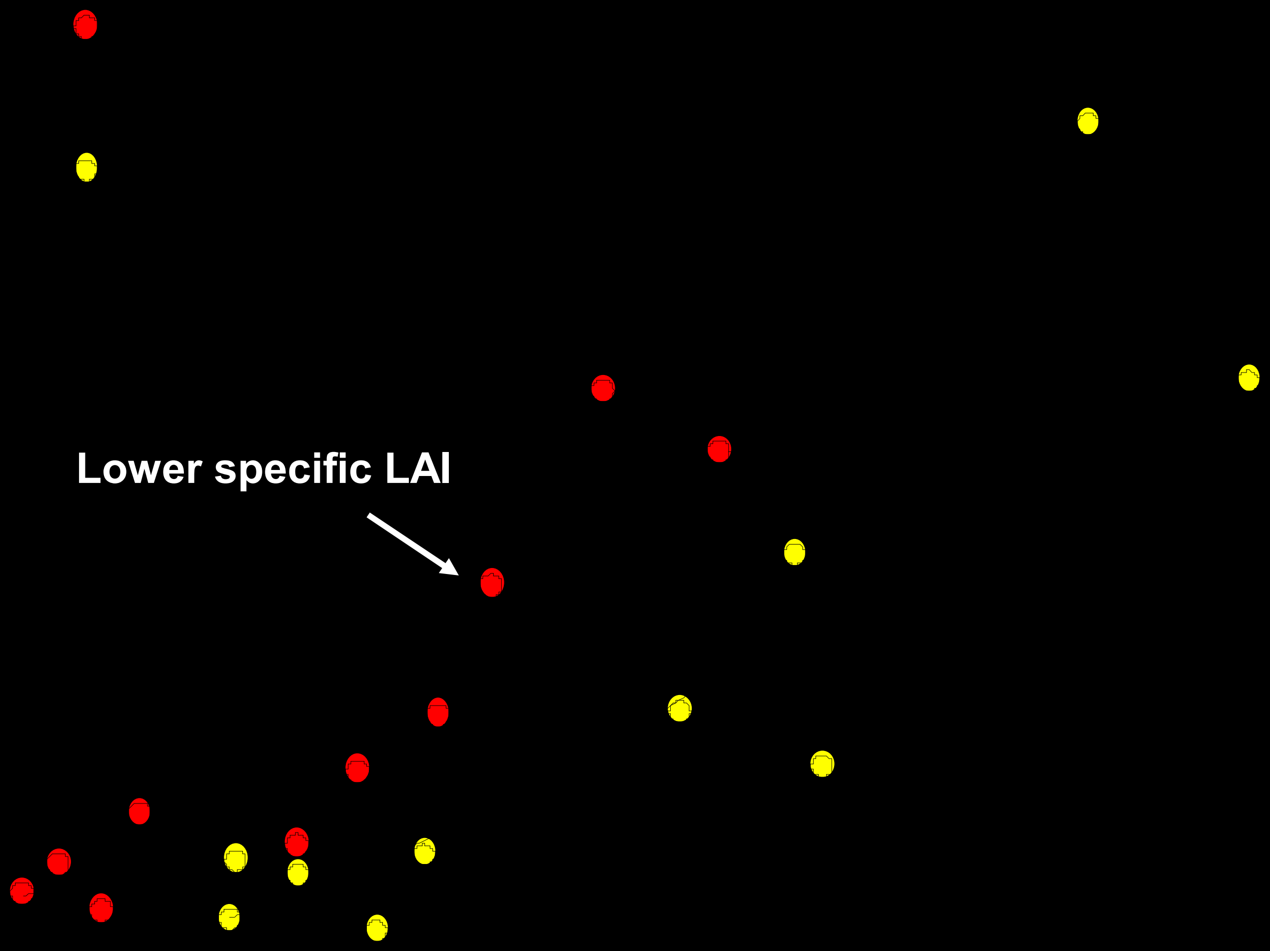
$r^2 = 0,98$; $n = 20$; $p < 0,01$



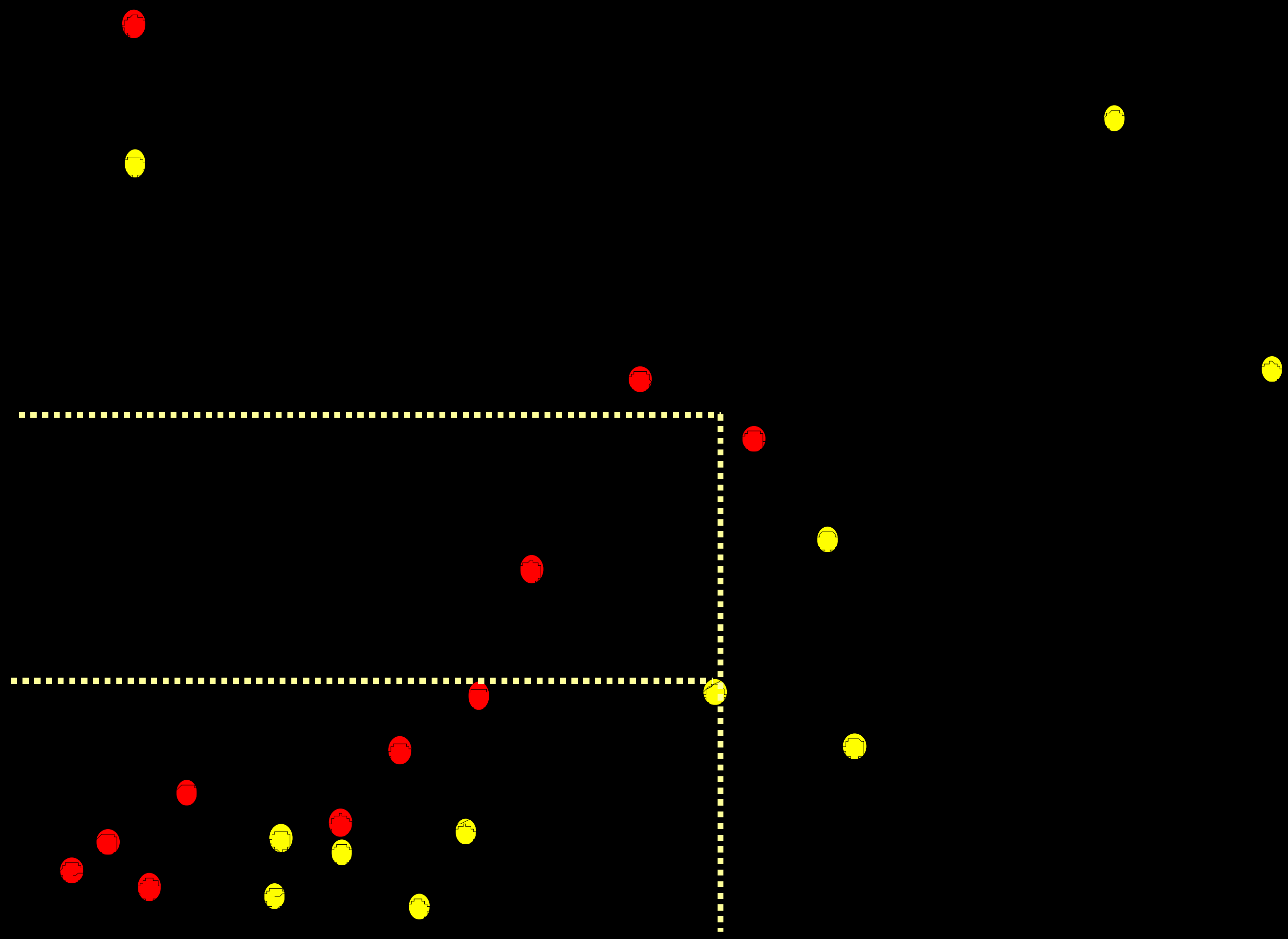
Mello & Gonçalves, 2004



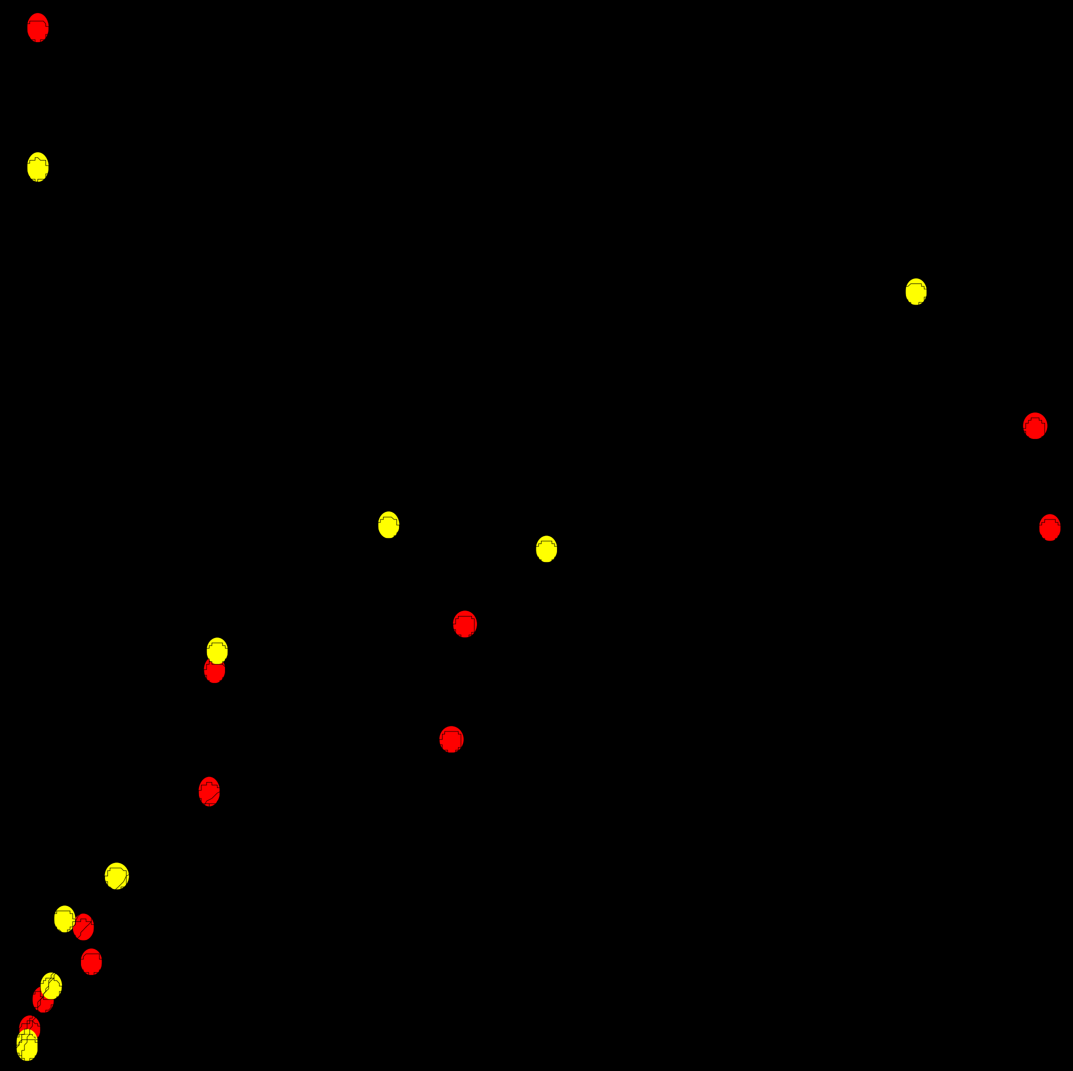
Mello & Gonçalves, 2004



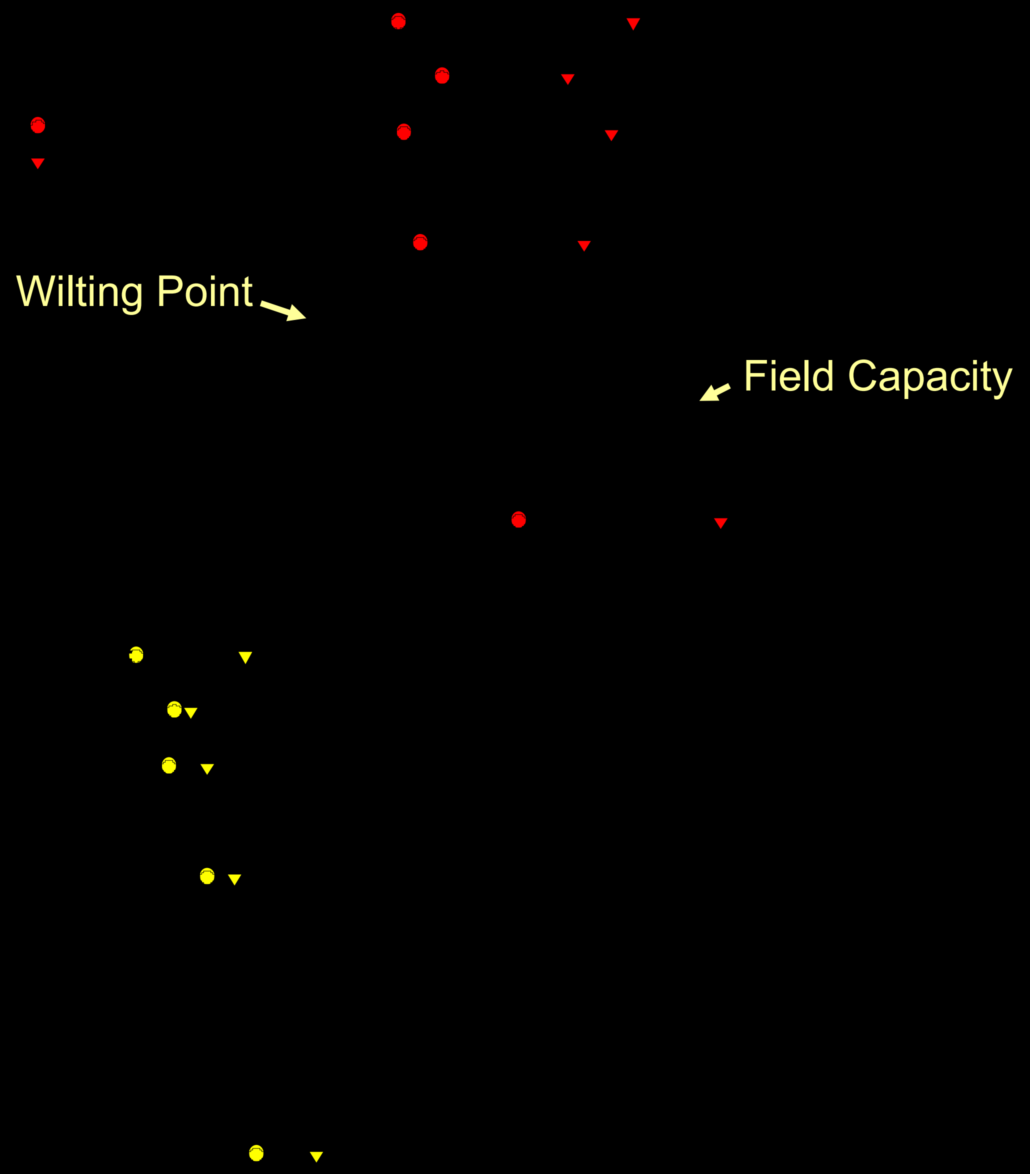
Mello & Gonçalves, 2004



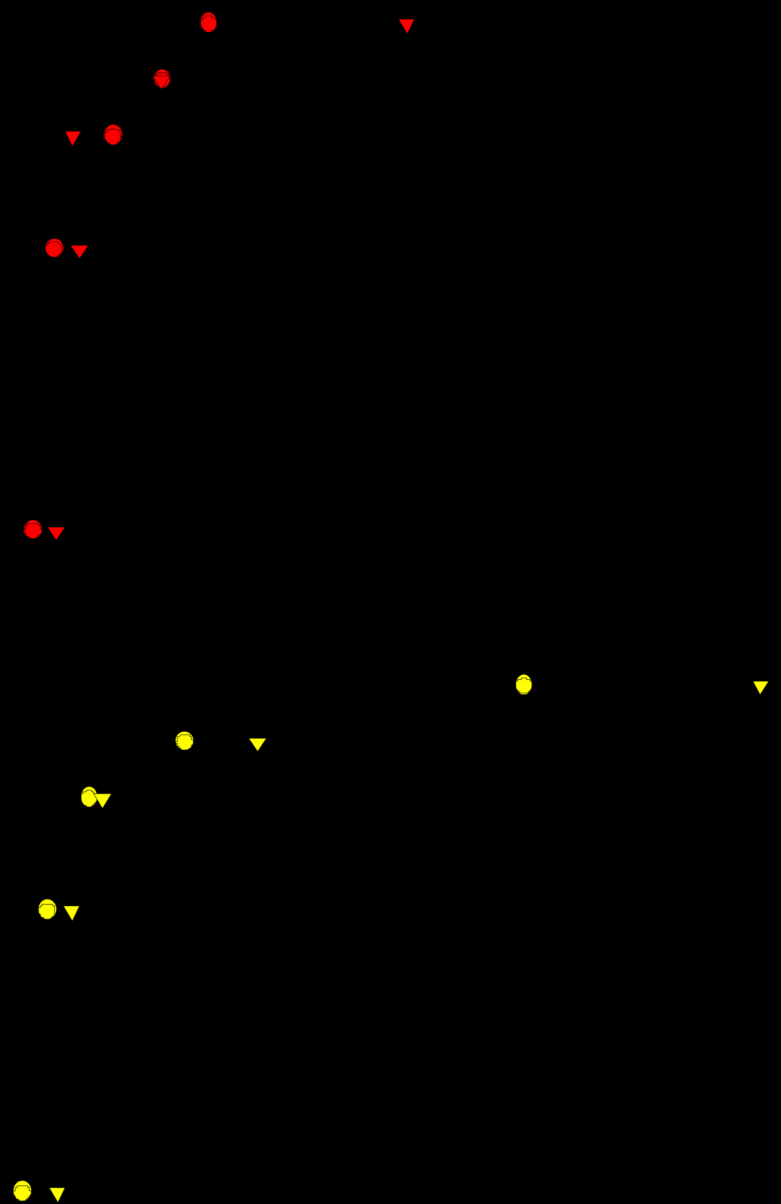
Mello & Gonçalves, 2004



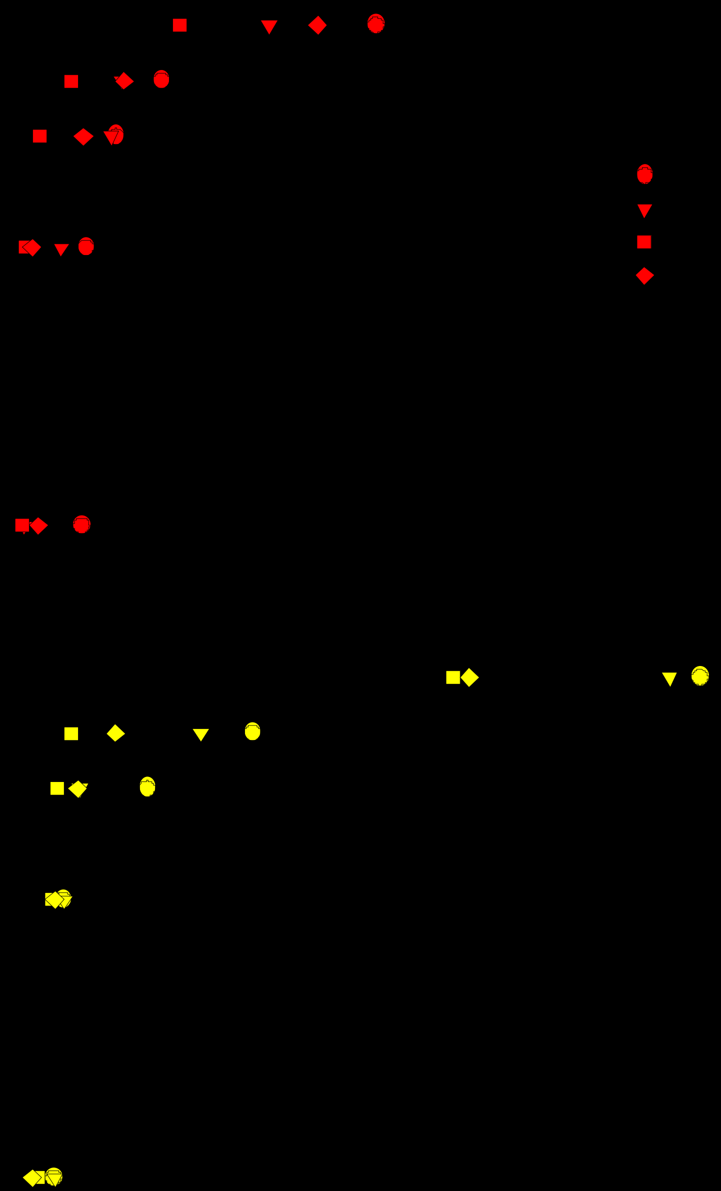
Mello & Gonçalves, 2004



Mello & Gonçalves, 2004



Mello & Gonçalves, 2004

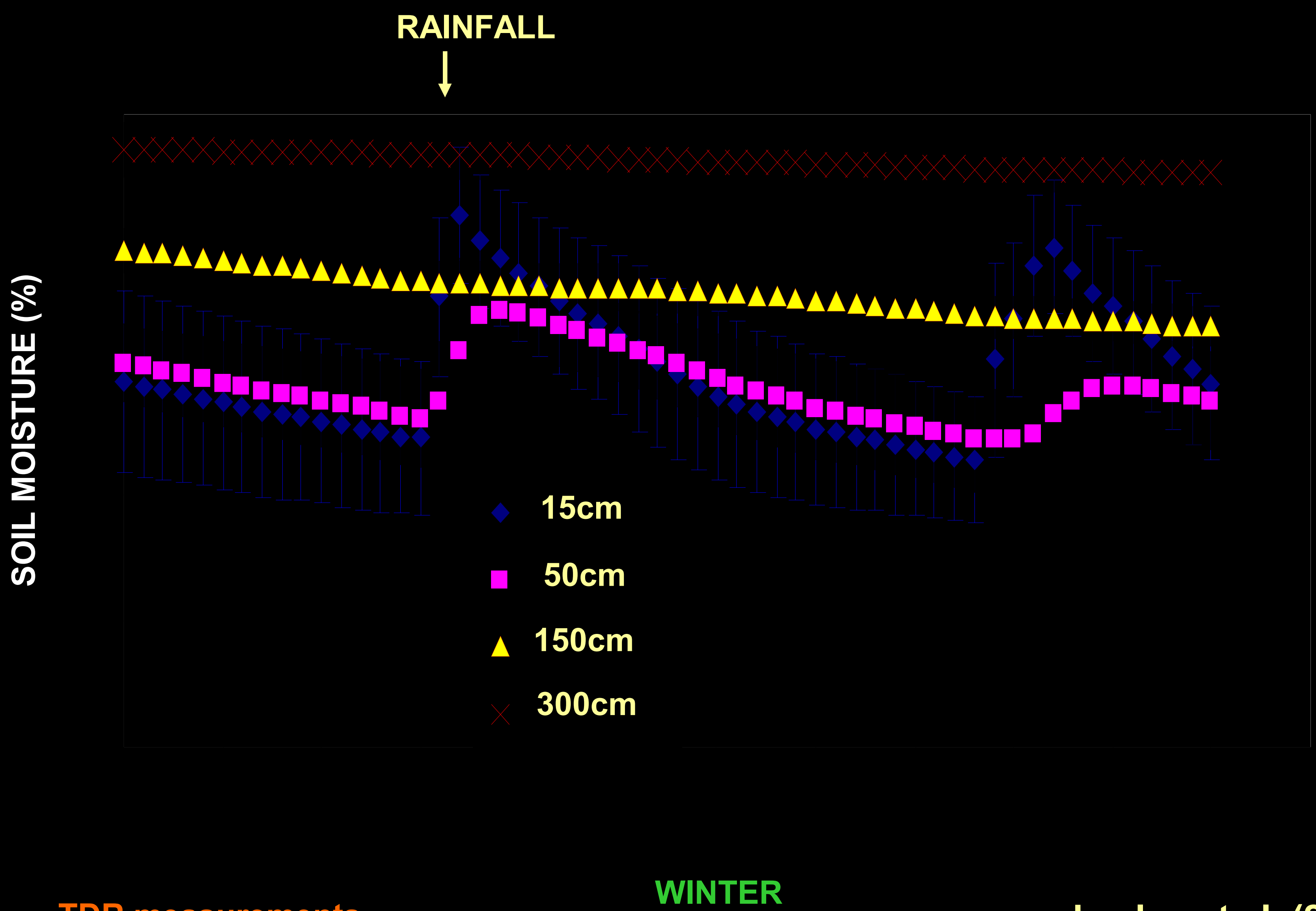


High fine root turnover depending on seasonal moisture shortage

Mello & Gonçalves, 2004

How deep the roots uptake the water from?

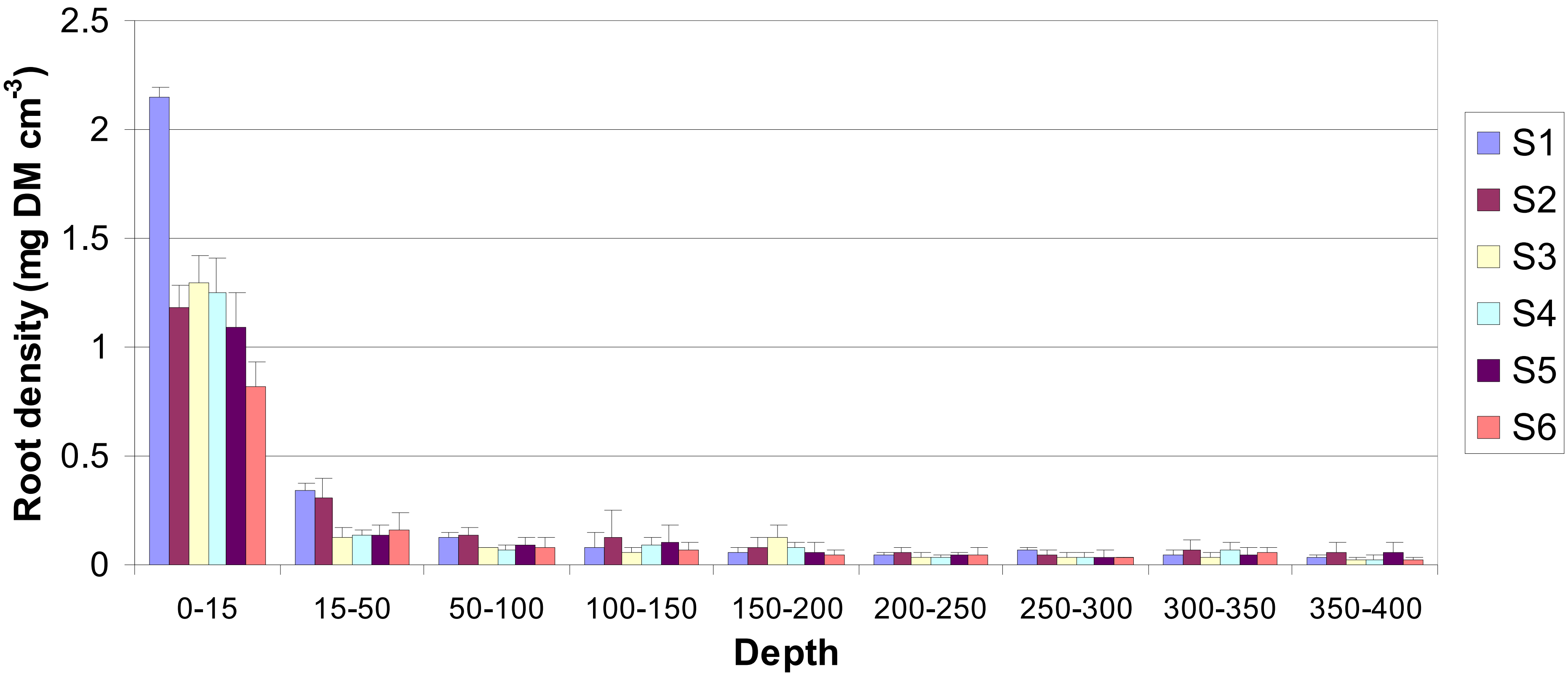
Oxisol (20% clay)
E. saligna **(4 to 5 yr)**

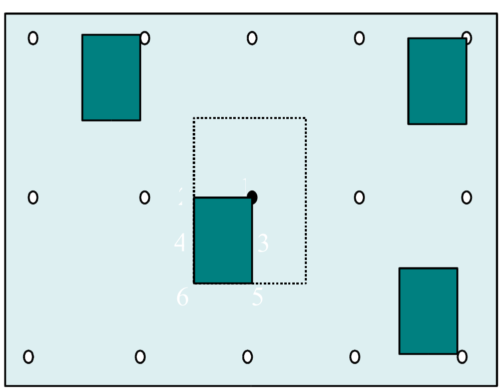


TDR measurements

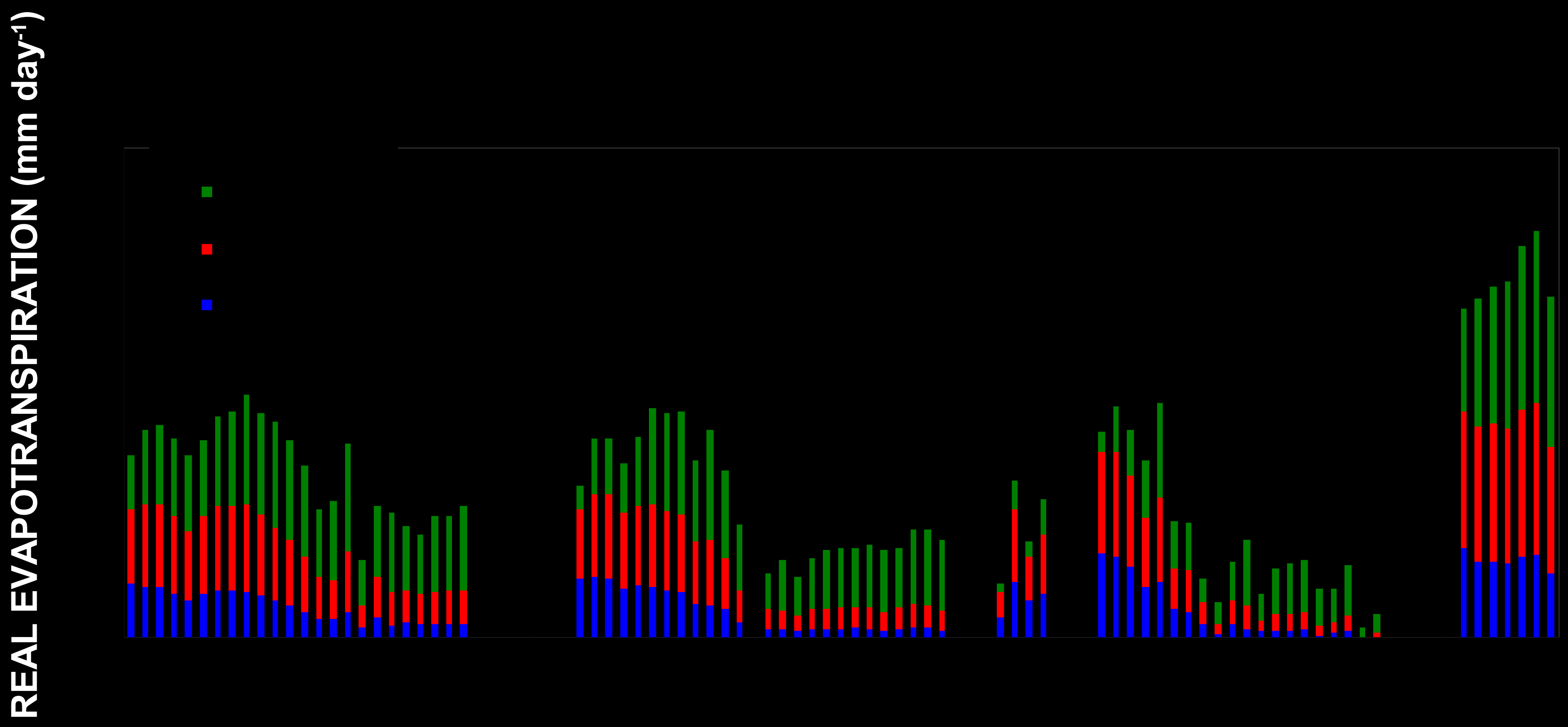
Laclau et al. (2004)

Density of fine roots (diameter < 1mm)





Laclau et al. (2004)



Based on soil moisture variation (TDR)

Laclau et al. (2004)

SILVICULTURAL PRACTICES

PRACTICES

Restricted Soil Cultivation

- Rippering
- Pitting

RIPPERING

INCREASE

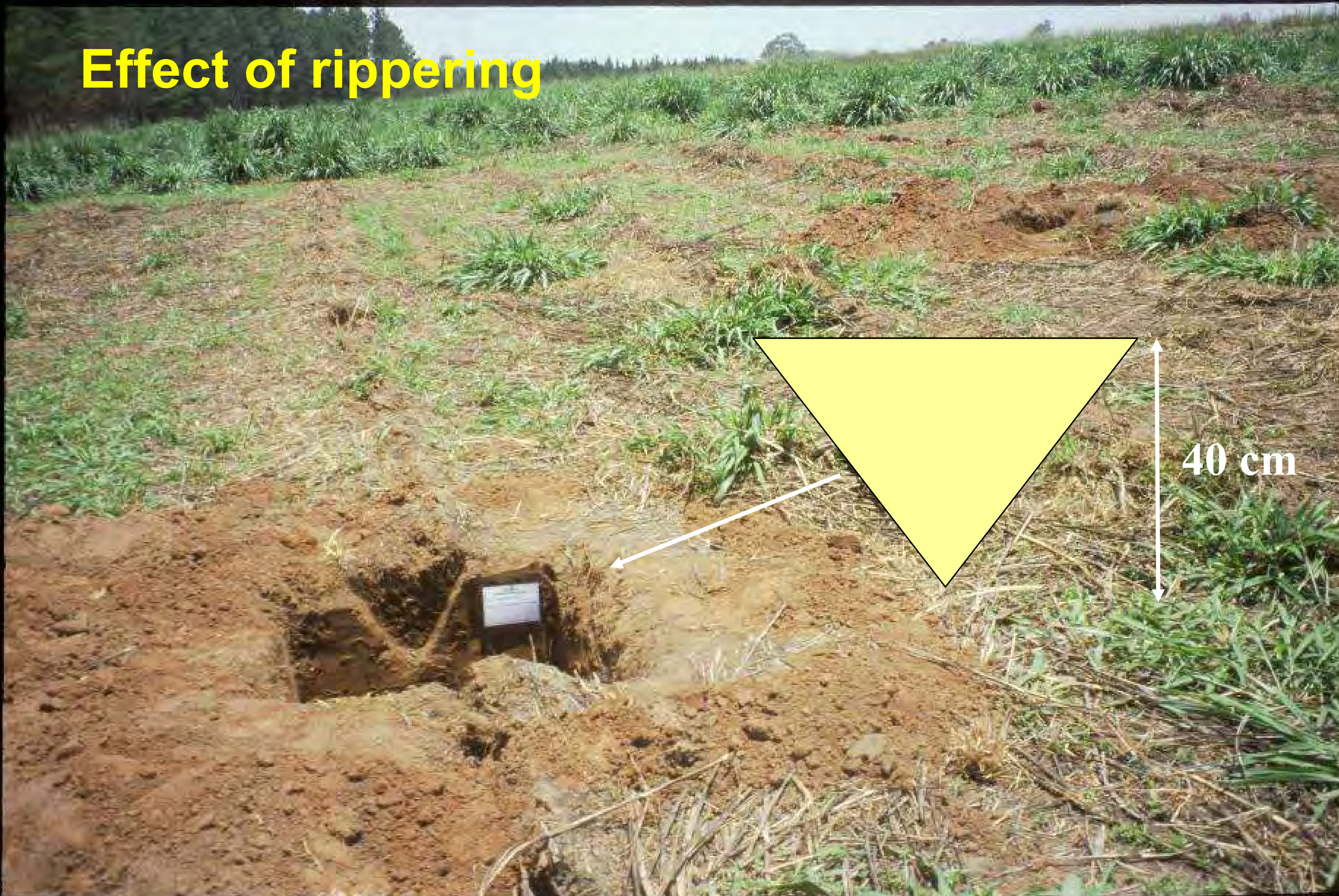
- Infiltration (preferentially close of planting row)
  - > soil-water and groundwater storage

- Soil volume exploration by roots

DECREASE

- Evaporation

Effect of rippering



Soil structure: granule, friable

Bulk density: sandy 1.4; loam < 1.2 g cm^{-3}

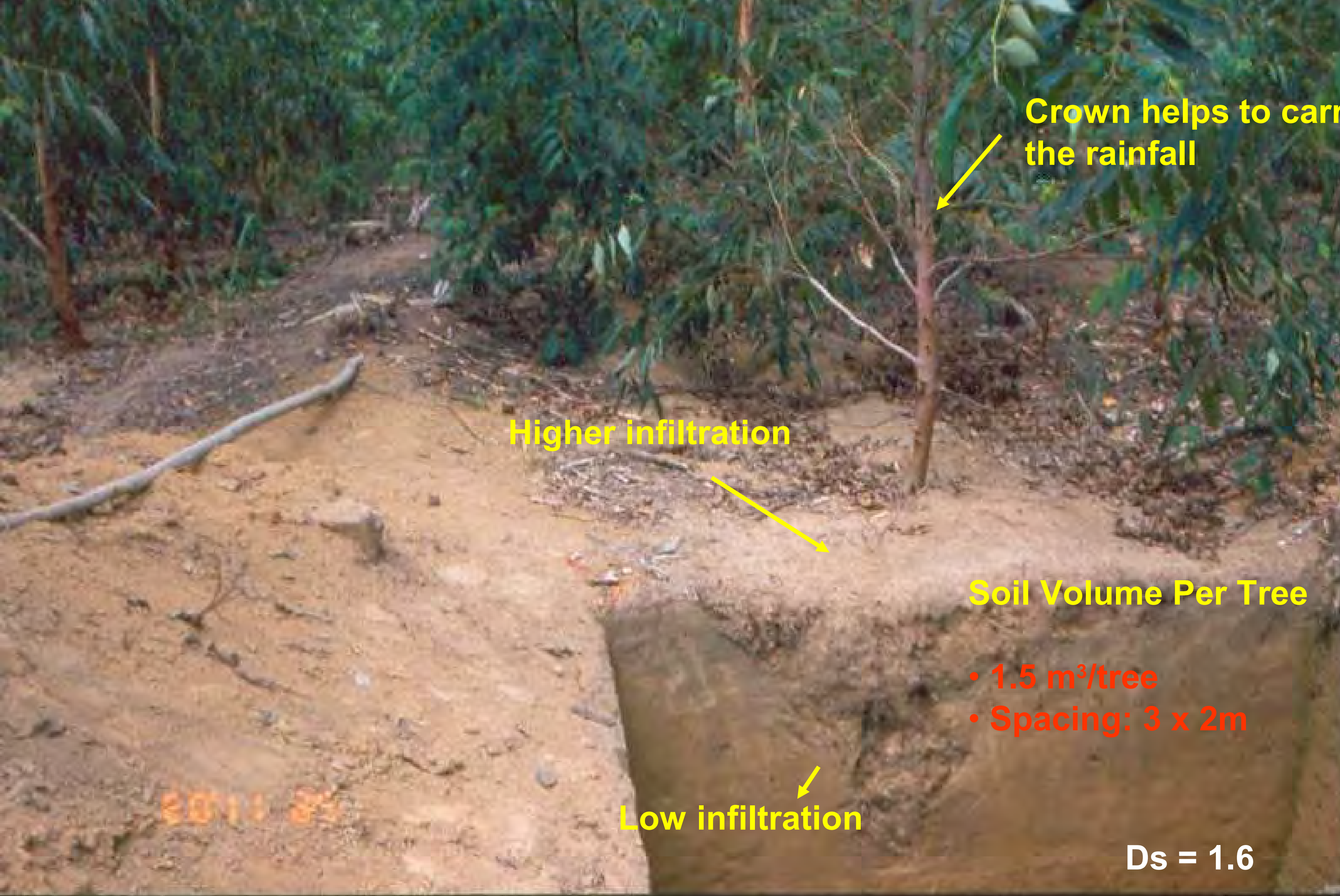
Drought: low to moderate (3 to 5 months per year)

Soil structure: cohesive

Bulk density: ≥ 1.6 g cm^{-3} (predominantly clay)

Drought: severe (5 to 7 months per year)

Restrict Rippering


Crown helps to carry
the rainfall
Higher infiltration
Soil Volume Per Tree
• 1.5 m³/tree
• Spacing: 3 x 2m
Low infiltration
Ds = 1.6

AVOID MOUNDING

Roots concentrated
on top layers

▸ more sensitive to drought

PRACTICES

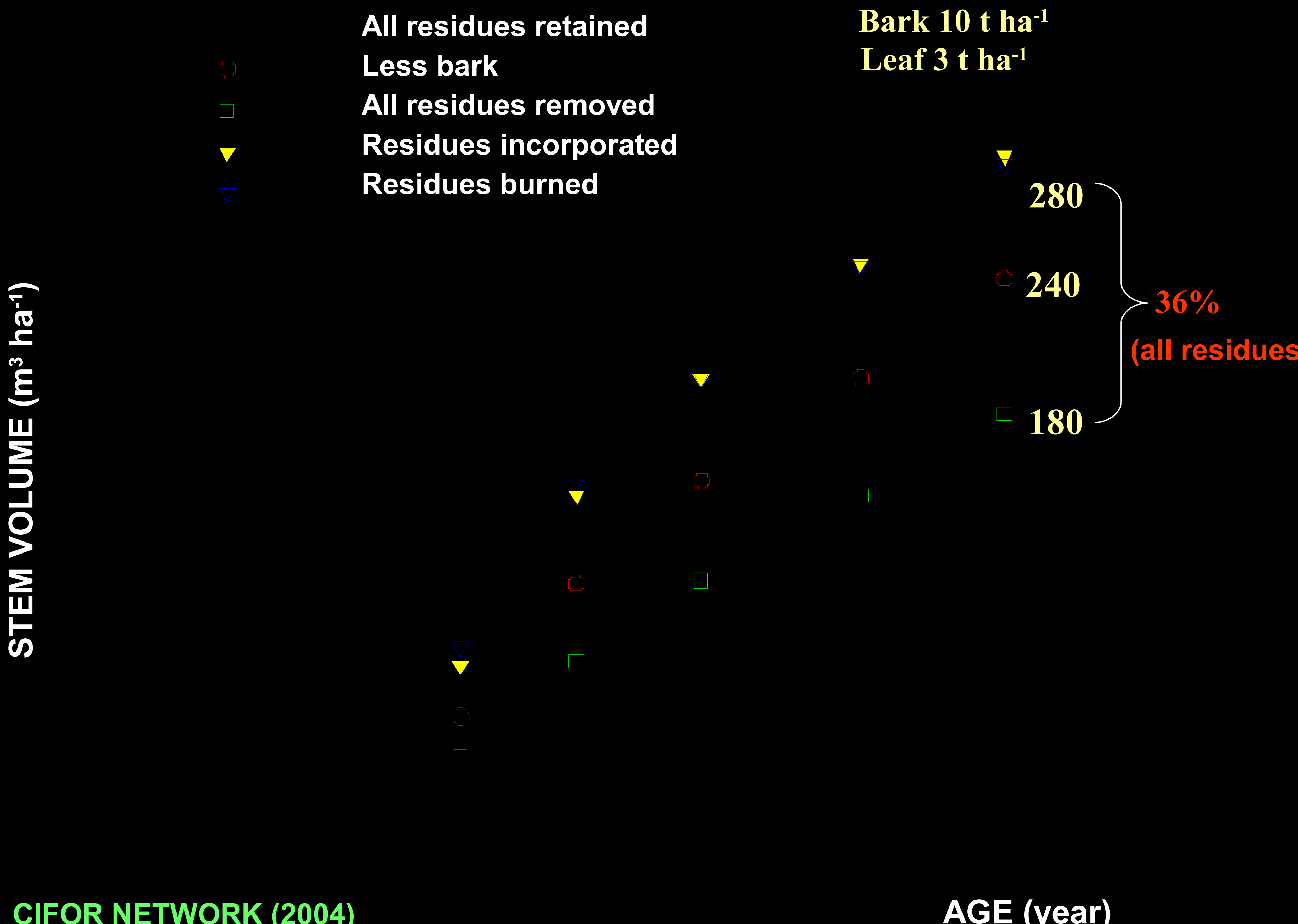
Restricted Soil Cultivation
- Rippering
- Pitting

Residue Retention
- Litter layer
- Slash
- Bark (pulp industry)

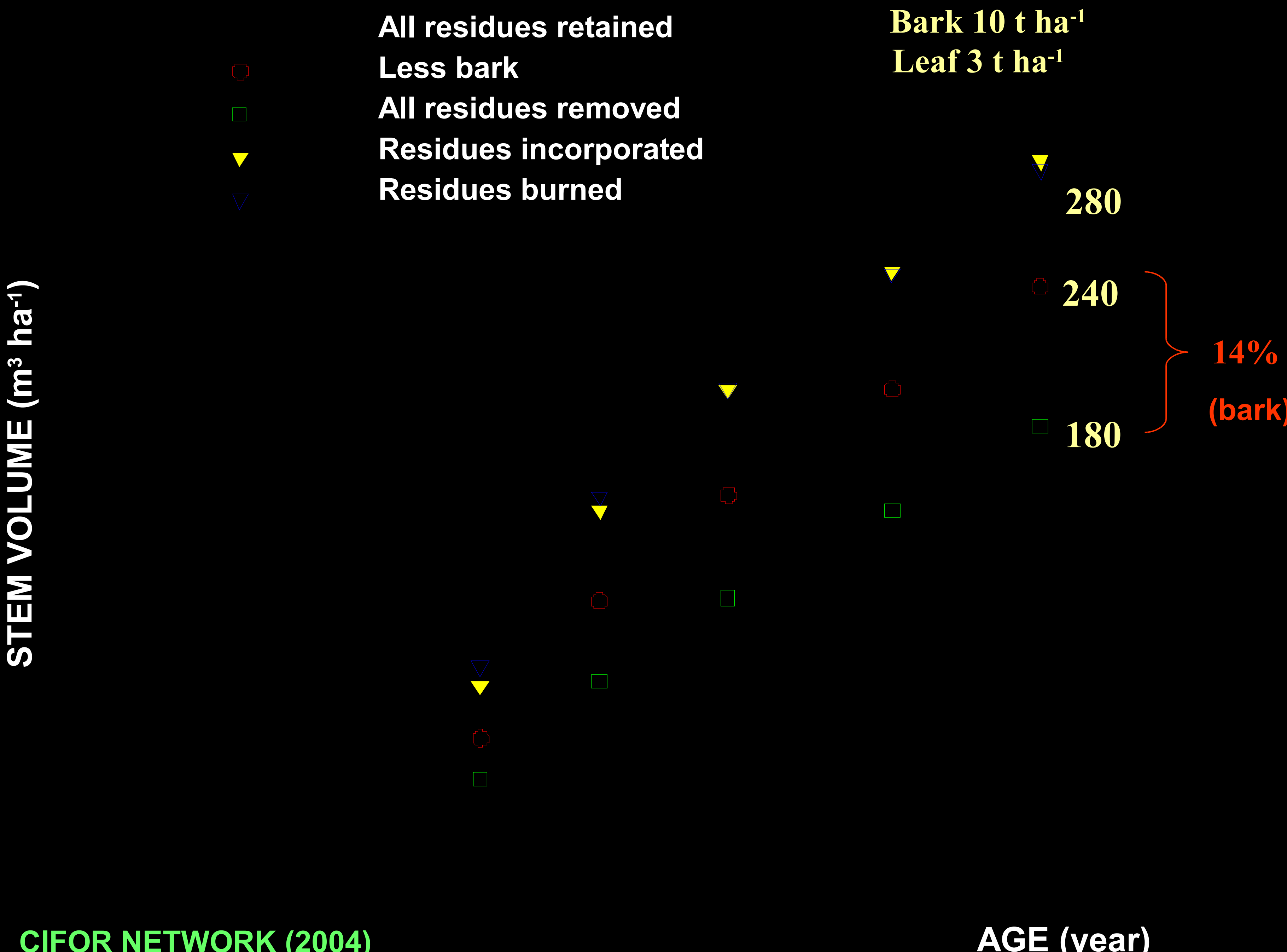

Litter layer = 20 to 25 t ha^{-1}
Slash = 8 to 10 t ha^{-1}

DEBARK WOOD FOR PULP INDUSTRY

Slash 8 t ha-1
Bark 12 t ha-1
Litter layer 20 t ha-1
∑ = 40 t ha-1
17 5 2004



CIFOR NETWORK (2004)



All residues retained
Less bark
All residues removed
Residues incorporated
Residues burned
Bark 10 t ha-1
Leaf 3 t ha-1
280
240
180
14%
(bark)
STEM VOLUME (m3 ha-1)
AGE (year)
CIFOR NETWORK (2004)

PRACTICES

Restricted Soil Cultivation
- Rippering
- Pitting

Residue Retention
- Litter layer
- Slash
- Bark (pulp industry)

Fertilization
- Base application
- Cover application

Initial wood biomass
40-paired plots
(control and fertilized)

Northern Brazil

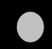
Severe drought

Stape & Binkley, 2002

Stape & Binkley, 2002

Clonal plantations

E. grandis x urophylla



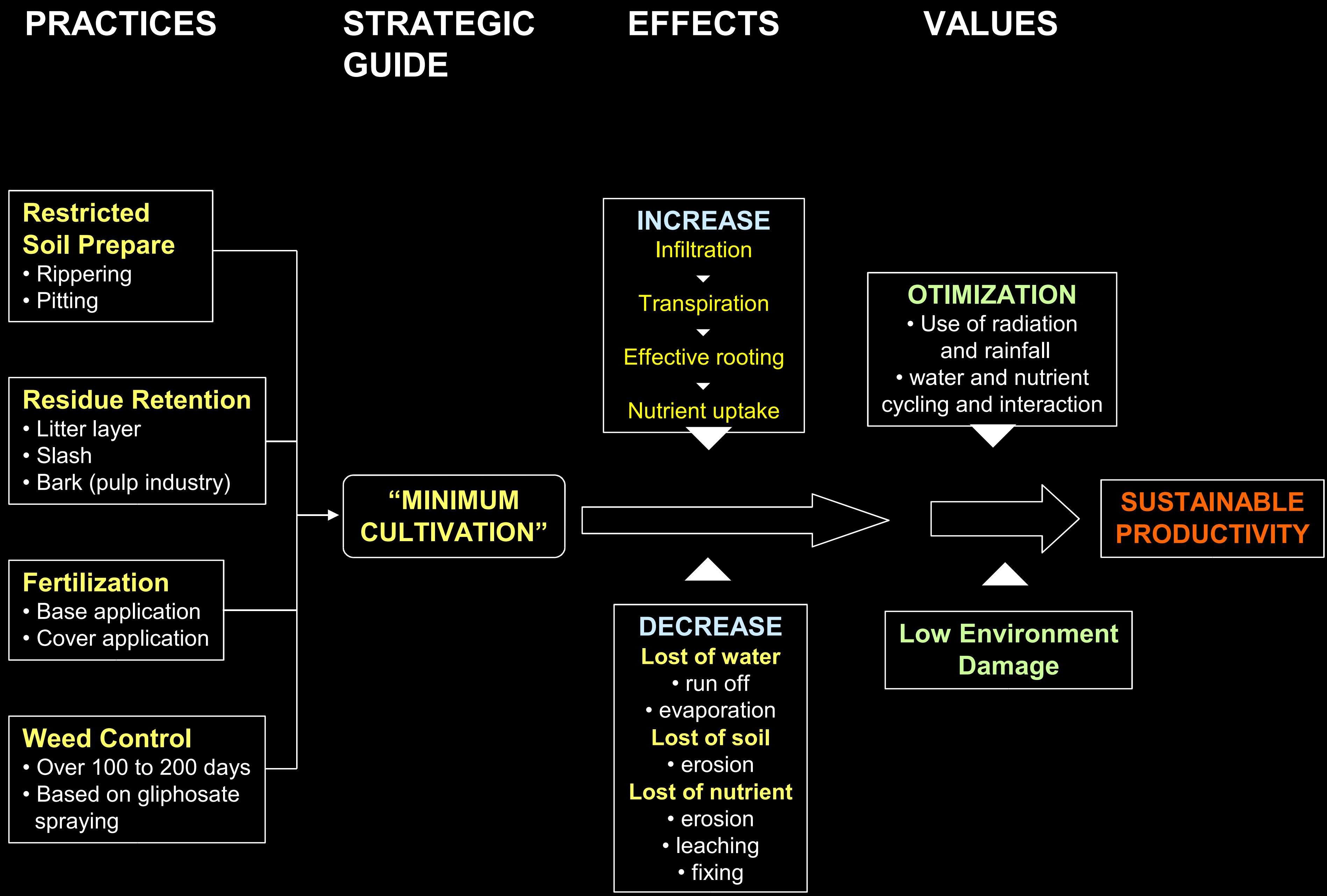
RAINFALL (mm yr^{-1})

Stape & Binkley, 2002

Lateral little pits

Prevent
- Leaching
- Fixing
- Weed competition

Fertilizer application
- **mainly P (30 to 50 kg ha^{-1})**



PRACTICES
STRATEGIC GUIDE
EFFECTS
VALUES
Restricted Soil Prepare
• Rippering
• Pitting
Residue Retention
• Litter layer
• Slash
• Bark (pulp industry)
Fertilization
• Base application
• Cover application
Weed Control
• Over 100 to 200 days
• Based on gliphosate spraying
"MINIMUM CULTIVATION"
INCREASE
Infiltration
Transpiration
Effective rooting
Nutrient uptake
DECREASE
Lost of water
• run off
• evaporation
Lost of soil
• erosion
Lost of nutrient
• erosion
• leaching
• fixing
OTIMIZATION
• Use of radiation and rainfall
• water and nutrient cycling and interaction
Low Environment Damage
SUSTAINABLE PRODUCTIVITY

CONCLUSION

The holding capacity (HC) increases directly with clay content;

As higher is the HC, higher is the efficiency of rainfall use.
This compensates partially the water shortage caused by climatic factors;

Available water play primary role in establishing the site quality;
soil fertility play secondary role;

The potential response to fertilization is higher when associated
with silvicultural practices that increase the efficiency of rainfall use;

The fine root density is a plastic variable, affected direct and inversely
by soil hold capacity and by seasonal soil moisture range.

Thank you