Precision Management: How & Why We Should Irrigate

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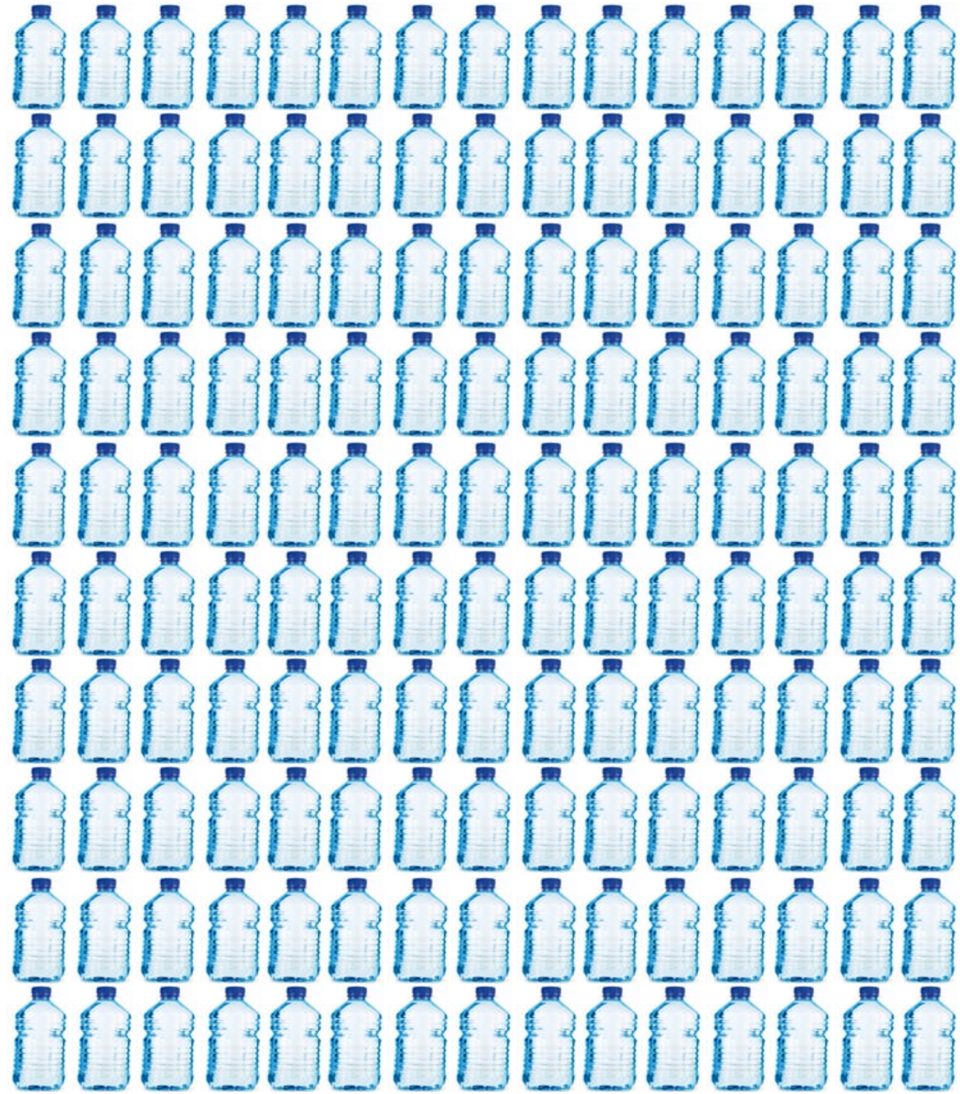
Let’s guess!

- 1 kg of apples ………. 200 l of water

=



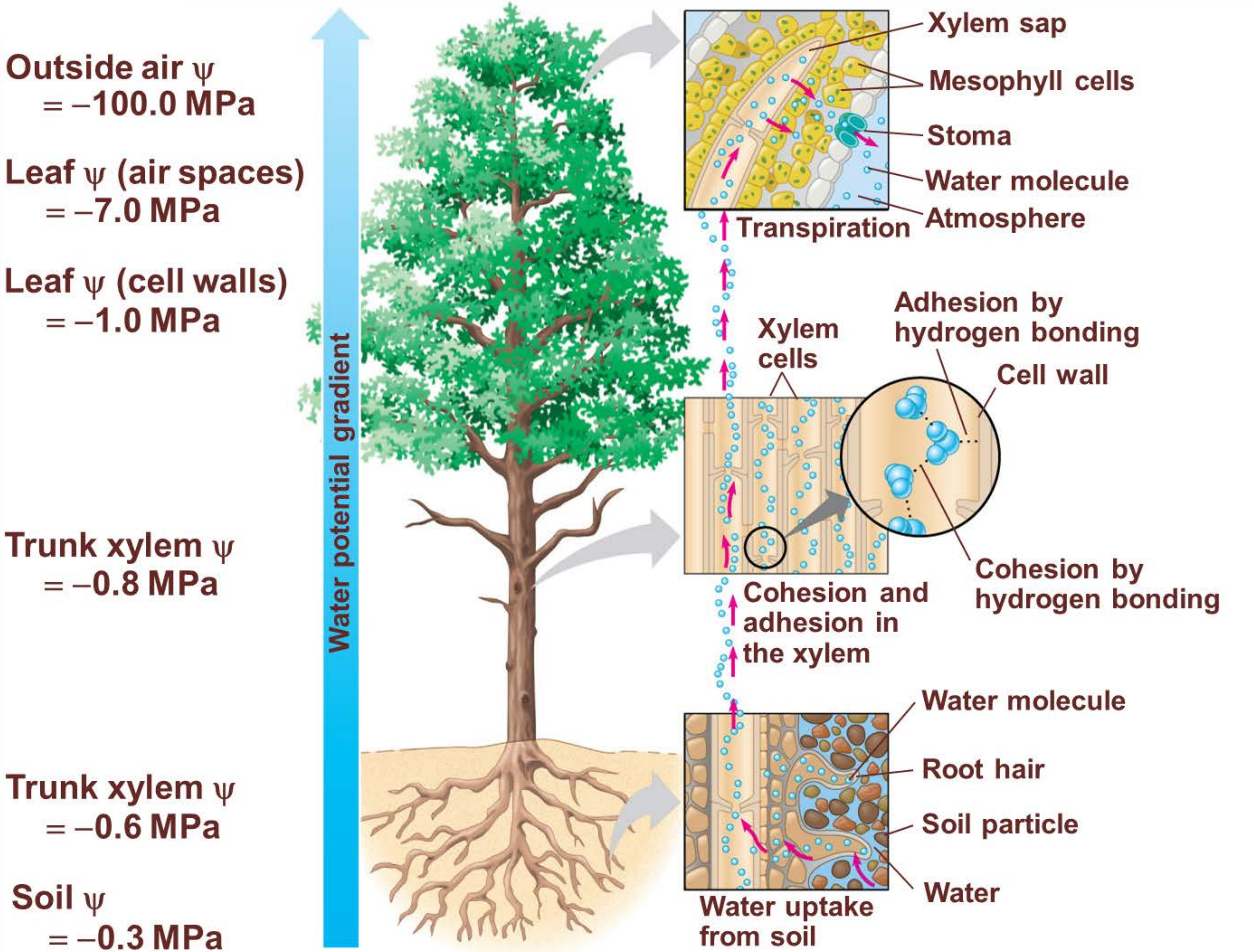
Let's guess!

- 1 kg of apples ………. 200 l of water
- 1 liter of milk ………… 1,000 l of water
- 1 beef steak …………. 1,200 l of water
- 1 Hamburguer ………. 1,400 l of water

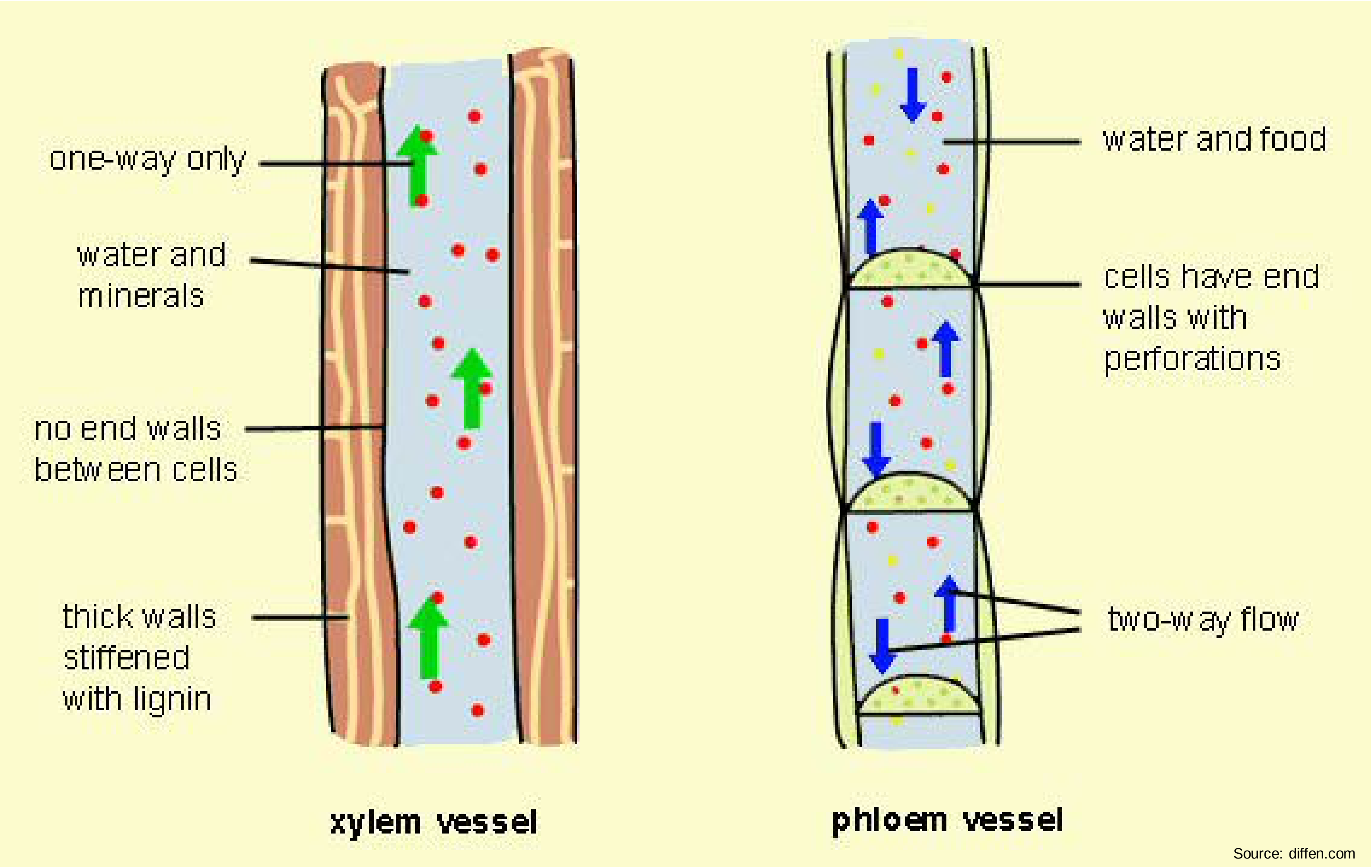
Water demands to feed population:

- 1 person/day ………. 3,500 – 4,500 l of water
- 1 family/day ………… 14,000 l of water
- 1 person/year ……….. 1,460 m^3 of water
- 1 family/year ………… 5,110 m^3 of water

How



Outside air ψ
= −100.0 MPa
Leaf ψ (air spaces)
= −7.0 MPa
Leaf ψ (cell walls)
= −1.0 MPa
Trunk xylem ψ
= −0.8 MPa
Trunk xylem ψ
= −0.6 MPa
Soil ψ
= −0.3 MPa
Water potential gradient
Xylem sap
Mesophyll cells
Stoma
Water molecule
Atmosphere
Transpiration
Xylem cells
Adhesion by hydrogen bonding
Cell wall
Cohesion by hydrogen bonding
Cohesion and adhesion in the xylem
Water molecule
Root hair
Soil particle
Water
Water uptake from soil


one-way only
water and
minerals
no end walls
between cells
thick walls
stiffened
with lignin
xylem vessel
water and food
cells have end
walls with
perforations
two-way flow
phloem vessel
Source: diffen.com

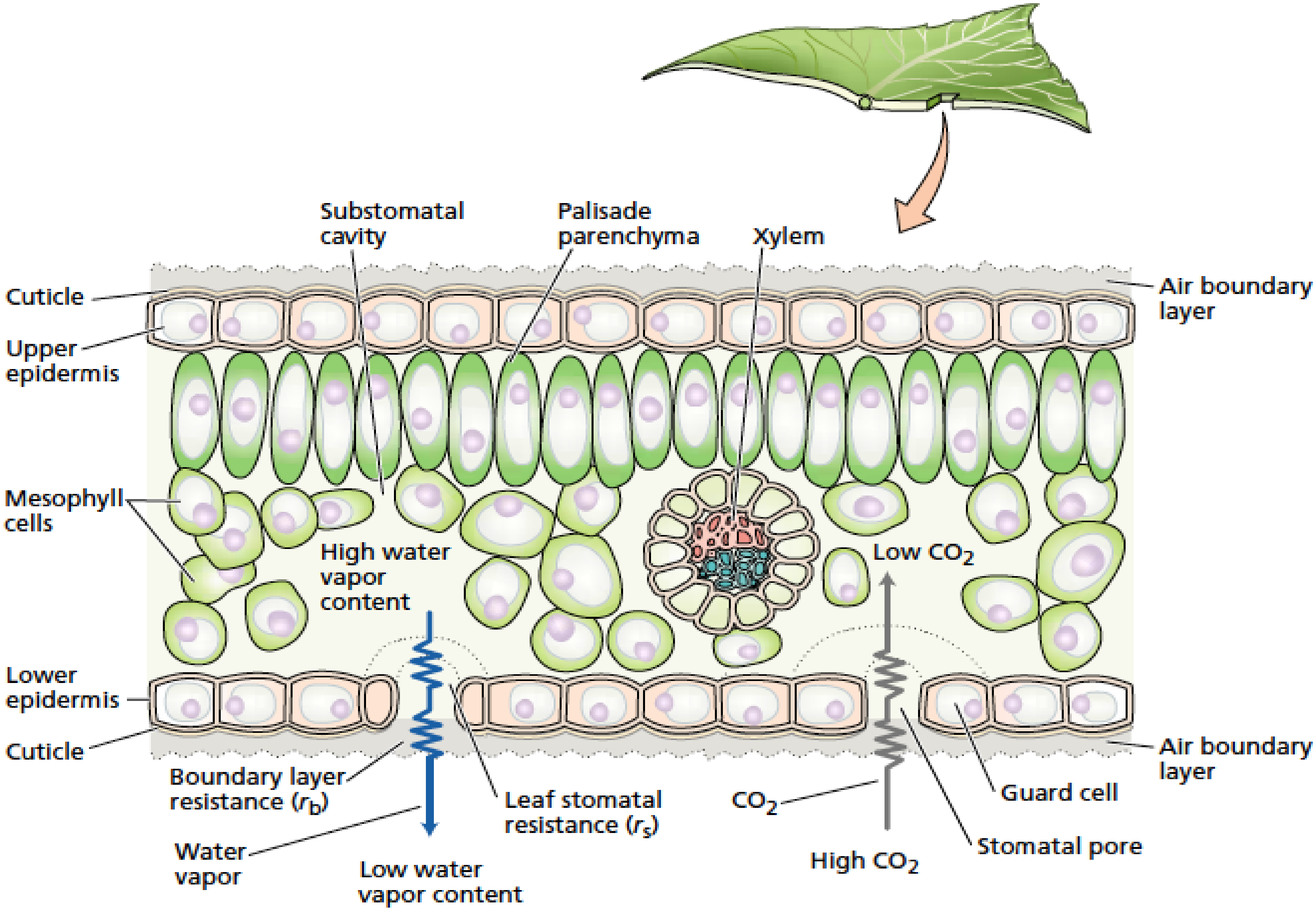
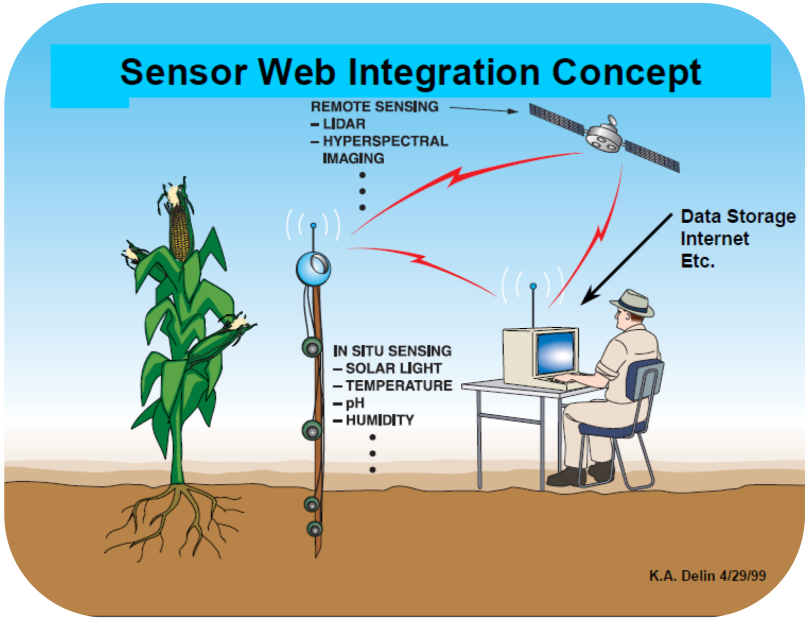


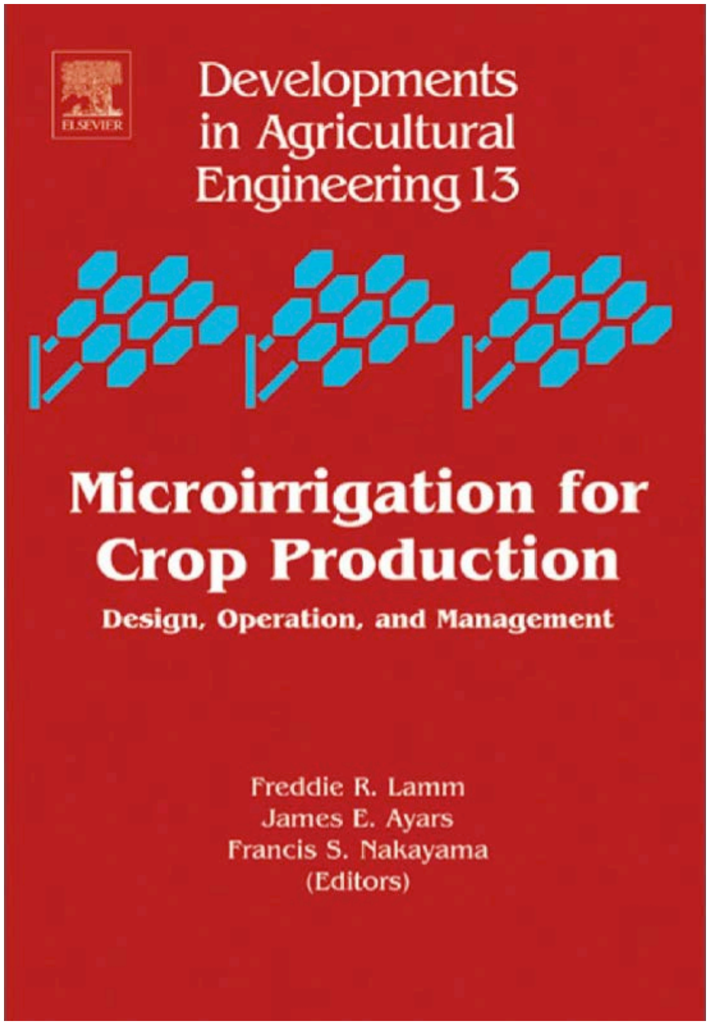
FIGURE 4.10 Water pathway through the leaf. Water is pulled from the xylem into the cell walls of the mesophyll, where it evaporates into the air spaces within the leaf. Water vapor then diffuses through the leaf air space, through the stomatal pore, and across the boundary layer of still air found next to the leaf surface. CO_2 diffuses in the opposite direction along its concentration gradient (low inside, higher outside).

Source: Taiz L., Zeiger E., 2010

How to irrigate?



Automating irrigation **schedulling** – basic principles



" Automating irrigation systems is not simply a process of selecting physical components to operate valves, motors, pumps, and switches, but rather one of collecting and interpreting data on soil water status, plant water use and stress, and weather, and then using this information to schedule irrigation based on previously established management goals."

J. Ayars & C. Phene on *Microirrigation for Crop Protection.*

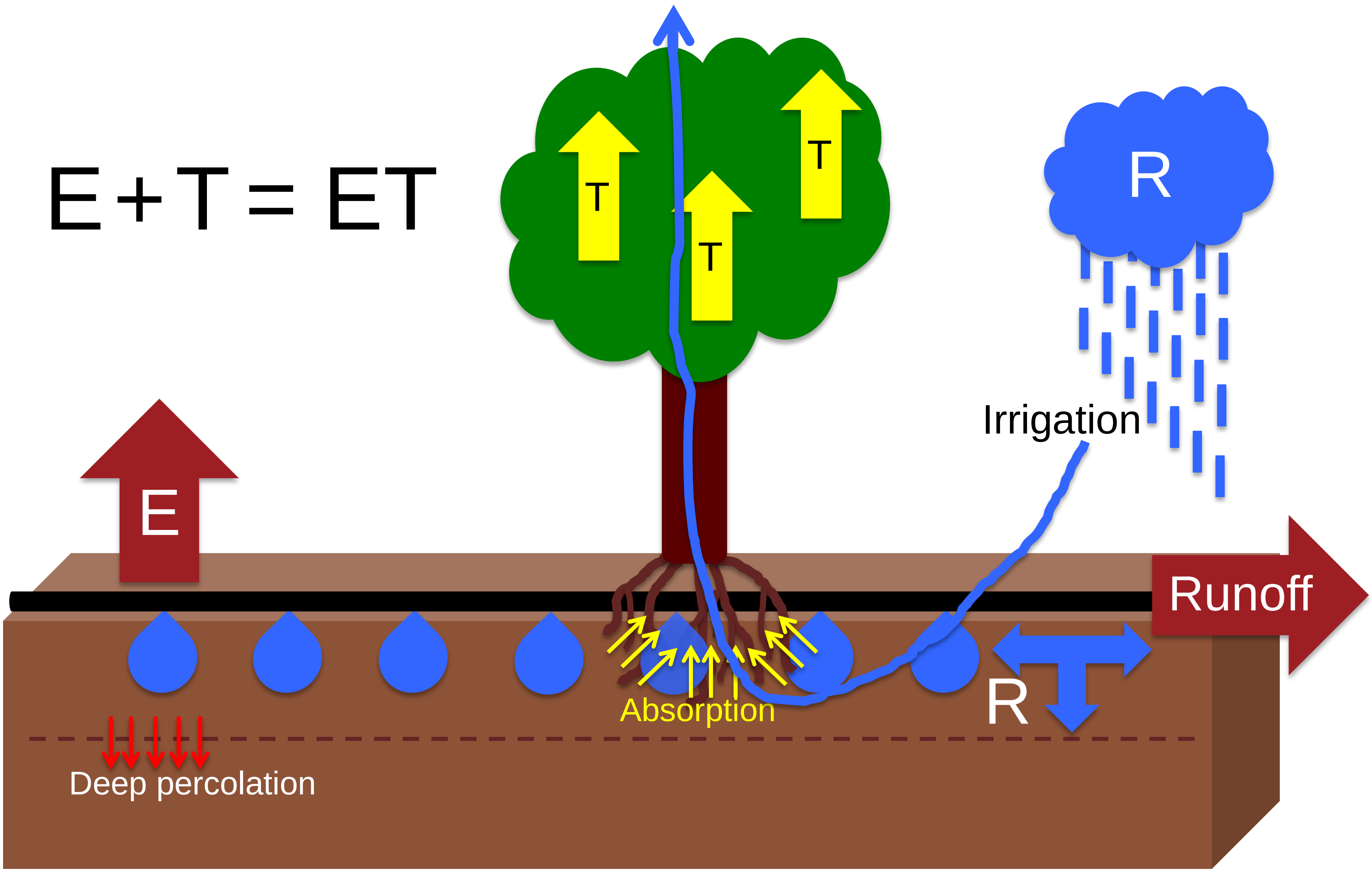
Automating irrigation **schedulling** – basic principles

- Irrigation schedulling: calculating irrigation dose & how to implement it

- Need to know:
  - ✓Location & weather
  - ✓Crop
  - ✓Soil

Water use & irrigation requirements

$E + T = ET$



Automating irrigation **schedulling** – dose

Water Balance with the FAO/Penman-Monteith (FAO-56) model:

2
Estimate ETc
ETc = ETo * Kc

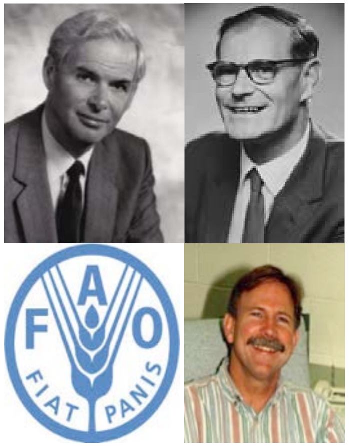
Weather data

Water balance

Irrigation need ≈ ETc

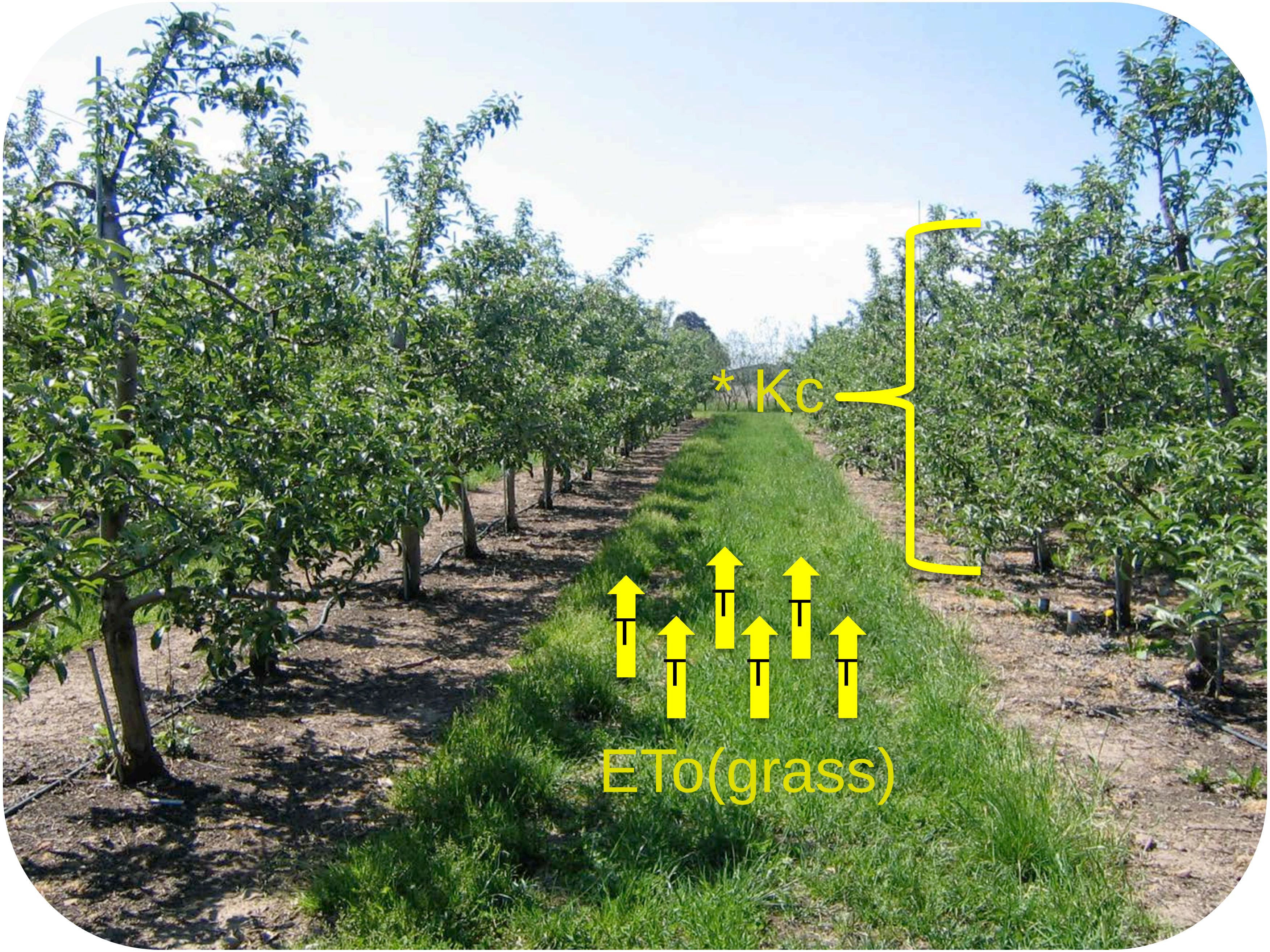
Automating irrigation **schedulling** – dose

FAO/Penman-Monteith equation (FAO-56)



$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)}$$

where	ET_o	reference evapotranspiration [mm day^{-1}],
	R_n	net radiation at the crop surface [MJ m^{-2} day^{-1}],
	G	soil heat flux density [MJ m^{-2} day^{-1}],
	T	mean daily air temperature at 2 m height [°C],
	u_2	wind speed at 2 m height [m s^{-1}],
	e_s	saturation vapour pressure [kPa],
	e_a	actual vapour pressure [kPa],
	e_s-e_a	saturation vapour pressure deficit [kPa],
	Δ	slope vapour pressure curve [kPa °C^{-1}],
	γ	psychrometric constant [kPa °C^{-1}].



* Kc
ETo(grass)

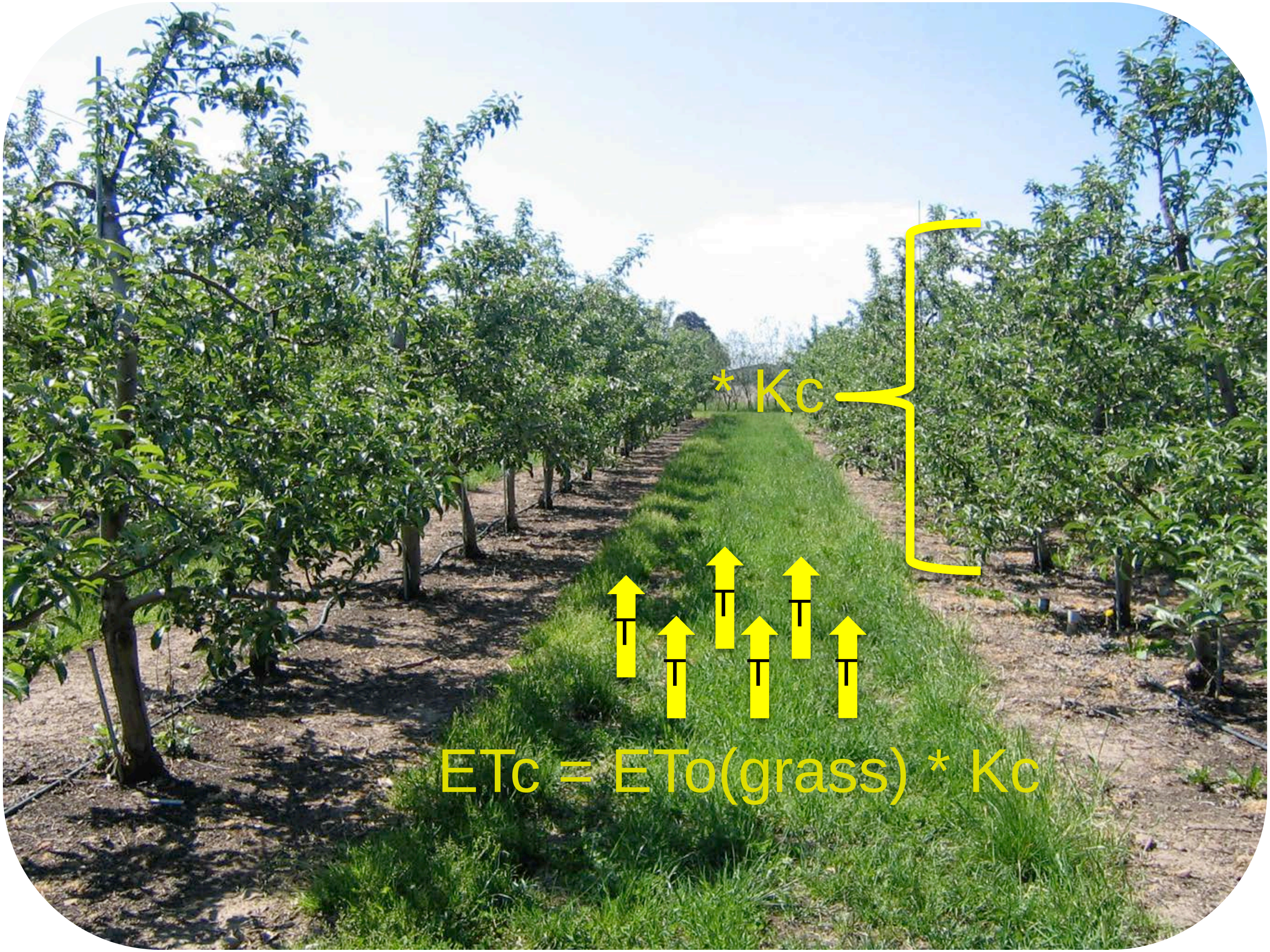
Table 12 continued

Crop	$K_{c\ ini}$[1]	$K_{c\ mid}$	$K_{c\ end}$	Maximum Crop Height (h) (m)
n. Fruit Trees				
Almonds, no ground cover	0.40	0.90	0.65[18]	5
Apples, Cherries, Pears[19]				
- no ground cover, killing frost	0.45	0.95	0.70[18]	4
- no ground cover, no frosts	0.60	0.95	0.75[18]	4
- active ground cover, killing frost	0.50	1.20	0.95[18]	4
- active ground cover, no frosts	0.80	1.20	0.85[18]	4
Apricots, Peaches, Stone Fruit[19, 20]				
- no ground cover, killing frost	0.45	0.90	0.65[18]	3
- no ground cover, no frosts	0.55	0.90	0.65[18]	3
- active ground cover, killing frost	0.50	1.15	0.90[18]	3
- active ground cover, no frosts	0.80	1.15	0.85[18]	3
Avocado, no ground cover	0.60	0.85	0.75	3
Citrus, no ground cover[21]				
- 70% canopy	0.70	0.65	0.70	4
- 50% canopy	0.65	0.60	0.65	3
- 20% canopy	0.50	0.45	0.55	2
Citrus, with active ground cover or weeds[22]				
- 70% canopy	0.75	0.70	0.75	4
- 50% canopy	0.80	0.80	0.80	3
- 20% canopy	0.85	0.85	0.85	2
Conifer Trees[23]	1.00	1.00	1.00	10
Kiwi	0.40	1.05	1.05	3
Olives (40 to 60% ground coverage by canopy)[24]	0.65	0.70	0.70	3-5
Pistachios, no ground cover	0.40	1.10	0.45	3-5
Walnut Orchard[19]	0.50	1.10	0.65[18]	4-5

continued...

18 These $K_{c\ end}$ values represent K_c prior to leaf drop. After leaf drop, $K_{c\ end} \approx 0.20$ for bare, dry soil or dead ground cover and $K_{c\ end} \approx 0.50$ to 0.80 for actively growing ground cover (consult Chapter 11).

Source: FAO No. 56


* Kc
ETc = ETo(grass) * Kc

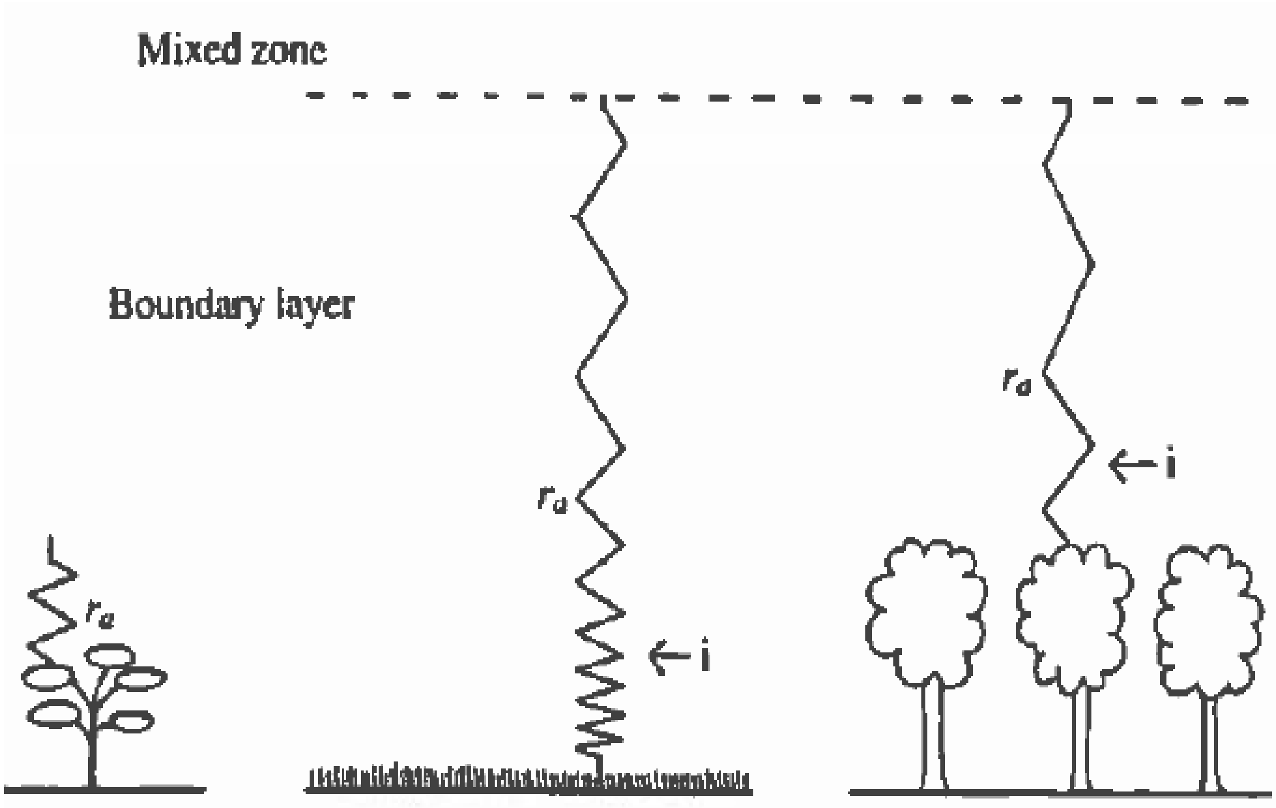
Automating irrigation **schedulling** – dose

Apple Water Use in a Humid Climate
The Problem

$\cancel{ETc = ETo * Kc}$ → too much irrigation in NY, especially in cool years

Automating irrigation **schedulling** – dose

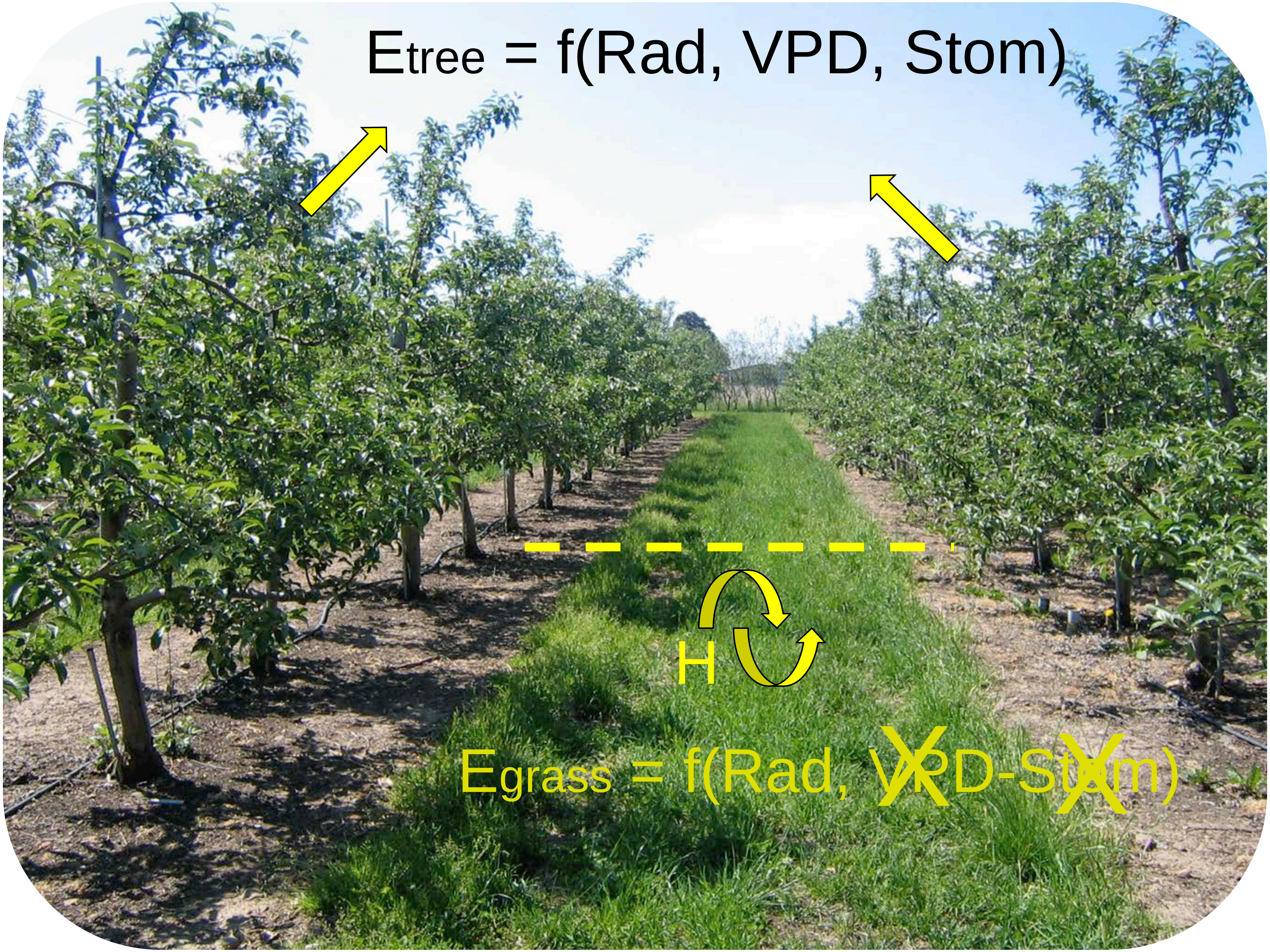
Apple Water Use in a Humid Climate - The Problem



Isolated Plant | Low Grass | Orchard

Tall structure of apple trees affects transpiration

From Jones H.G., Plants and Microclimate 3rd Ed, 2014



Source: A. Lakso

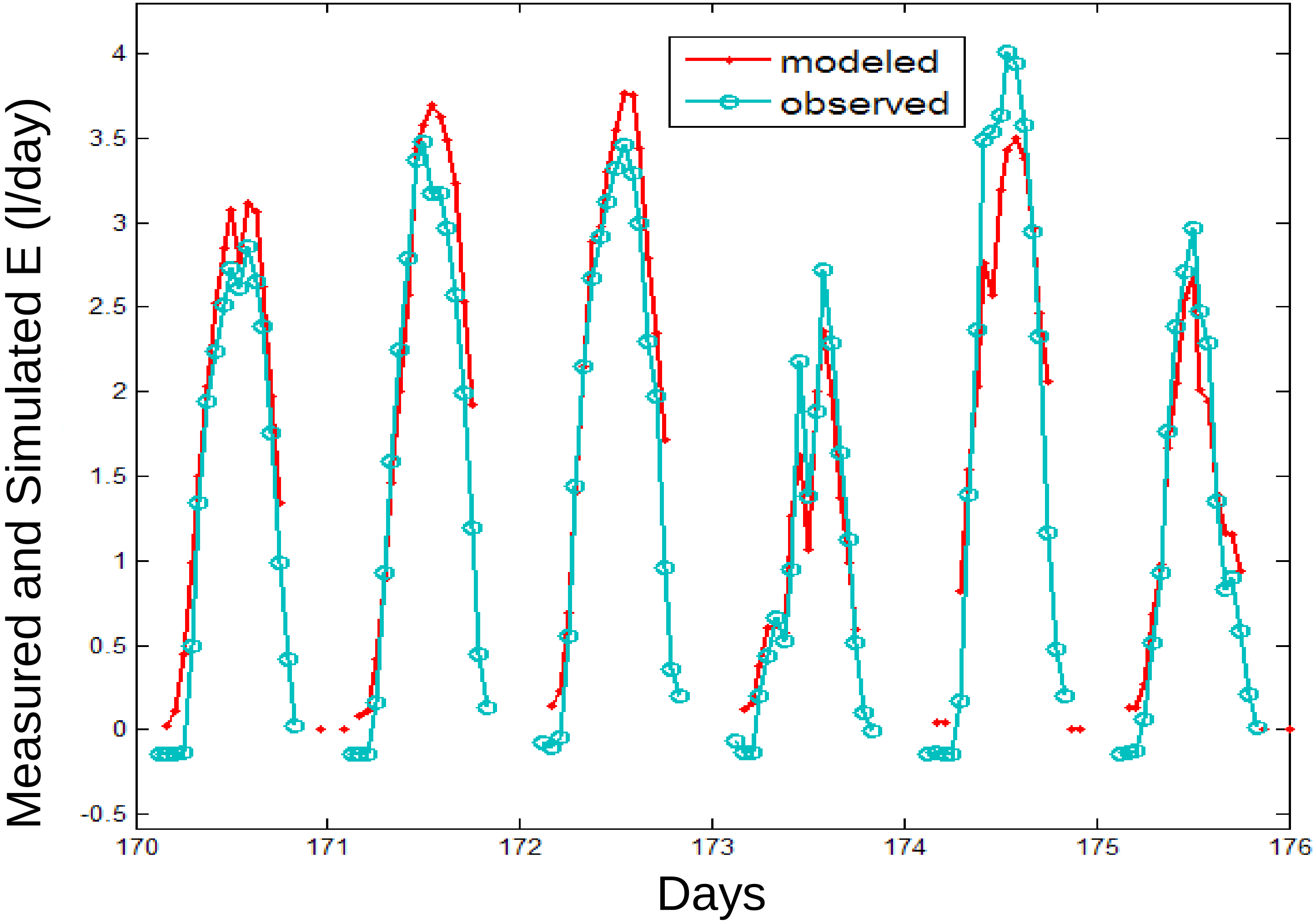
Measurement of Tree ET in New York

- Sap flow gauges were used with short-term direct calibration with “balloon” gas exchange, then balloons removed

- Key micromet parameters measured simultaneously

Source: A. Lakso

Apple-Specific Penman-Monteith Equation



Dragoni, D. and Lakso, A.N. 2011. An apple-specific ET model. Acta Hort. 903:1175-1180.

Getting the Model to Users

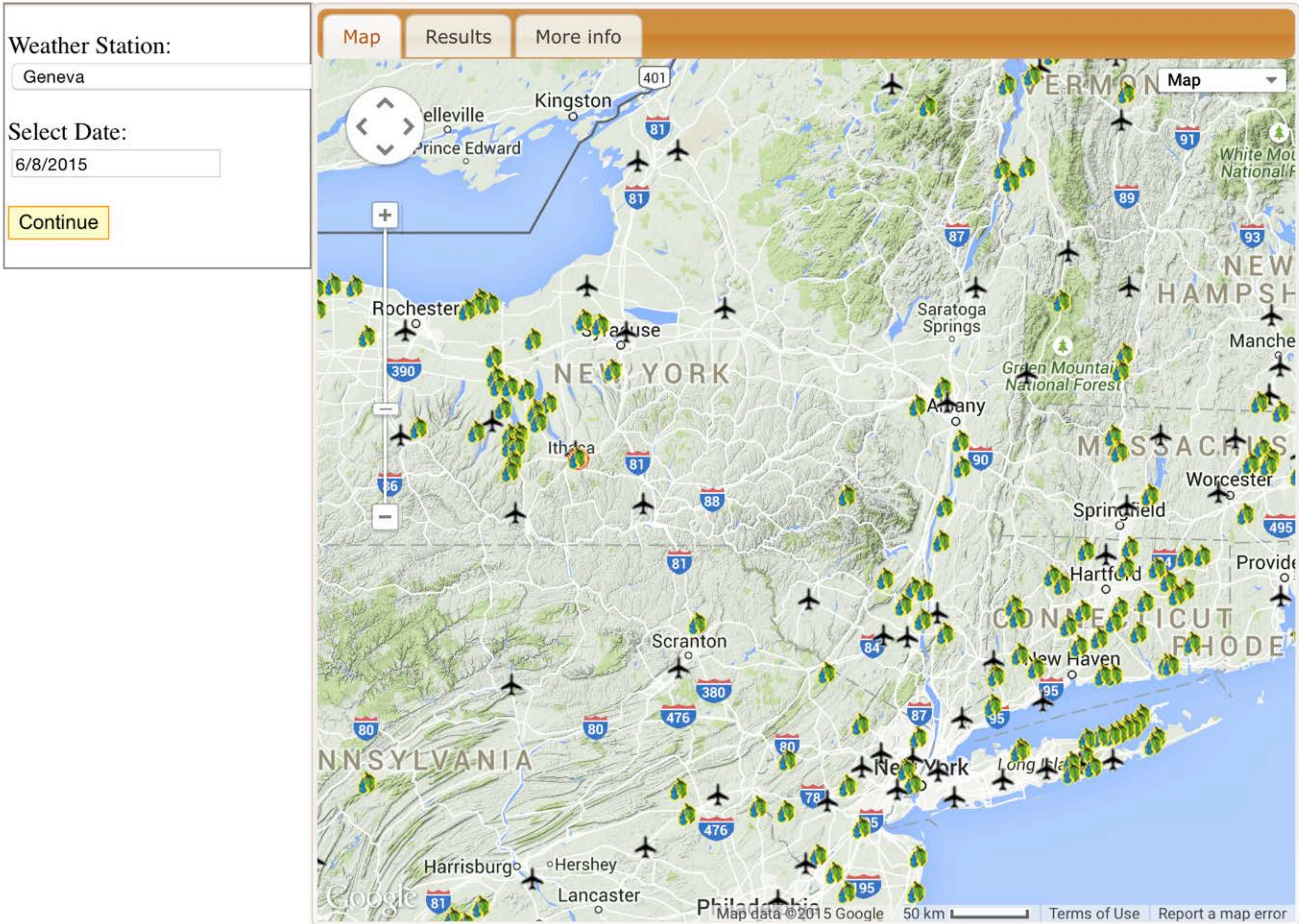
Online version: **Cornell Apple ET Model**

Programmed to automatically calculate daily apple tree ET based on data from weather stations in the apple-growing regions

Collaboration with Dr. Art DeGaetano, Director

Cornell Apple ET Model

http://newa.cornell.edu/cropmanagement/appleirrigation



Cornell Apple ET Model

Weather Station:
Geneva

Select Date:
6/8/2015

Continue

Map | Results | More info

Apple ET Model for Geneva

Change green tip date or tree density and click "Calculate" to recalculate results. Changing "Age of Orchard" will automatically recalculate table.

Green tip date	In row spacing	Between row spacing	Trees per acre	Age of orchard	Water balance
4/17/2015	3 feet	12 feet	1210	Mature	

Apple Evapotranspiration Model Results

Date	Orchard ET (gallons)		Rainfall		Irrigation	Water Balance (gallons/acre)	
	per tree	per acre	inches	gallons/acre	gallons/acre	Daily	Cumulative
Jun 1	0.2	252	0.23	4372	0	4120	0
Jun 2	0.7	859	0.00	0	0	-859	-859
Jun 3	1.9	2321	0.00	0	0	-2321	-3180
Jun 4	1.4	1708	0.00	0	0	-1708	-4888
Jun 5	2.0	2397	0.53	10074	0	7677	0
Jun 6	1.4	1716	0.09	1711	0	-5	-5
Jun 7	2.0	2388	0.00	0	0	-2388	-2393
Jun 8	0.5	660	1.29	24520	0	23860	0
Jun 9	1.1	1288	0.51	9694	0	8406	0
Jun 10	2.1	2596	0.05	950	0	-1645	-1645
Jun 11	2.0	2380	-	-	0	-2380	-4025
Jun 12	1.8	2163	-	-	0	-2163	-6189
Jun 13	1.6	1939	-	-	0	-1939	-8128
Jun 14	2.0	2399	-	-	0	-2399	-10,526

Water requirement calculation

EXAMPLE:

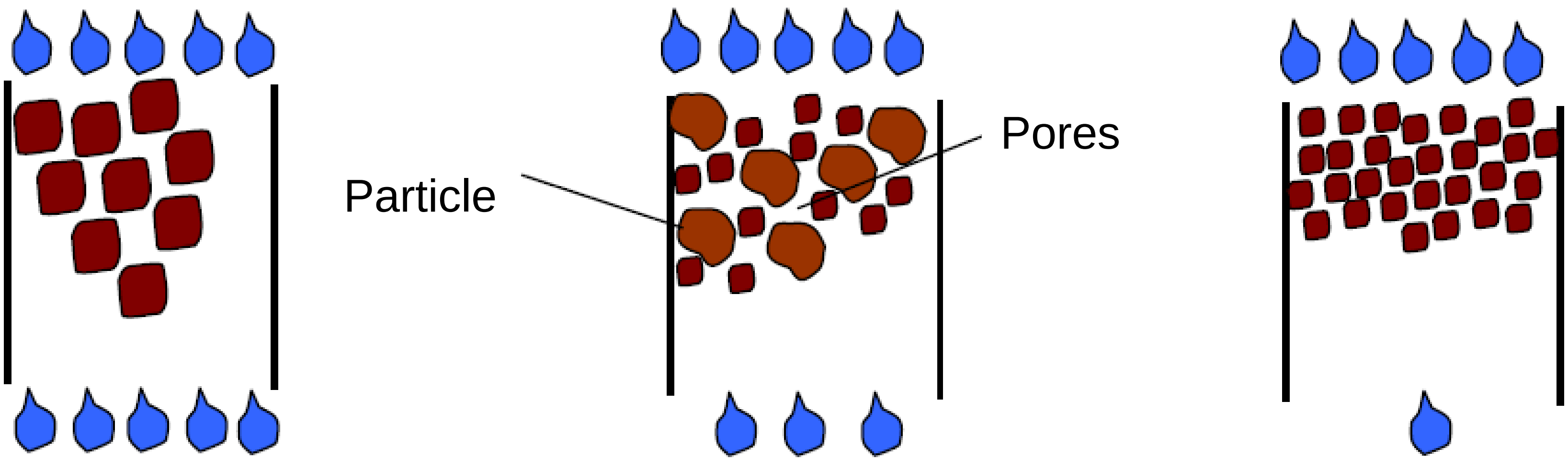
If we need to irrigate 10,526 gallons/acre:

$$\frac{10{,}526}{1037} = 10\ h$$

Application rate = 1 / 42 ~ 0.02 GPH / ft^2

1037 GPH / acre

Each soil has its own properties



Sandy soil

Quick drainage
Low humidity retention

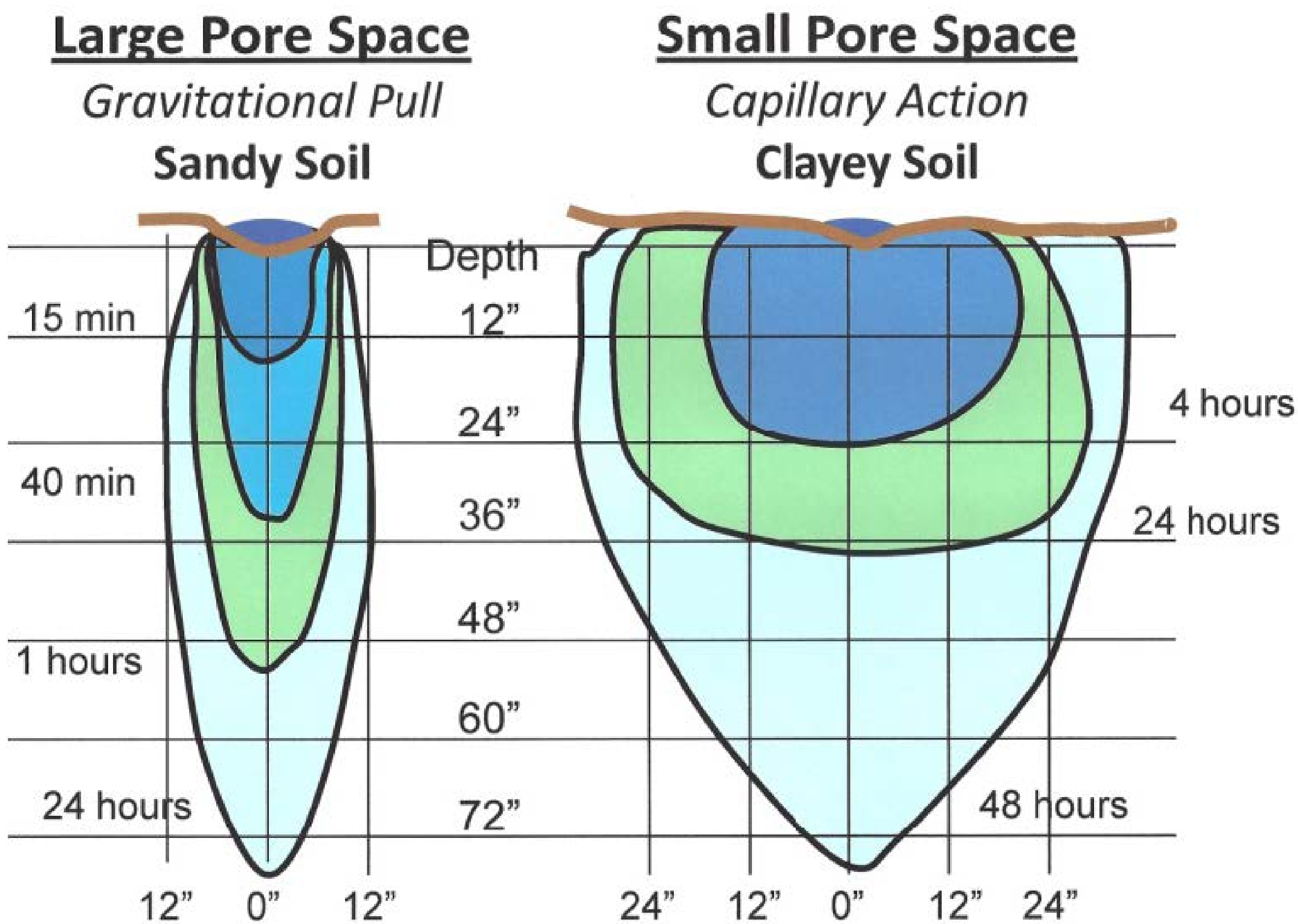
Loam type soil

Slow drainage, but not limiting
Good humidity retention

Clay soil

Very slow & poor drainage
High humidity retention
Aireation problems

Source: agriculture.vic.gov.au



Source: intechopen.com

Water requirement calculation

If we need to irrigate 10,526 gallons/acre:

$$\frac{10{,}526}{1037} = 10\ h$$

Sandy soils irrigate daily: 1.6 h/day

Clay soils irrigate twice a week: 5 h/day

Why

Why irrigate

Functions of water in plants:

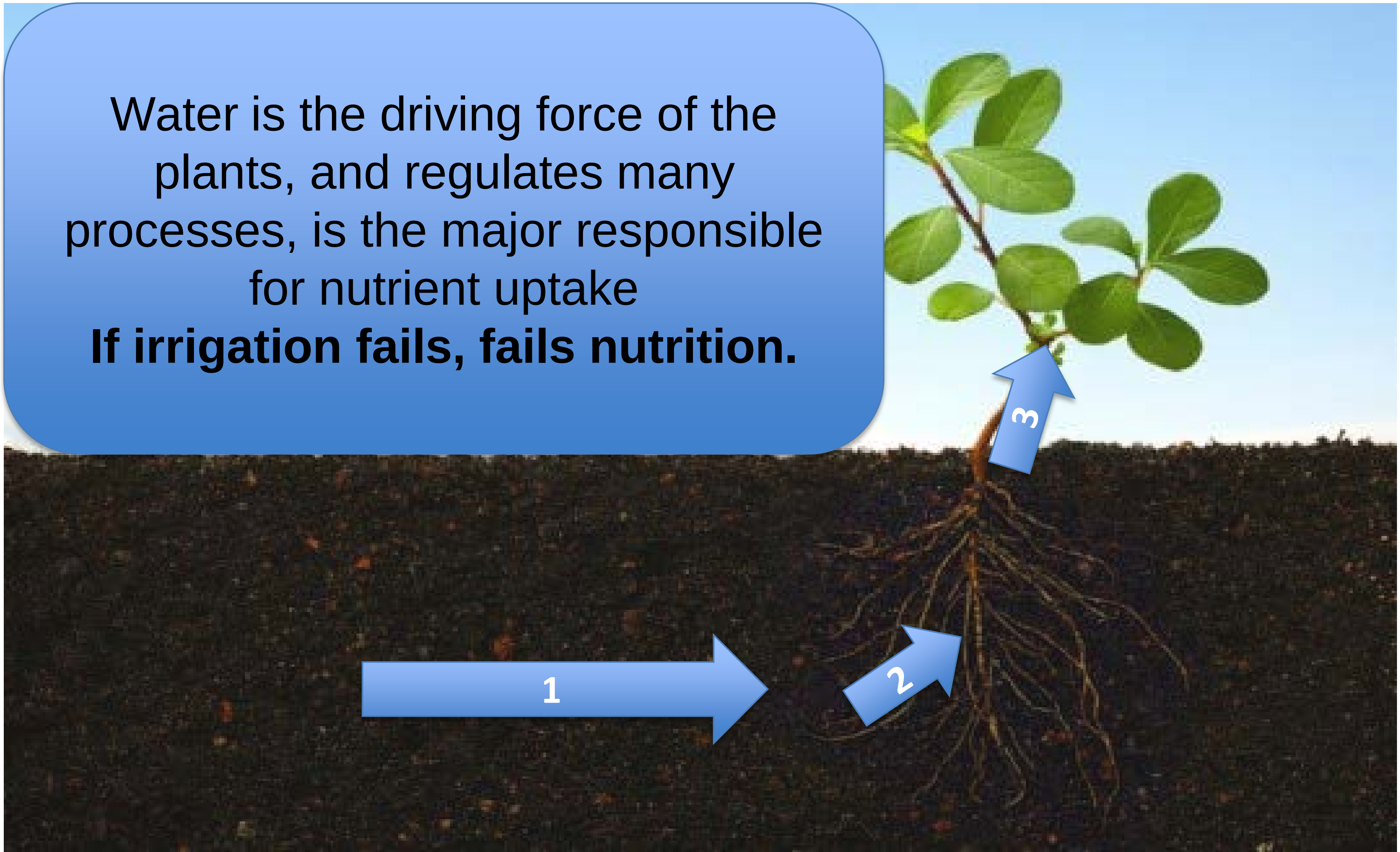
- ✓ Mantenance of cell turgor
- ✓ It regulates the plant temperature (through transpiration)
- ✓ Uptake & transport of nutrients & secondary plant compounds
- ✓ Element involved in many internally chemical processes (Photosynthesis)

What if water is missing?

Nutrient uptake

Water is the driving force of the plants, and regulates many processes, is the major responsible for nutrient uptake

If irrigation fails, fails nutrition.



Why irrigate

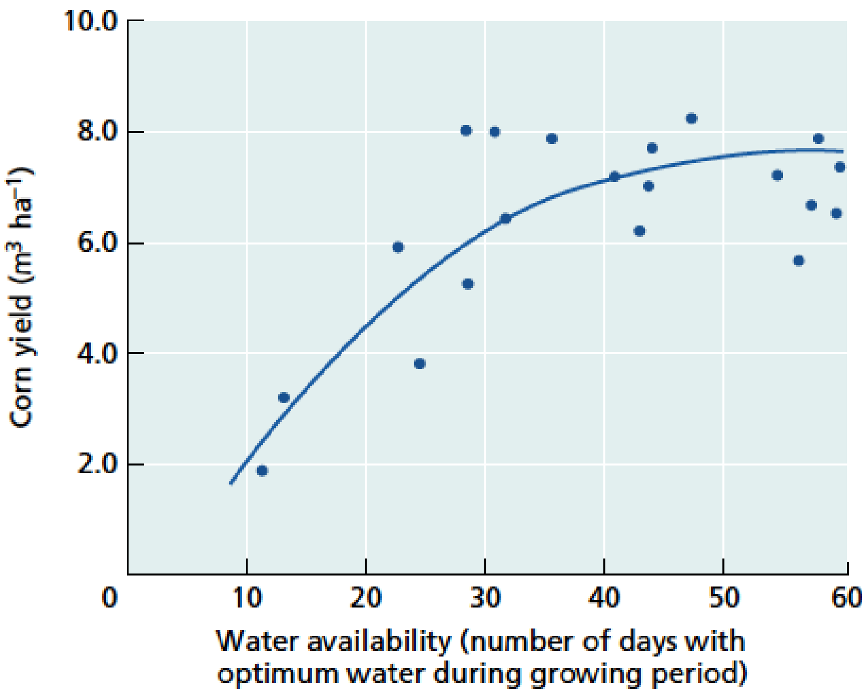


FIGURE 3.1 Corn yield as a function of water availability. The data plotted here were gathered at an Iowa farm over a 4-year period. Water availability was assessed as the number of days without water stress during a 9-week growing period. (Data from *Weather and Our Food Supply* 1964.)

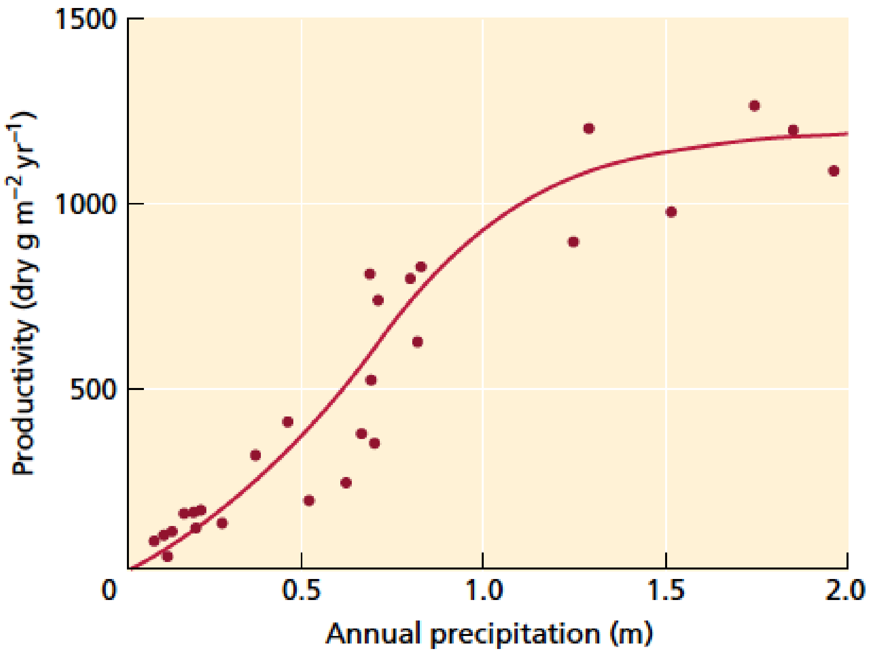
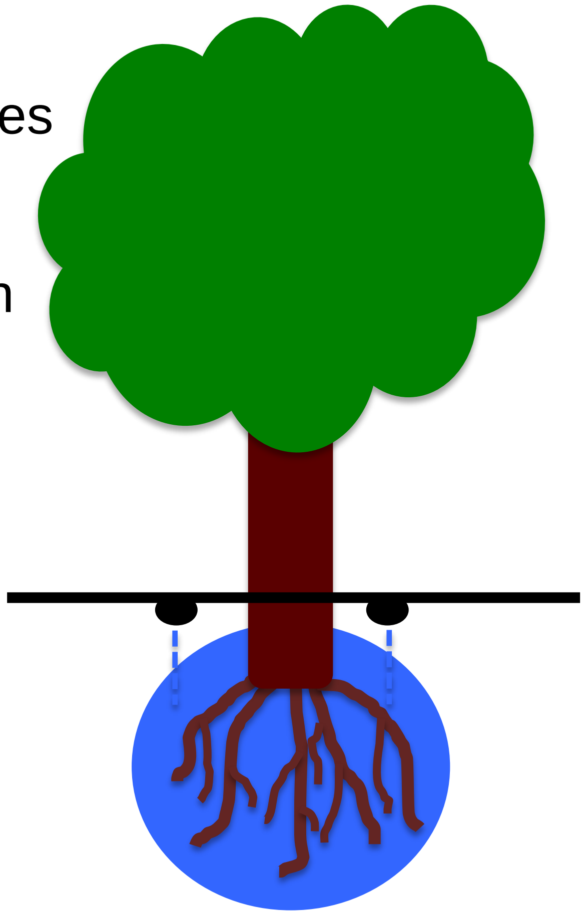


FIGURE 3.2 Productivity of various ecosystems as a function of annual precipitation. Productivity was estimated as net aboveground accumulation of organic matter through growth and reproduction. (After Whittaker 1970.)

Water Stress with Young Trees

- Limited root system due to digging in nursery
- Transplant shock
- Rapid Leaf area development with branched trees

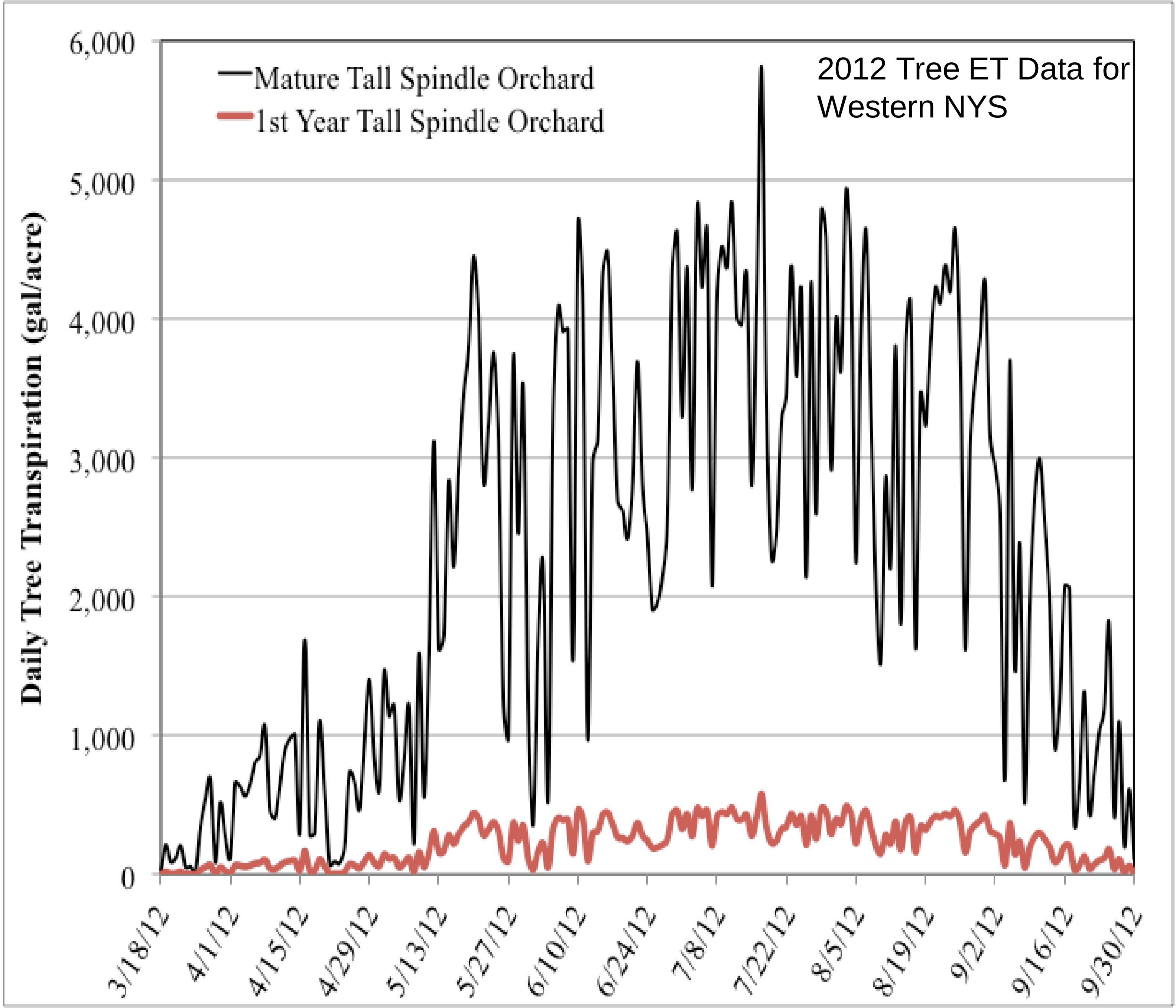


- Highly feathered trees experience water stress in late May and June due to limited root systems and extensive leaf area

- Water must be applied frequently to limit water stress on newly planted trees. Trickle irrigation must be installed within 2 weeks of planting

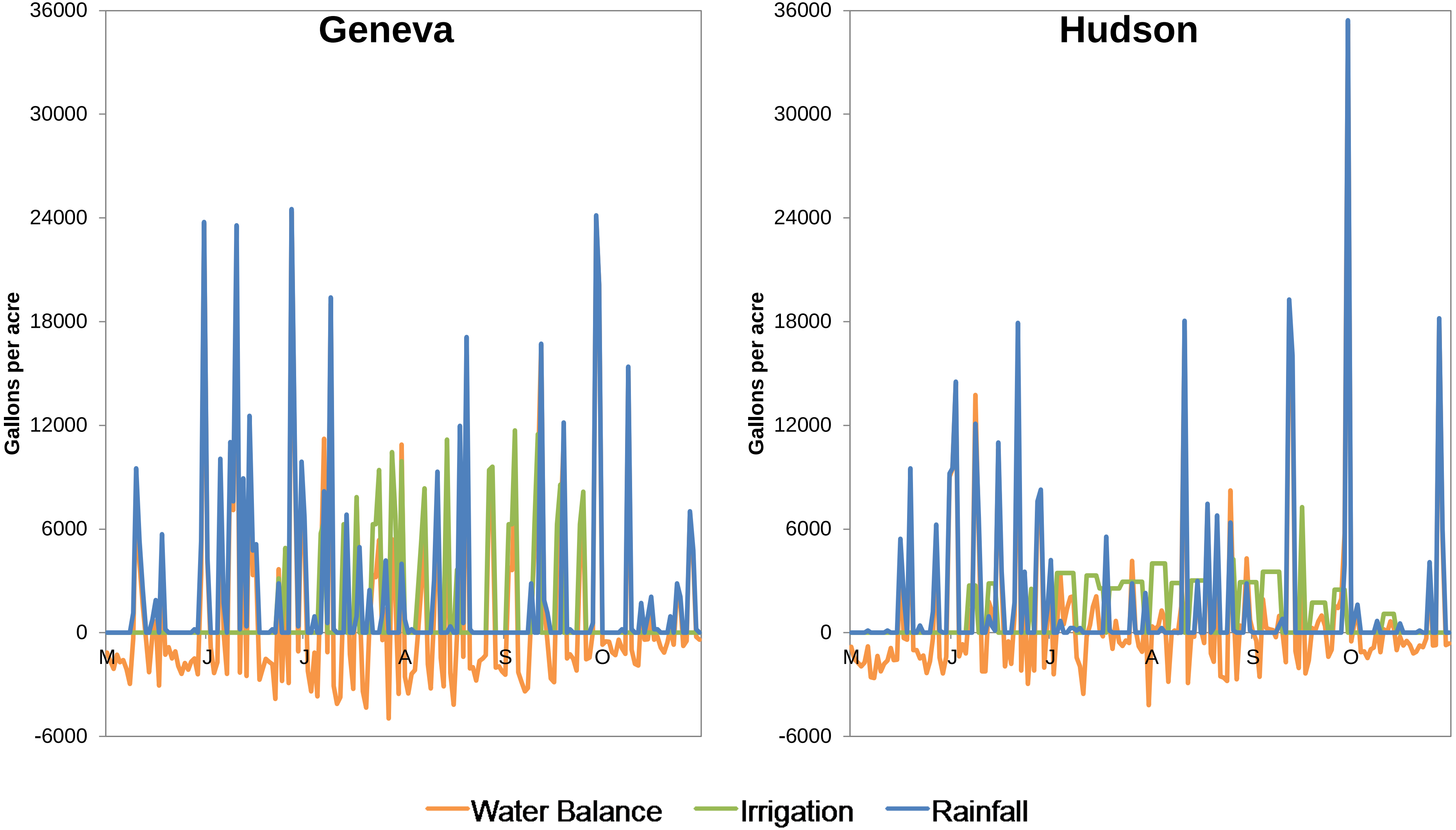
- Newly planted trees have limited nutrient uptake due to damaged root systems.

2015 Trial



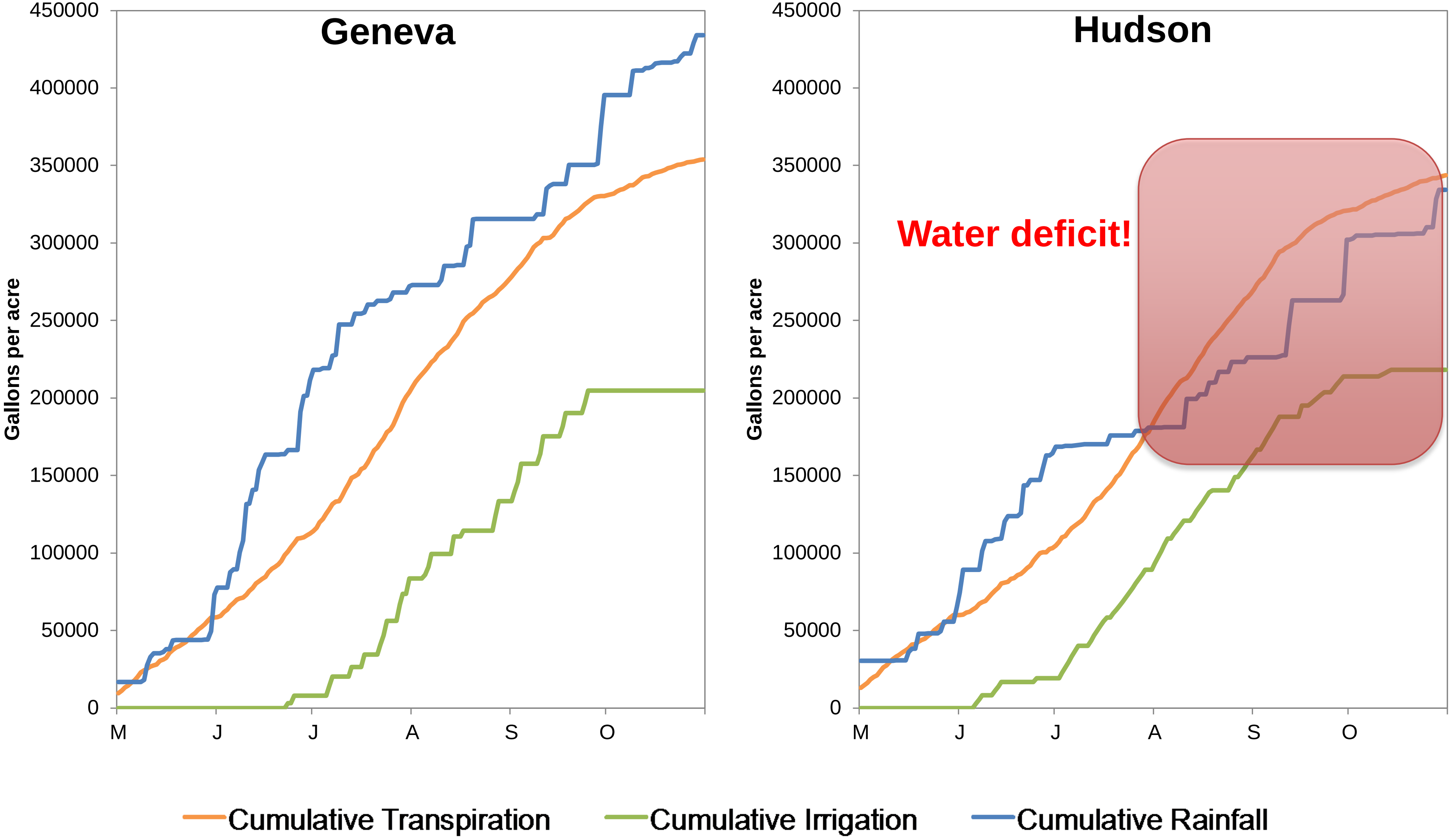
2012 Tree ET Data for Western NYS
Mature Tall Spindle Orchard
1st Year Tall Spindle Orchard
Daily Tree Transpiration (gal/acre)
6,000
5,000
4,000
3,000
2,000
1,000
0
3/18/12
4/1/12
4/15/12
4/29/12
5/13/12
5/27/12
6/10/12
6/24/12
7/8/12
7/22/12
8/5/12
8/19/12
9/2/12
9/16/12
9/30/12

2015 Data



Geneva
Hudson
Gallons per acre
36000
30000
24000
18000
12000
6000
0
-6000
M
J
J
A
S
O
Water Balance
Irrigation
Rainfall

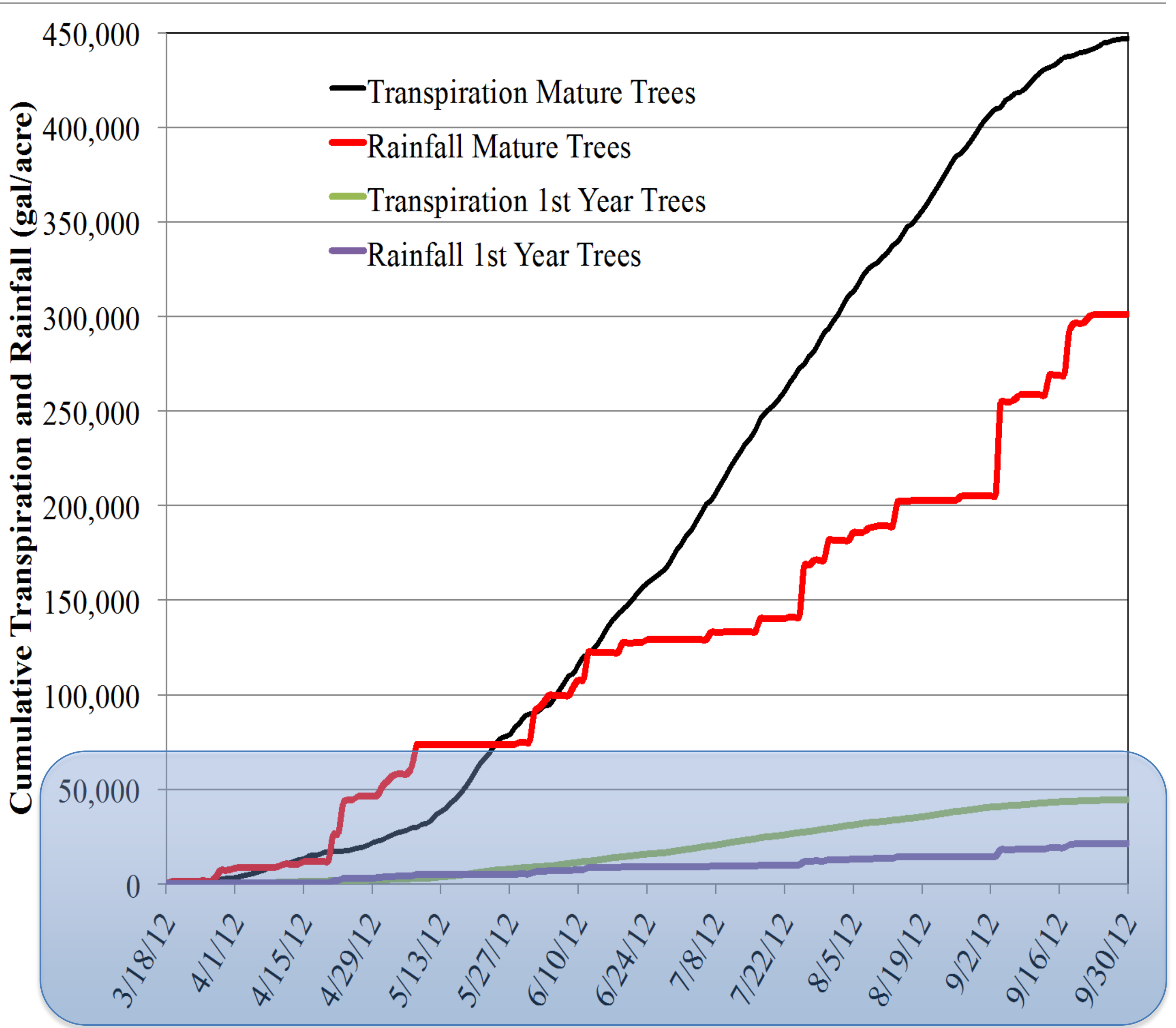
2015 Data



Geneva
Hudson
Water deficit!
Gallons per acre
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
M
J
J
A
S
O
Cumulative Transpiration
Cumulative Irrigation
Cumulative Rainfall

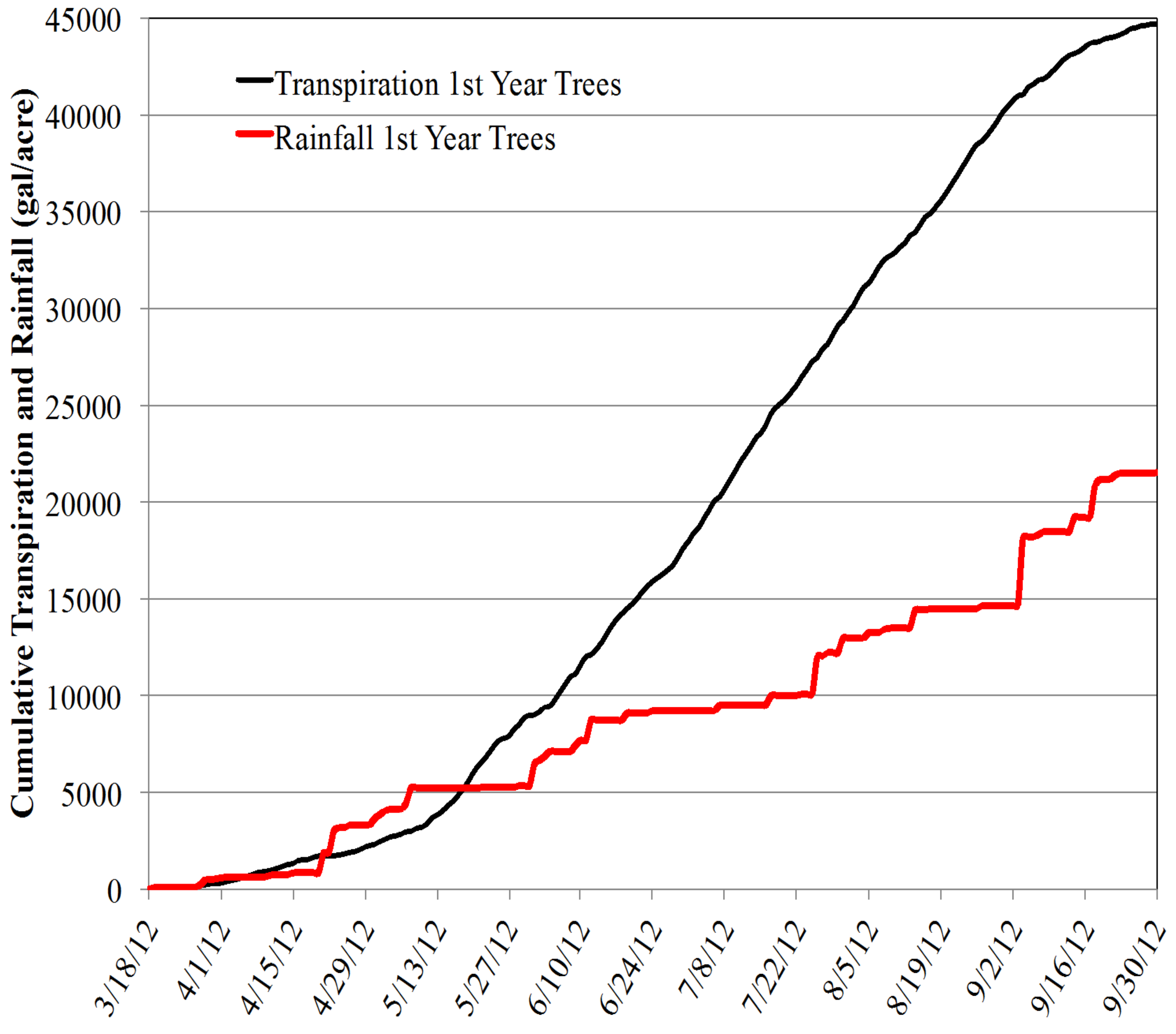
2012 Cumulative Water Balance for Western NYS

Mature Trees



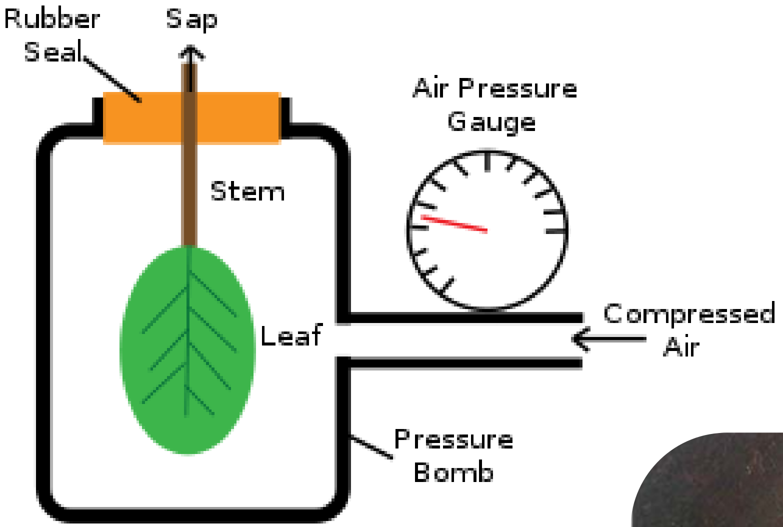
2012 Cumulative Water Balance for Western NYS

YoungTrees



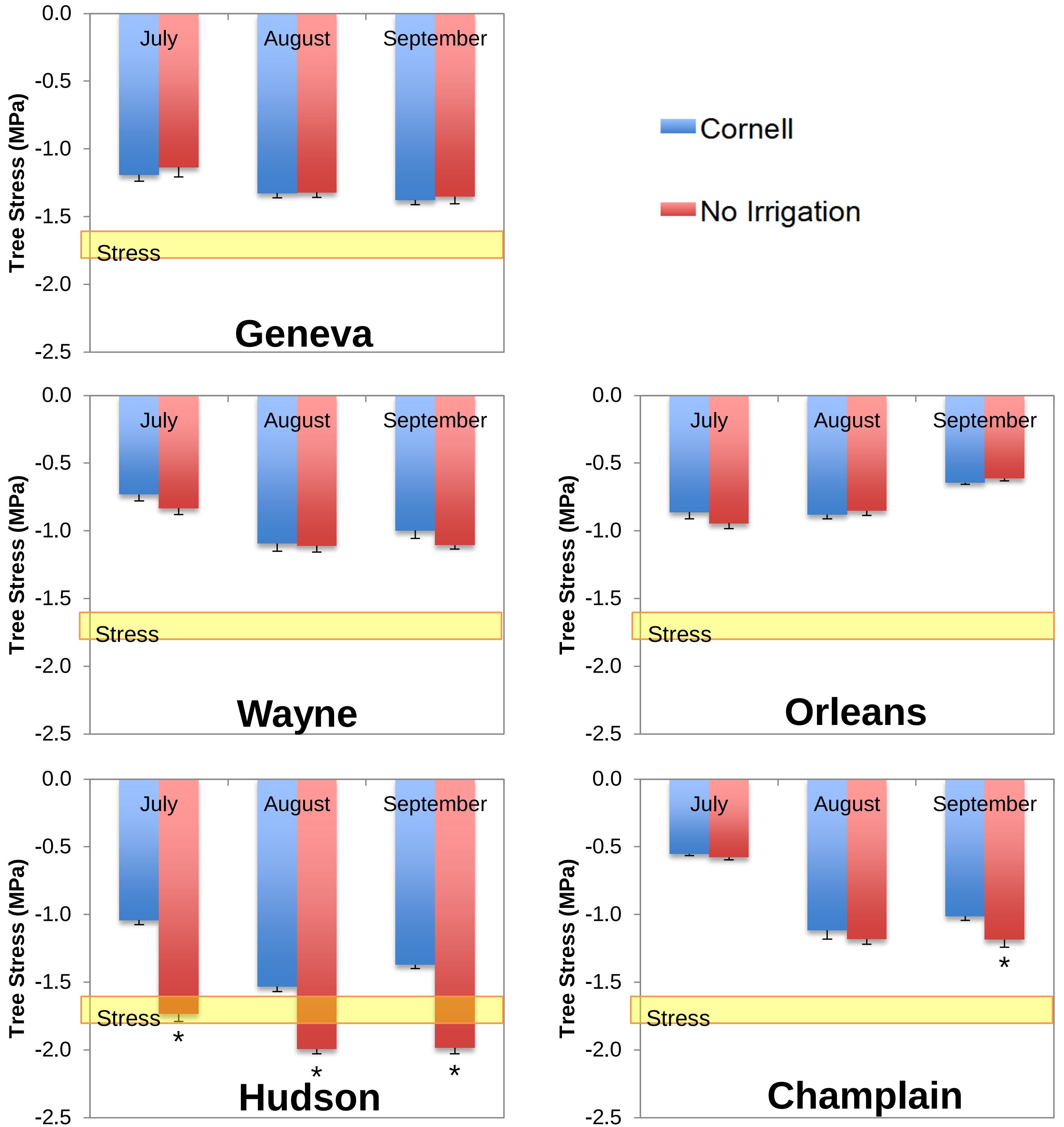
Assessing Tree Water Status

Assessing Tree Water Status



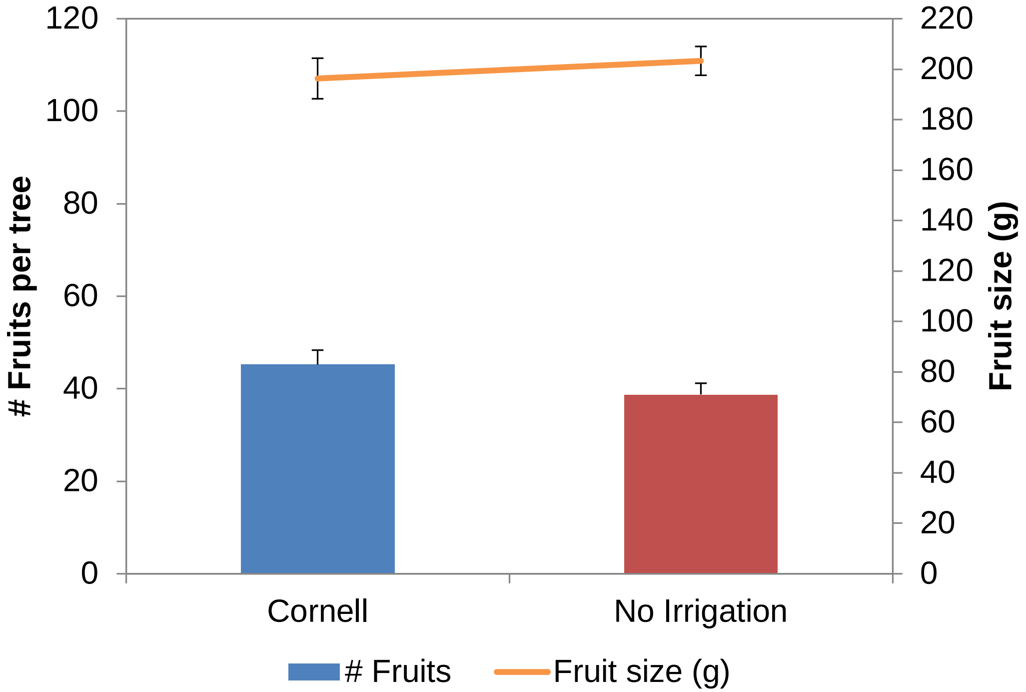
Source: thefullwiki.org

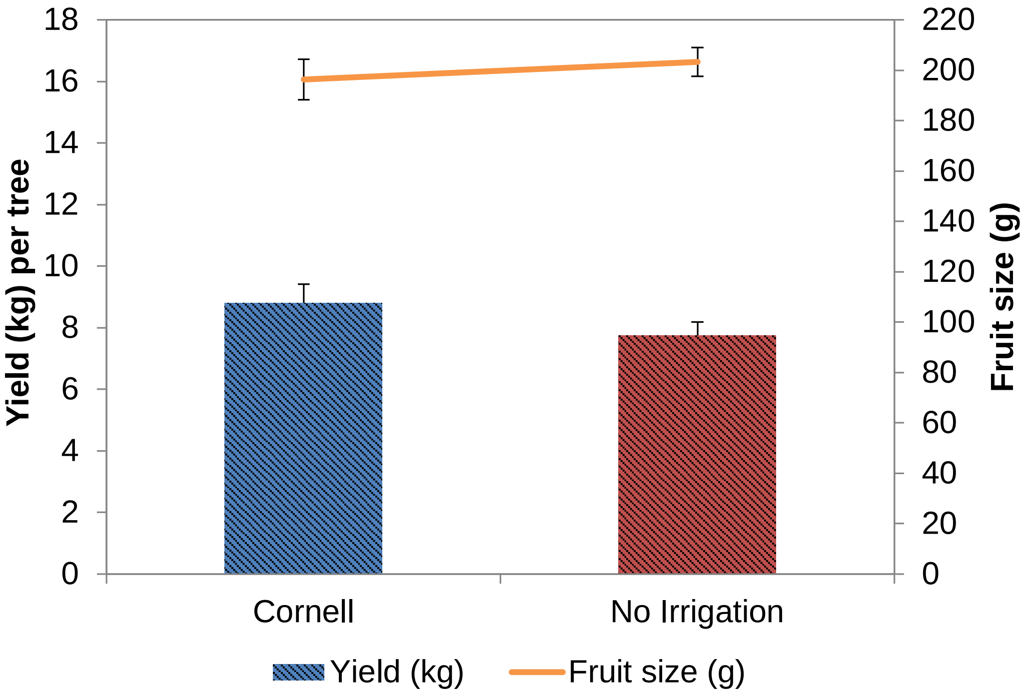
Source: nrelscience.org

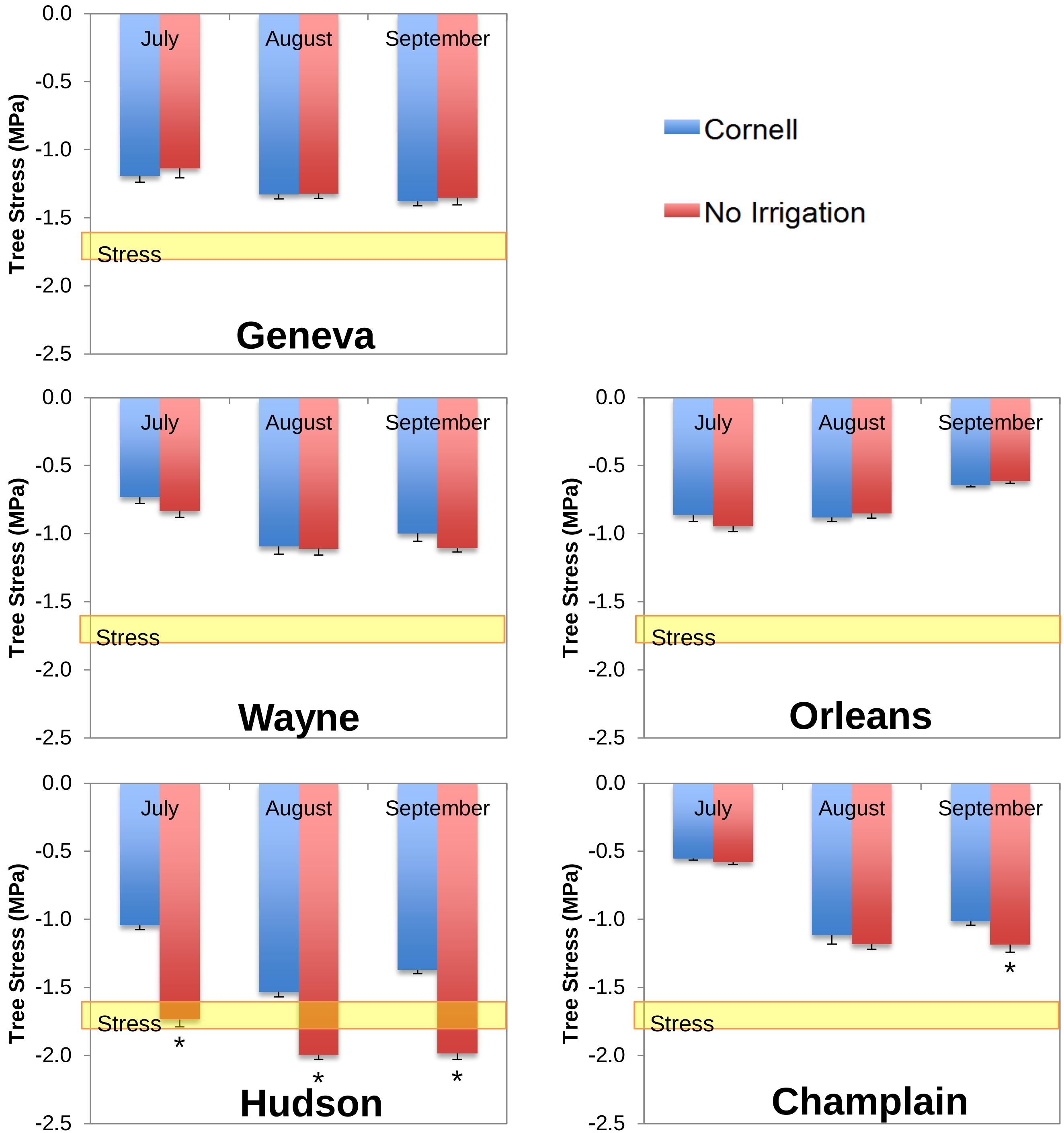

Cornell
No Irrigation
Geneva
Wayne
Orleans
Hudson
Champlain
July
August
September
Stress
Tree Stress (MPa)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
*

2015 Data

Geneva







Cornell
No Irrigation
Tree Stress (MPa)
0.0
-0.5
-1.0
-1.5
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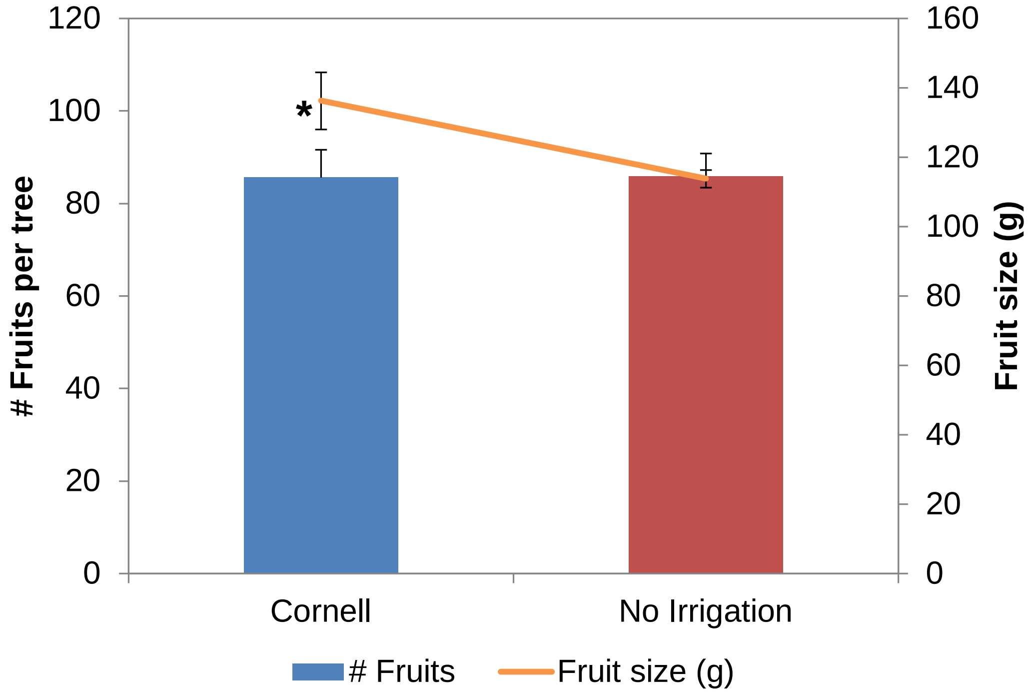
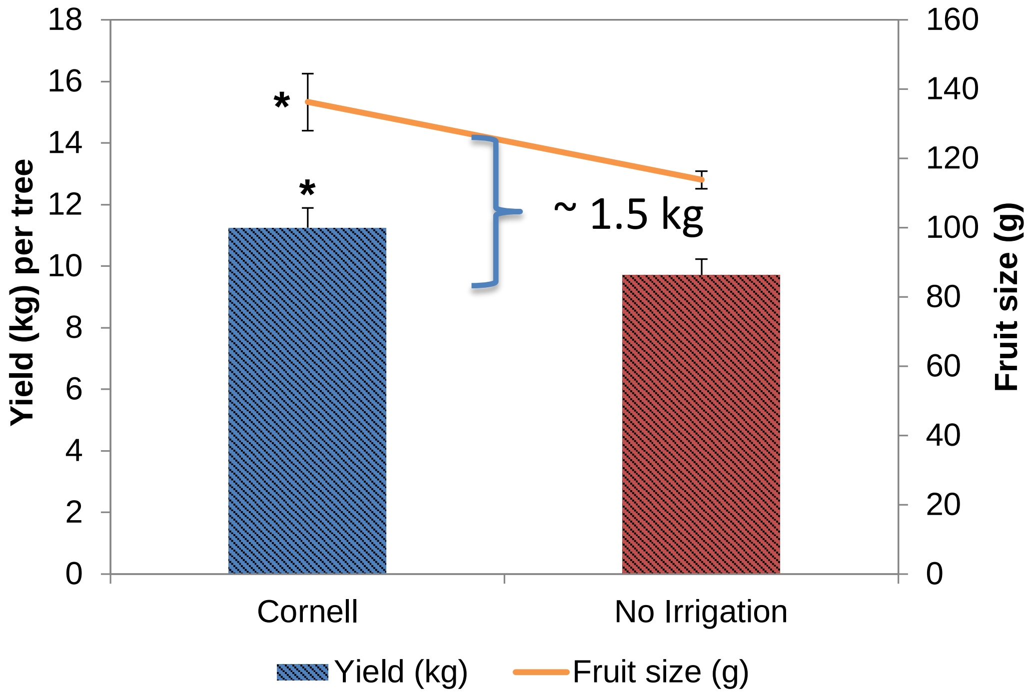
-2.5
July
August
September
Stress
*
Geneva
Wayne
Orleans
Hudson
Champlain

2015 Data
Hudson





Per acre	Irrigated	Non-irrigated	Difference
Yield	11.2 kg/tree	9.7 kg/tree	1.5 kg/tree
Yield (1,117 trees)	12,560 kg	10,849 kg	1,710 kg
Yield (1,980 trees)	22,263 kg	19,231 kg	3,032 kg
Yield (1,117 trees)	692 bu	598 bu	94 bu
Yield (1,980 trees)	1,227 bu	1,060 bu	167 bu
Income (1,117 trees)	7,410 $	5,858 $	1,552 $
Income (1,980 trees)	13,135 $	10,385 $	2,750 $

Per ha	Irrigated	Non-irrigated	Difference
Yield	11.2 kg/tree	9.7 kg/tree	1.5 kg/tree
Yield (2,778 trees)	31,236 kg	26,982 kg	4,254 kg
Yield (4,902 trees)	55,118 kg	47,611 kg	7,507 kg
Yield (2,778 trees)	1,722 bu	1,487 bu	235 bu
Yield (4,902 trees)	3,038 bu	2,625 bu	414 bu
Income (2,778 trees)	18,429 $	14,570 $	3,859 $
Income (4,902 trees)	32,520 $	25,710 $	6,809 $

Keep in mind

- Newly planted apple trees can undergo water stress soon after growth starts limiting first year growth
- Trickle irrigation has its largest impact in the first few years and so should be installed early in the first year
- In dry years, the application of water should begin in mid-May. In other years, the application of water can be delayed until early June. **Check Cornell model**
- Using the ET model to precisely apply the proper amount of water will help ensure that proper fruit size is achieved each year


Thanks for your attention!