Barossa Improved Grazing Group
Soil Moisture Monitoring Workshop

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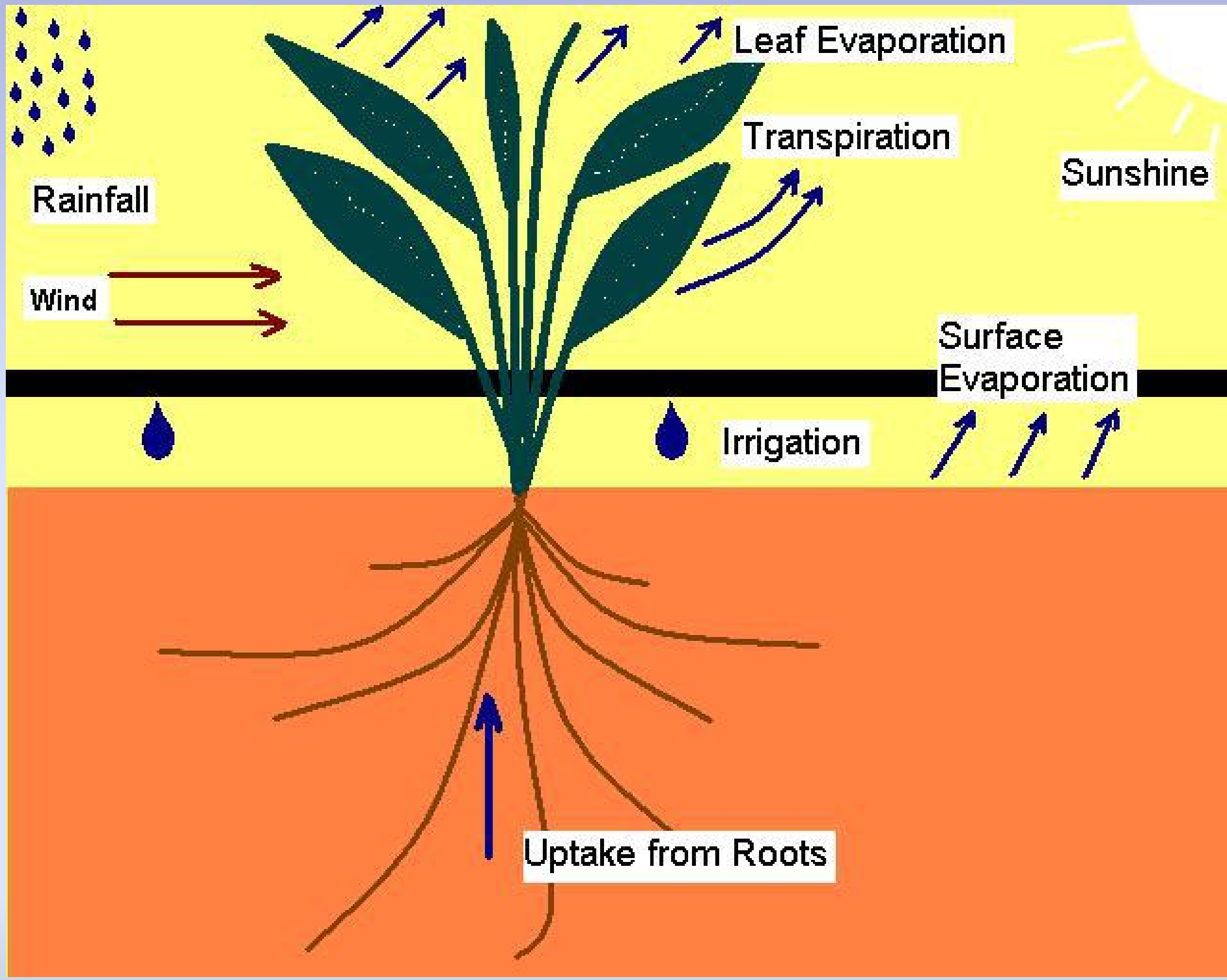
Outline

- The Plant Engine and its drivers
- Water Uptake in Plants
- Limiters to Growth
- Modelling plant growth
- Water Use Efficiency
  - Dryland crops
  - Irrigated crops
- Water Use and Yield
- Probing for Moisture

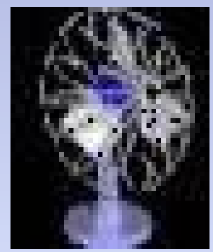
The Plant Engine

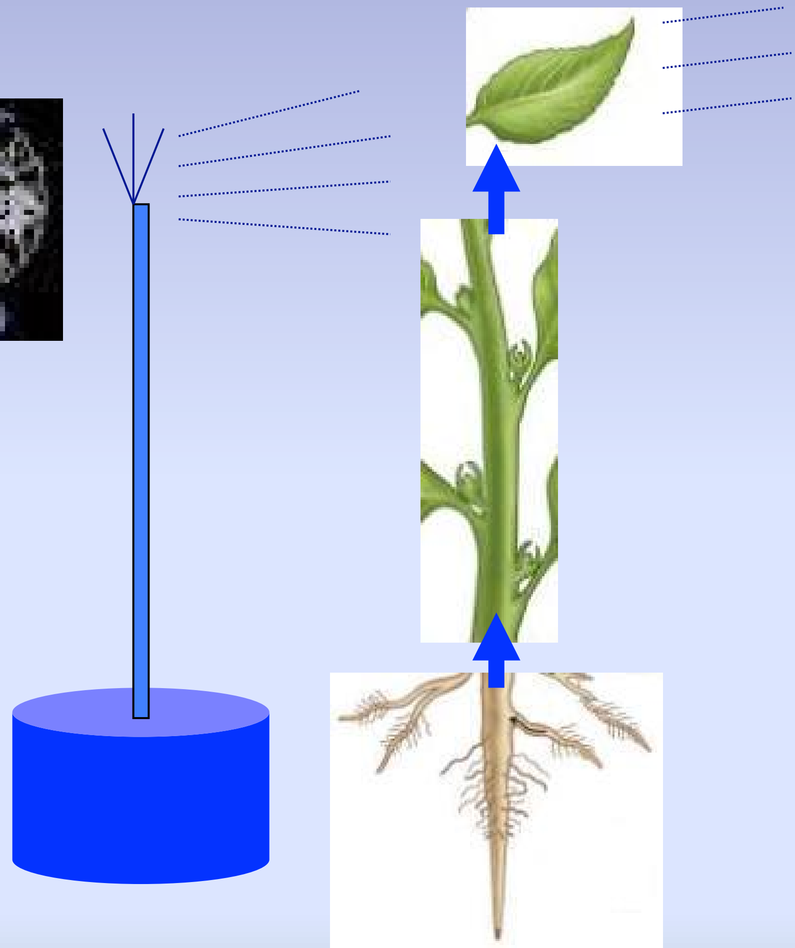


Water uptake in Plants

Siphon effect

- Stomata – little openings on leaves
- Open to let water in to atmosphere
- Creates pressure gradient
- Water drawn up from soil, through roots, trunk, stem & in to leaves





Primary Drivers of Water Use

Factor	Relationship to Water Use	Impact
Solar Radiation	↗	Primary Driver of Growth - Provides energy for cell growth & division - Increased radiation = increased growth
Air Temperature	↗	Transpiration increases with increasing temperature
Relative Humidity	↘	Harder for water molecules to escape to the air
Wind Speed	↗	More air passing over leaf surface -> more water removed

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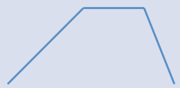
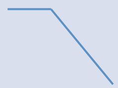
Limiting Factors to Water Use

Factor	Relationship to Water Use	Impact
Water Availability		Too wet: roots oxygen deprived Ideal Zone: plant takes up as much water as conditions allow Stress zone: transpiration reduced by stress Too Dry: transpiration stops, cells die
Nutrient Availability		Too little: growth restricted Ideal Zone
Chemical Barriers		Salt, boron etc.: restrict capacity for chemical reactions to occur

Maximising Water Use Efficiency

Factor	Impact on WUE	Maximising UE	
		Dryland	Irrigated
Surface Evaporation	Water Lost to plants	Increase soil cover (stubble retention) - Reduces soil temperature - Reduces albedo	
Runoff	Water lost to plants	Retain stubble Manage contours	Retain stubble Match irrigation rate to infiltration rate
Through drainage	Water lost to plants	Build water holding capacity	Improve scheduling Avoid over-irrigation
Retained water	Increases WUE	Increase soil water holding capacity - Increase organic content - Increase soil carbon - Clays: add gypsum, Sands: add clay	
Agronomic factors	Increase WUE	- Varietal selection, sowing date etc. etc.	

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WUE and Yield

- Pasture water requirements
  - Perennial pasture: 10 to 14 Ml / Ha for unrestricted yield
- Yield Models
  - Developed to provide a means of forecasting yield
  - Provides season on season comparison
  - Fosters comparison between farms/districts
  - Allows "what if" analysis

- Many flavours
  - French and Schultz
  - Baldock N-Calculator
  - APSIM / Yield Prophet
  - Rodrigues & Sadras

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French and Schultz

- Developed in 1984
- Identified a practical max yield of 20kg/mm/Ha for wheat
  - Pasture: 15? 18? 30 ? 45 kg/mm/Ha???
  - increase through plant breeding, soil management, water retention
- Yield in any season reduced by water stress
- Driven by rainfall
  - Total Rainfall = actual or forecast rainfall for growing season
  - Effective rainfall = Total Rainfall less Evaporation and Drainage
    - 70mm for pasture
  - Pasture Yield = Effective Rain * (15kg DM)/mm/Ha
    - Can calculate for each rainfall decile and evaluate different options

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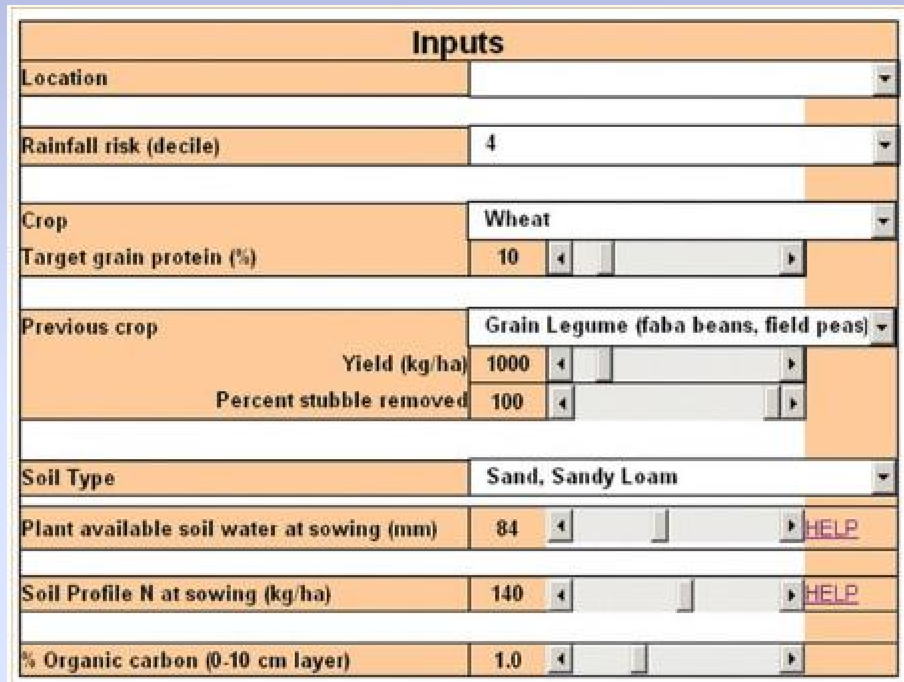
N Calculator (Mallee Calculator)

- Developed in 2004
- Builds on French and Schultz
- Adds Nutrient status
- Priming the Model
  - Select location (to link to long term rainfall records)
  - Set soil type (governs holding capacity)
  - Select previous crop (type, yield, stubble management)
  - Select target protein content
  - Enter starting moisture status (soil test, soil probe)
  - Enter inorganic nitrogen reserves (soil test)
  - Select Risk Profile (i.e. choose appropriate rain decile)



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N Calculator (Mallee Calculator)

- Run model
  - Calculates potential yield
  - Calculates fertiliser requirements
- Major benefits
  - Increases understanding of nitrogen demand
  - Reduced exposure to rainfall risk
    - Single nitrogen application at start of season
    - Split application
      - Half up front at sowing
      - Review in August/Sept based on rainfall to date

Outputs	
Growing season rainfall (mm)	192
Estimated total available water (mm)	242
Potential yield with given rainfall and soil water (t/ha)	3.1
Potential yield (accounting for sowing date (t/ha)	1.8
Attainable yield (accounting for nominated maximum) (t/ha)	1.8
N requirements to achieve nominated yield/protein (kg/ha)	96
N from incrop mineralisation of soil organic matter (kg/ha)	39
N contribution or uptake due to stubble (kg/ha)	-4
N available (inorganic at sowing + stubble + soil) (kg/ha)	80
Estimated fertiliser requirement (kg N/ ha)	16

APSIM – Yield Prophet

- Introduced concept of plant modelling
- Available for wheat but not for pasture
- Evolution of CERES models
- APSIM Wheat
  - Models growth of number of wheat varieties
  - Inputs
    - Variety
    - Sowing depth
    - Starting moisture levels
    - Starting nutrient levels
    - Fertiliser input
    - Rainfall
    - Climate data
  - Outputs
    - Crop growth stage
    - Likely harvest date
    - Likely yield

APSIM Limitations

- Assumes starting season moisture & then models water use
  - Errors accumulate over time
  - Needs accurate match of soil on site to model
- No local climate data
  - Causes errors in water use estimation
- Development Options
  - Include data from soil moisture probes
  - Include data from local weather station.

Rodriguez and Sadras (2008)

- Expands model to introduce "productive" water use

$$Yield = (ET) * (T/ET) * (TE) * (HI)$$

ETc= evapotranspiration of crop (from AWS)

T/ET = transpiration efficiency or fraction of ET which contributes to crop growth

Water stress -> dec crude protein & dec water soluble carbohydrate

TE = yield per mm or water (e.g. 15 kg/ha/mm)

HI = harvest index or fraction of total biomass which is represented by grain

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Combined Model

- Reverse the process
  - Start with in-field soil moisture and climate data
    - Soil probes: give daily water use
    - Weather station: gives expected water use
      - Includes impact of timing of rainfall
    - Calculate water stress = Actual Water Use / Modelled Water Use
    - Calculate daily yield given level of stress
  - Sum yield to date based on actual crop water use
    - Simple Yield = 15kg/Ha per mm
    - More Complex Yield = growth stage + biomass accumulation
  - Forecast future yield based on rainfall deciles

Soil Moisture Monitoring

- Investigating merits of use as a tool for pasture management
- Proven beneficial to dryland wheat growers
  - – Primarily a risk management tool
  - – Now being combined with other in field data
    - Rainfall
    - Wind (for spray drift)
    - Delta-T (using air temperature & relative humidity)
    - Plant disease models (using climate data)

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Soil Moisture Monitoring

- Why?
  - Is soil moist (and warm) enough to promote good germination?
  - Is there enough moisture left to sustain growth?
  - When can I move stock on or move it off
  - Do I apply more nutrients?
- Soil moisture monitoring gives you more information on which to base these decisions

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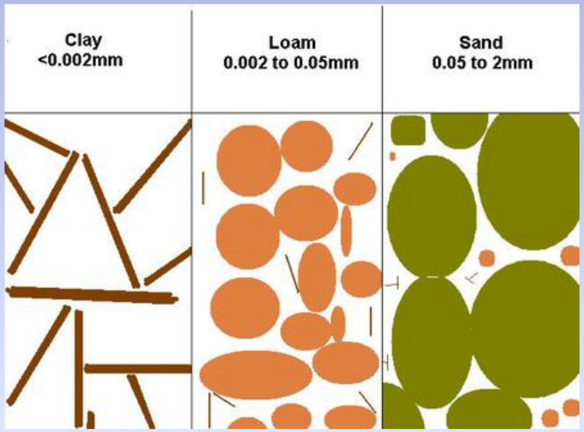
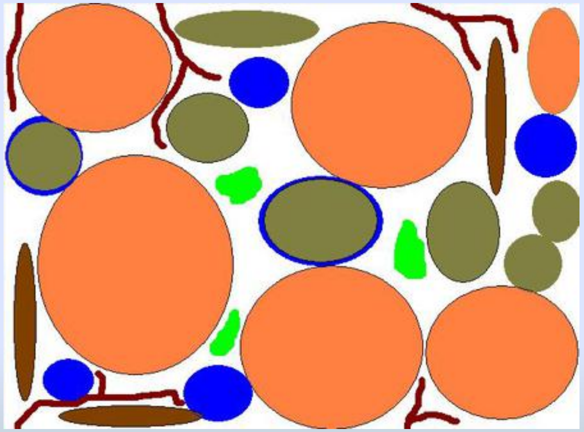
Water holding in soils

- Related to soil type and structure
- Sand
  - Large particle size
  - Poor holding forces
- Clay
  - Smallest particle size
  - Strong holding force
- Loam
  - In between





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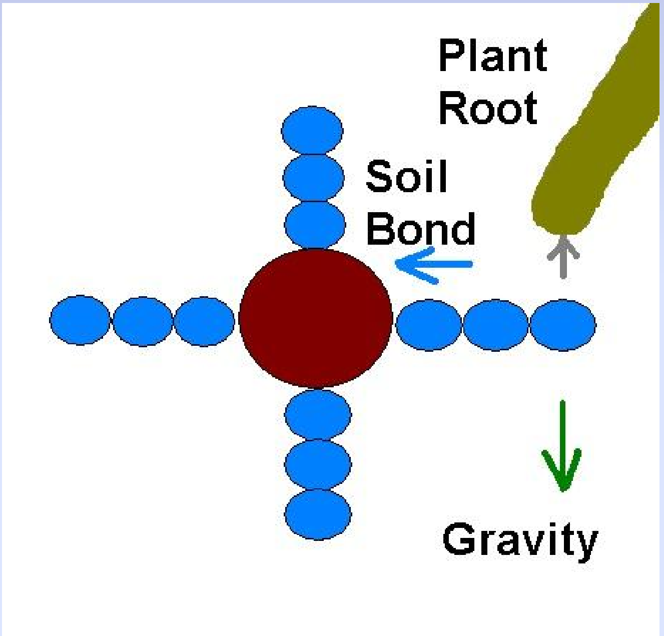
The plant's point of view

- Battle between competing forces
  - Tension holding water to soil
  - Gravity
  - Suction exerted by plant root



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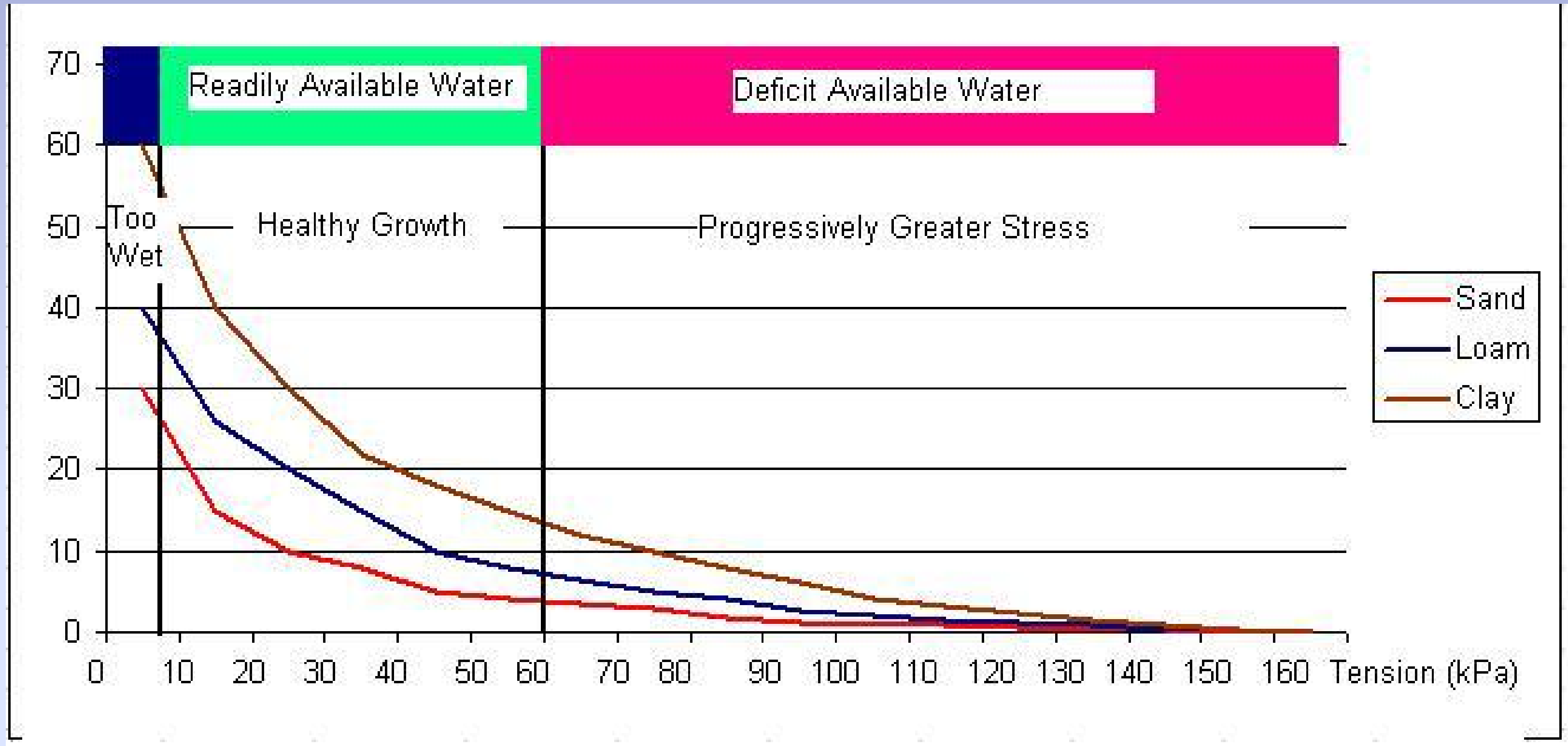
Soil Water Release Curves



- Show relationship between content and tension
- Identify key pints: DUL, CLL, RAW, PAW, TAW

Two sides of the story

- Soil Tension
  - Direct reading of water status of plant
  - Easy to interpret
  - Doesn’t tell “How much is in the bucket”

- Soil Content
  - Soil dependent
  - Needs to be interpret based on knowledge of plant & soil
  - Can be related to “mm in soil”

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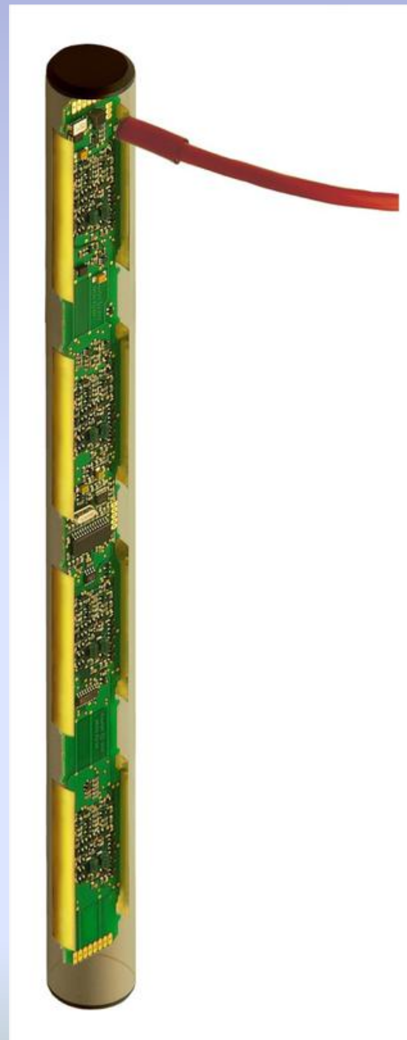
Two sides of the story

- Soil Tension
  - Gypsum blocks
  - Tensiometers
- Cheap but limited tension range
- No multi-level products

- Soil Content
  - Neutron probe
  - TDR (time domain reflectometry)
  - Dielectric measurement (capacitance probes)
- Now dominate

Theory of Capacitance Sensors

- Typically each sensor consists of a pair of metal plates or rings
- Analogous to the tuning dial on an old radio
  - As dial turned plates go in and out of mesh
  - This changes frequency at which radio tunes
  - In probe, moisture between the plates changes the capacitance & between the plates & hence frequency of the circuit
  - Measure change in frequency and convert to percentage moisture



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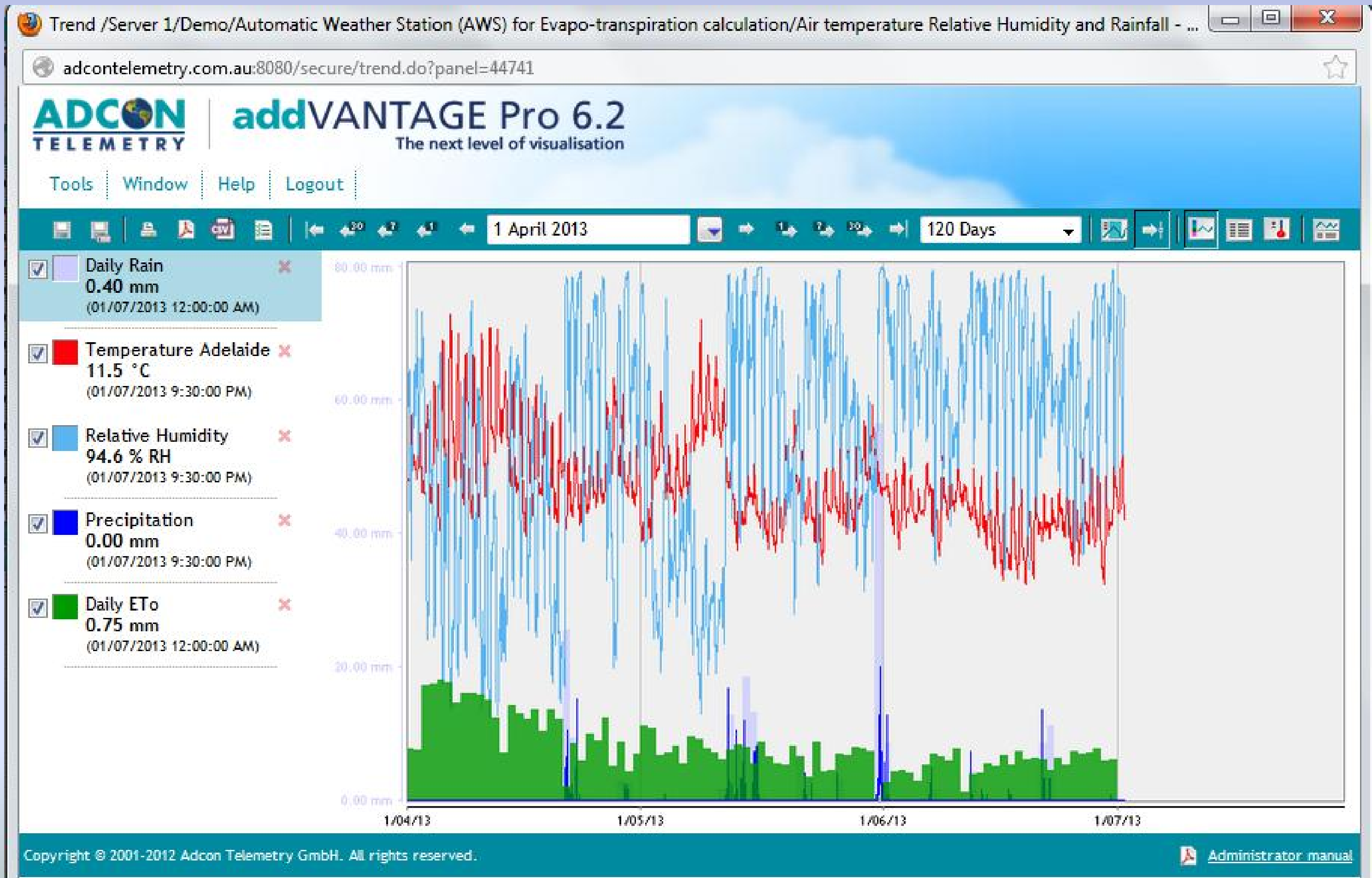
Pasture water use (ctd)

- Evapotranspiration data from local AWS



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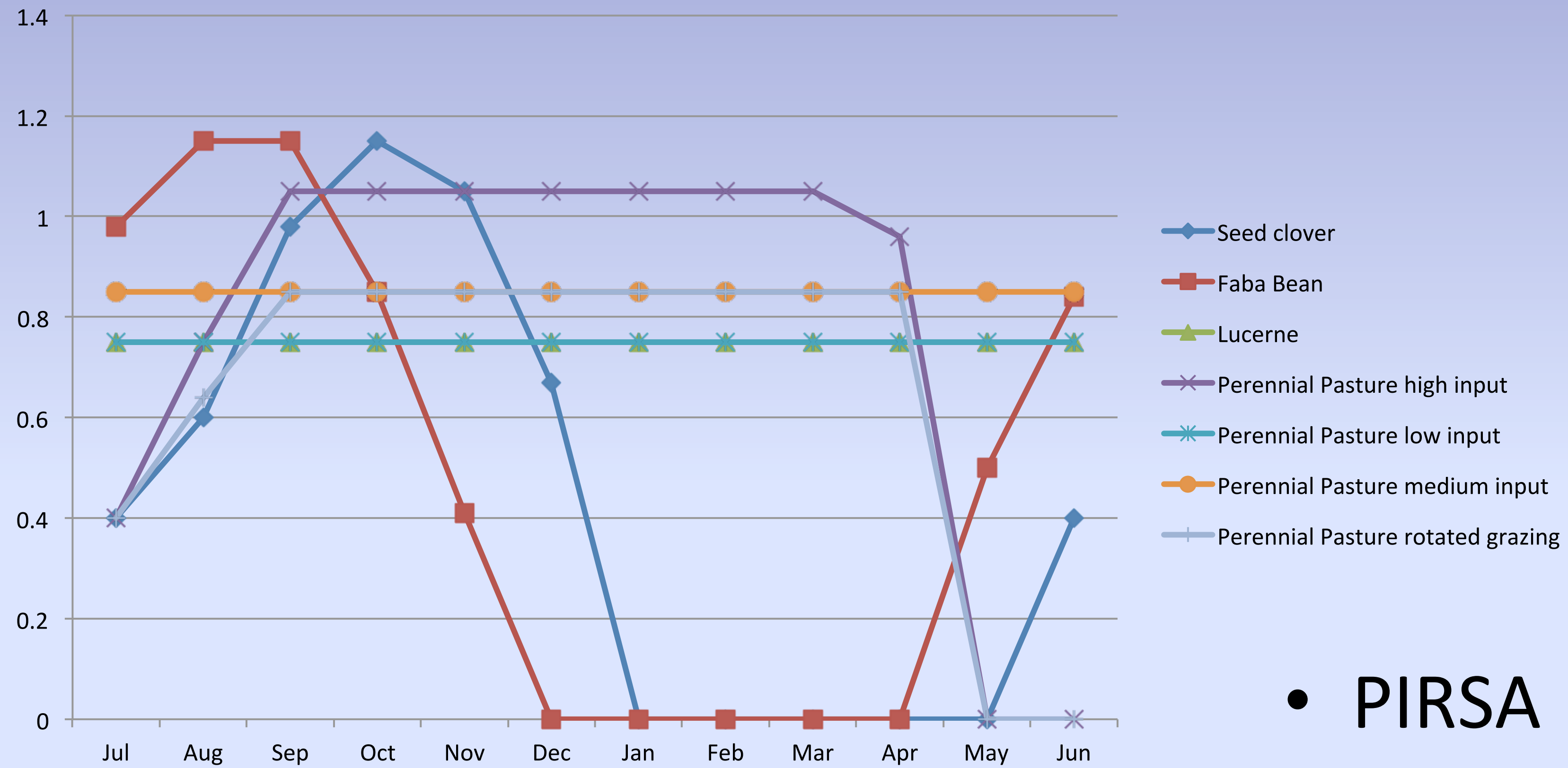
Pasture water use



- PIRSA

- Automatic Weather Station: gives modeled water use
- Soil Moisture Probe: gives actual water use
- Stress Index = Actual Water Use / Expected Water Use

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Modelled Pasture Water Use

- In formula form:

Major Stage	Minor Stage	Duration	Start Date	Kc	Ky
Sewing		5	1/05/2010	0.32	0
Initial	Establishment	20	6/05/2010	0.32 + ((d-5)*0.012333)	0.2
	Tillering	20	26/05/2010	0.32 + ((d-5)*0.012333)	0.2
Crop Development	Head Development	20	15/06/2010	0.32 + ((d-5)*0.012333)	0.2
Mid Season	Flowering	45	30/07/2010	1.06	0.65
	Yield Formation	40	8/09/2010	1.06	0.55
Late Season	Ripening	40	18/10/2010	1.06 + (d - 155)*(-0.01866))	0
	Harvest	0	18/10/2010		0

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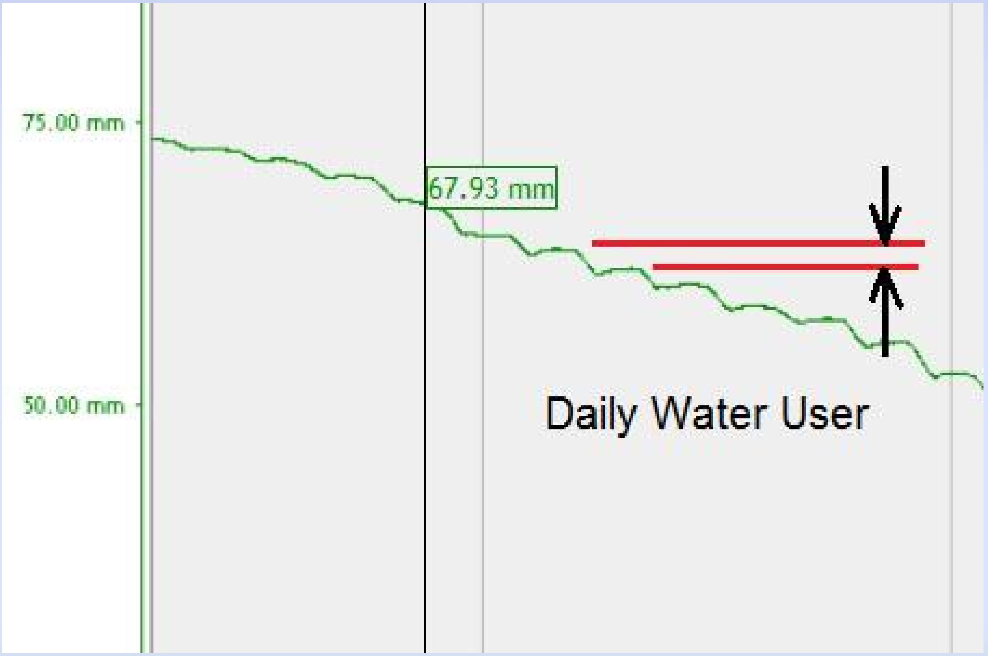
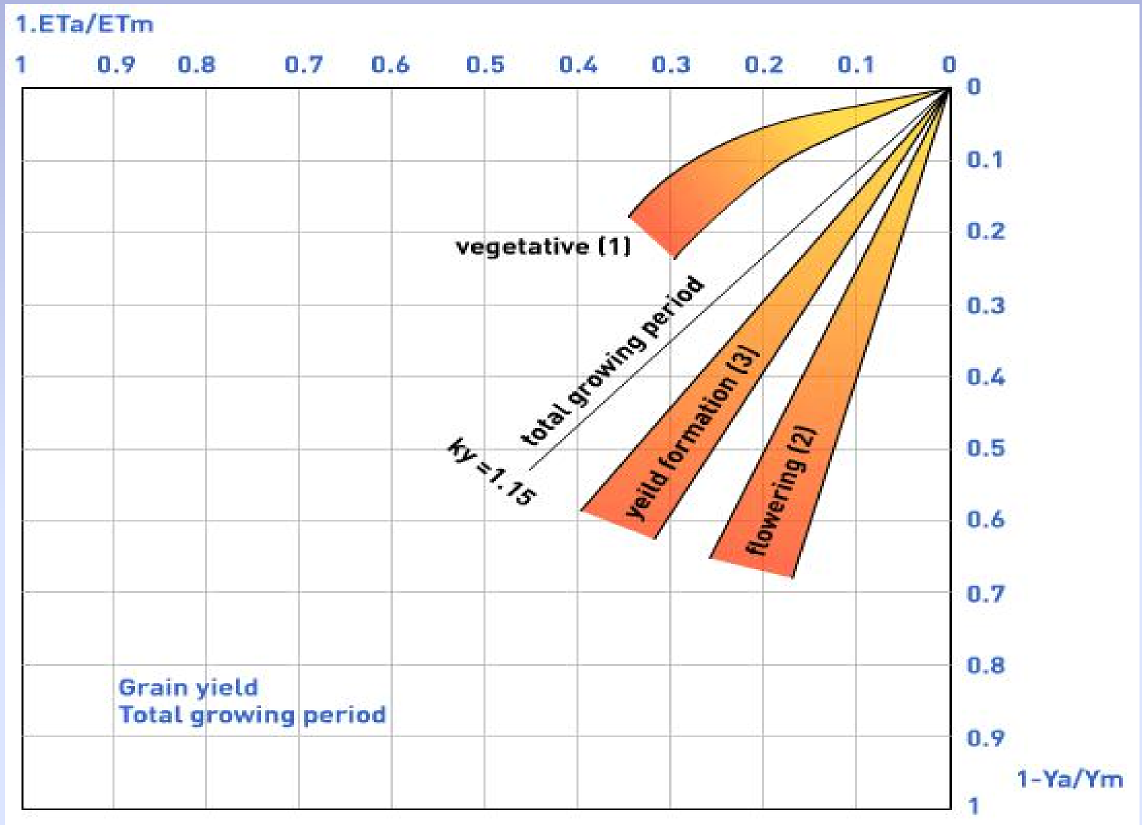
Actual Pasture Water Use

- Soil Moisture Probes
  - Monitor sum or total moisture in root zone



Pasture water use (ctd)

- Estimate maximum yield
- Estimate yield loss due to water stress
  - e.g. 30% water stress in Feb => 50% yield reduction
- Estimate Yield Loss due to nutrient deficiency
- Estimate yield loss due to chemical & physical barriers
- Calculate reduced yield



- Estimate likely future rain based yield at each rainfall decile

Decile	April	May	June	July	Aug	Sept	Oct
5	38.7	41.8	58.2	55.6	58.5	50.3	44