A Quick Guide to Sap Flow Sensors and Irrigation Management

There are many ways sap flow sensors and data can be used for irrigation management.

This quick guide focuses on three aspects of irrigation management:

- total crop water use
- irrigation scheduling or timing
- regulated deficit irrigation.

Total Crop Water Use

How much water does your tree or crop use per day? Does water use increase or decrease on cooler or hotter days?

Just about every grower knows how much irrigation they apply to their crops. Surprisingly, very few growers know how much water their crop is using or transpiring.

Here are some examples: grapevines use between 5 and 20 litres per day; pears over 100 litres per day; and California redwoods, some of the tallest trees in the world, can transpire around 2000 litres per day – that's 2 tonne of water per tree, per day!

But what about almonds? Citrus? Avocado? Or other crops? Different varieties, rootstocks, sites, and many other factors can influence tree water use.

The SapLinx Sap Flow Sensor (Figure 1) provides an indication of your tree's daily water use. SapLinx records an estimate of the tree's hourly sap flow which can then easily be converted into an estimate of water use per day, per week, per acre, etc.

Figure 1. *A SapLinx Sap Flow Sensor installed on the trunk of a pear tree.*

The results can be surprising.

For example, a grower from Victoria, Australia, has been managing pear trees since the early 1980's. He believed his trees used no more than 40 to 50 litres per tree per day. The SapLinx sensor estimated total pear water use in excess of 100 litres per day. Therefore, this grower was potentially under-irrigating his crop.

Another grower from Queensland, Australia estimated the water use of his macadamias to be around 130 litres per day. But, the SapLinx sensor estimated around 40 litres per day. Therefore, this grower was potentially over-irrigating the orchard and wasting water through leaching and excessive runoff.

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Examples of Total Tree Daily Sap Flow in Chardonnay (top) and Pear (bottom).

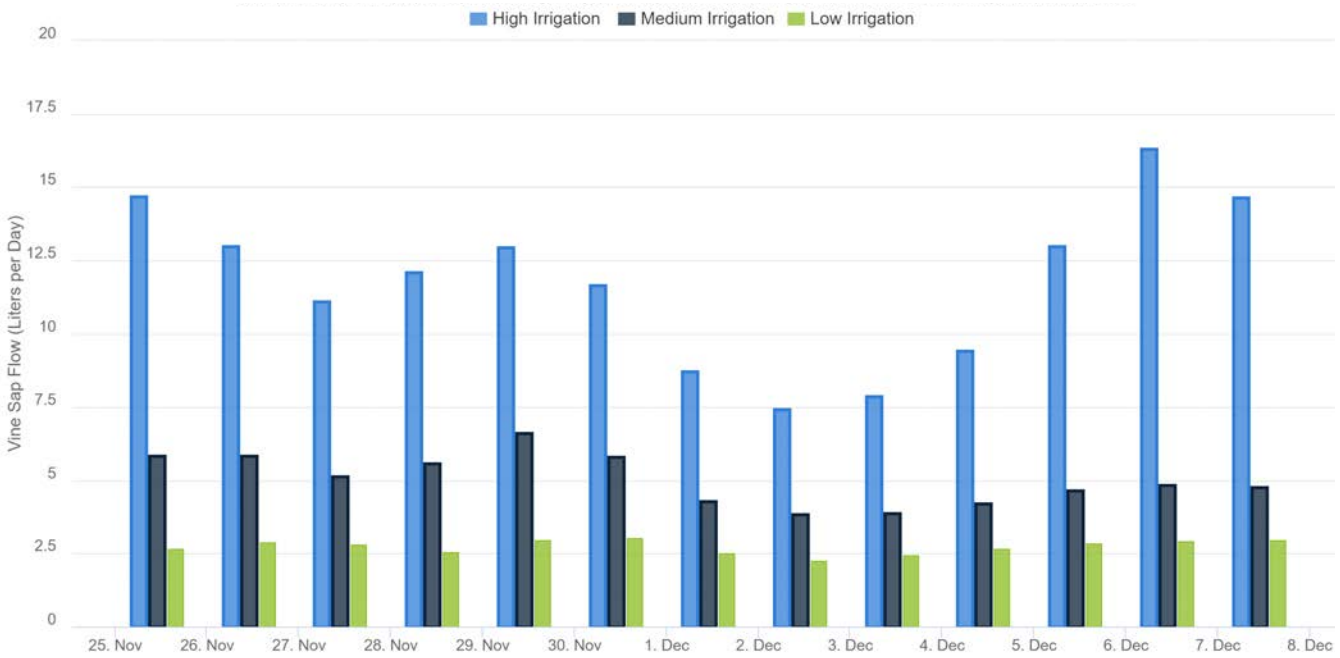

Figure 2. *Different irrigation treatments affect total vine sap flow in Chardonnay growing in the Riverina region of New South Wales, Australia. The High Irrigation vine is using around 10 to 15 litres per day, the Medium vines around 4 to 8 litres per day, and the Low vines around 2.5 litres per day.*

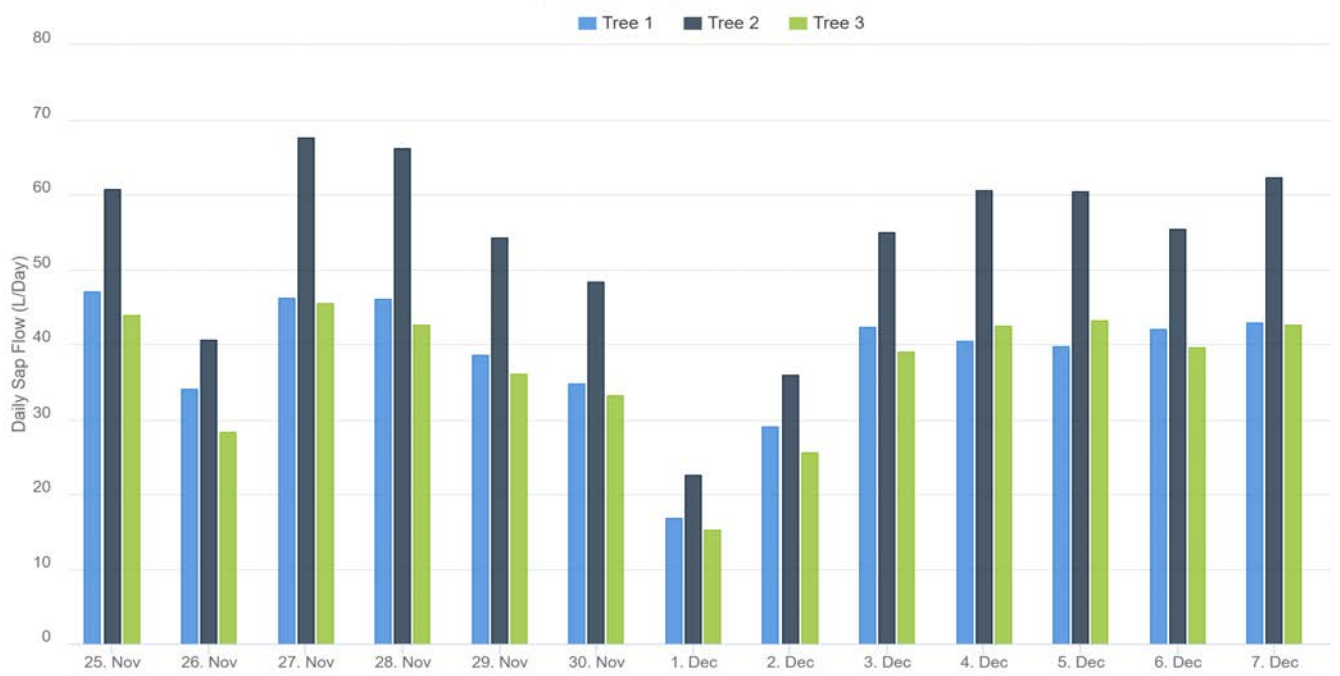

Figure 3. *Total tree water use can vary between trees of the same size, growing in the same row and plot. For example, this figure shows three pear trees, growing in the Yarra Valley, Victoria, Australia, with a basal trunk diameter of approximately 30cm. The three pear trees are growing in the same row next to each other. Total daily water use in Trees #1 and #3 was as high as 48 litres per day; whereas Tree #2 total daily water use was regularly over 60 litres per day.*

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When should you irrigate?

Irrigation timing and frequency depends on many factors such as crop, time of season, and purpose of irrigation (e.g. maximise growth, preparing for harvest etc).

Generally (but not always!), sap flow should be maintained at the highest rate possible. When sap flow is high, generally the tree is healthy and potentially absorbing as much carbon dioxide as possible for fruit growth and yield.

In regions where daily maximum temperature and solar radiation are very consistent, midday sap flow, or maximum daily sap flow, should also be consistent from day to day. If midday sap flow declines over subsequent days, then the tree needs irrigation. For example, in **Figure 4** maximum sap flow is declining throughout the week. This trend in sap flow should be avoided.

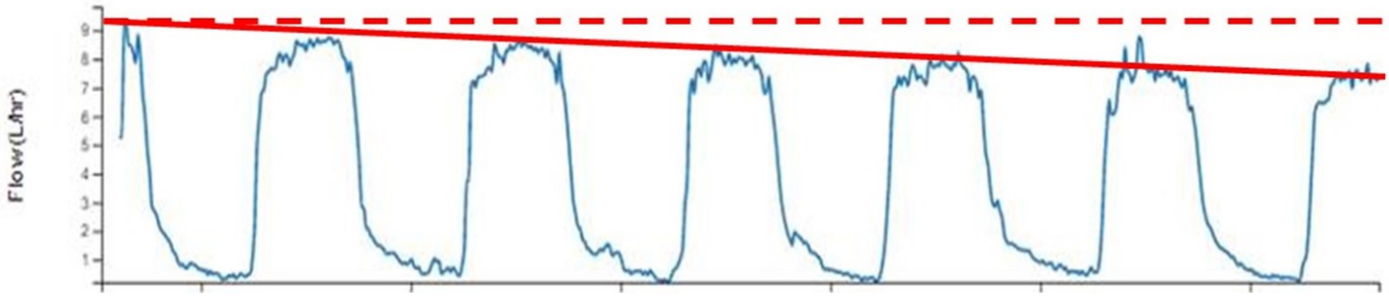

***Figure 4**. An example where midday, or peak, sap flow is declining over subsequent days. The dashed line represents maximum sap flow on the first day and this is where maximum sap flow should be on subsequent days. However, the solid red line shows the downward trend in peak sap flow day after day. Generally, such a trend should be avoided and irrigation could have commenced on day 2 or 3.*

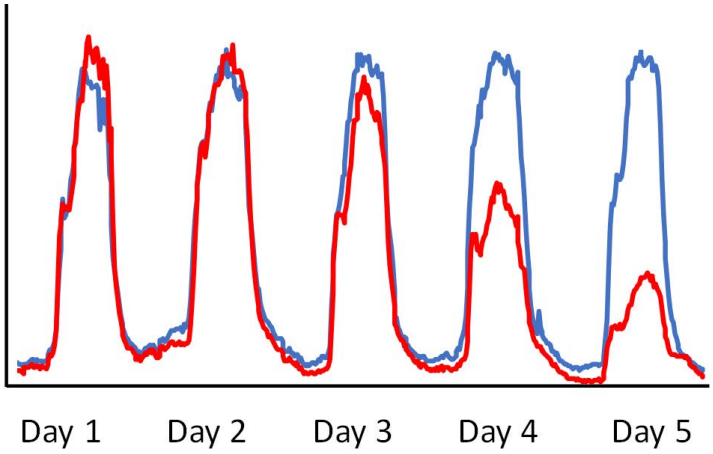

***Figure 5.** The blue line is ETo and the red line is sap flow. The data match on days 1 and 2 but sap flow starts to decline from day 3. Irrigation should commence by day 3.*

Evapotranspiration as a Reference Point

Sap flow also increases and decreases according to weather conditions. Therefore, midday or peak sap flow may be lower or higher because the weather is cooler or hotter.

In this case, sap flow can be compared with a reference point such as evapotranspiration (ETo) **(Figure 5)**. The ETo may be measured via a near-by weather station.

Sap flow will match ETo on cooler and hotter days. But, if sap flow starts to noticeably decrease relative to ETo, then it is time for irrigation.

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Sap Flow and Daily Maximum Air Temperature

A simpler method is to compare sap flow against daily maximum air temperature. This is a useful approach in regions where the weather can be different from day to day.

In **Figure 6**, for example, daily maximum air temperature ranges from approximately 12 to 27 °C (54 to 81 °F) over one week. A quick look at the graph also shows that total tree sap flow is increase and decreasing with daily air temperature.

However, for Tree #1 (blue bars), sap flow declined on 4th and 5th December when air temperature was increasing.

Over these same days, Tree #2 (black bars) sap flow increased with maximum daily air temperature.

Irrigation was applied on the 6th of December and there was approximately 10% increase in Tree #1 total daily water use.

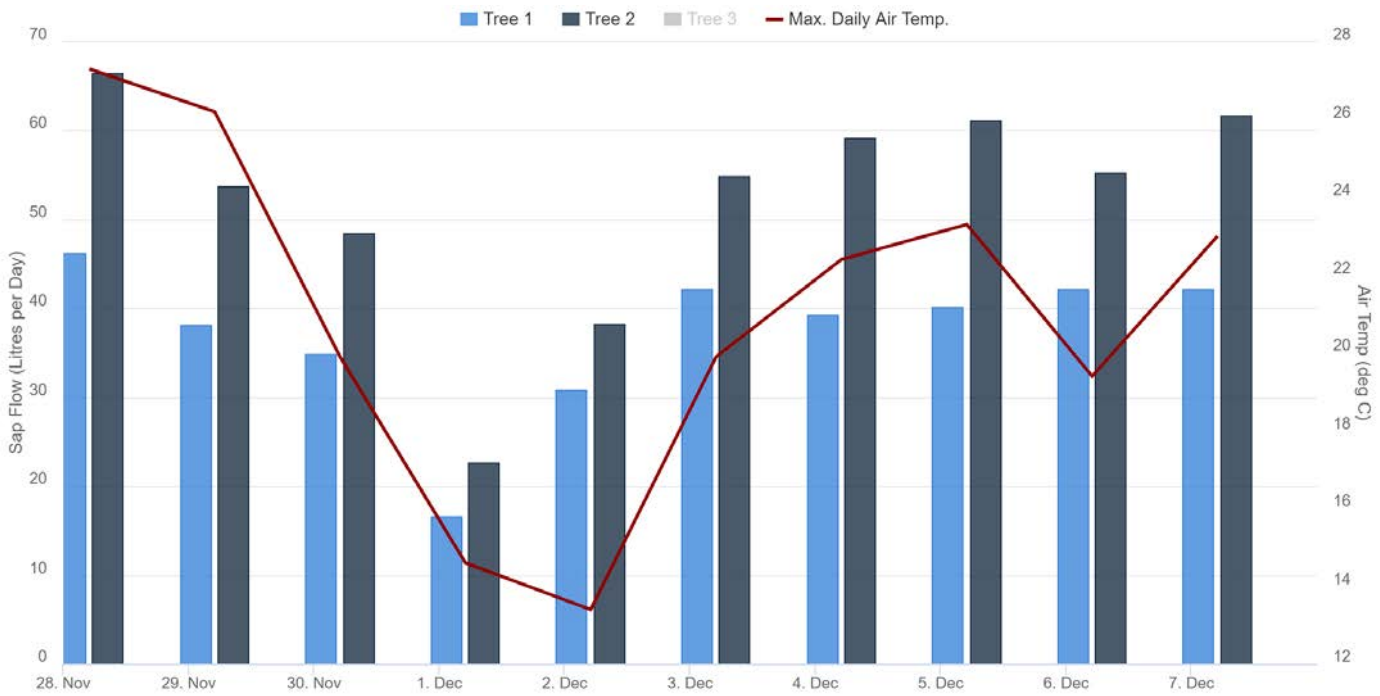

Figure 6. *Two weeks of total daily sap flow in two pear trees (blue and black bars) with maximum daily air temperature (red line). Tree #1 (blue bars) diverged from air temperature on 4th and 5th December. That is, total daily sap flow did not increase, but plateaued or decreased, with increasing air temperature. This pattern indicates that this tree required irrigation.*

Regulated Deficit Irrigation (RDI)

RDI is generally defined as the practice where a crop is irrigated at some amount less than an optimal or total amount. RDI is used by growers for many reasons including saving water or improving fruit quality at certain periods of the growing season.

Sap flow sensors can be used to determine the irrigation levels for RDI.

There may be several approaches to this, but a common approach is to irrigate a crop at a level less than evapotranspiration (ETo or ETc with a crop factor). The ETo or ETc value is usually measured via a nearby weather station. Plant transpiration can be measured with a sap flow sensor.

Sap flow measurements can be easily converted to crop transpiration by measuring the crown area. This is the amount of tree canopy area. Then, divide total tree sap flow by crown projection area (CPA). That is, transpiration (mm) = sap flow (litres per tree) / CPA (metres square, m^2, per tree).

Sap flow, measured as transpiration (mm), can then be used to calculate irrigation input and timing. You can also observe hourly sap flow data to ensure that irrigation levels are maintained at the correct level. **Figure 7** shows daily transpiration data measured from a sap flow sensor versus modelled (potential) evapotranspiration, as an example.

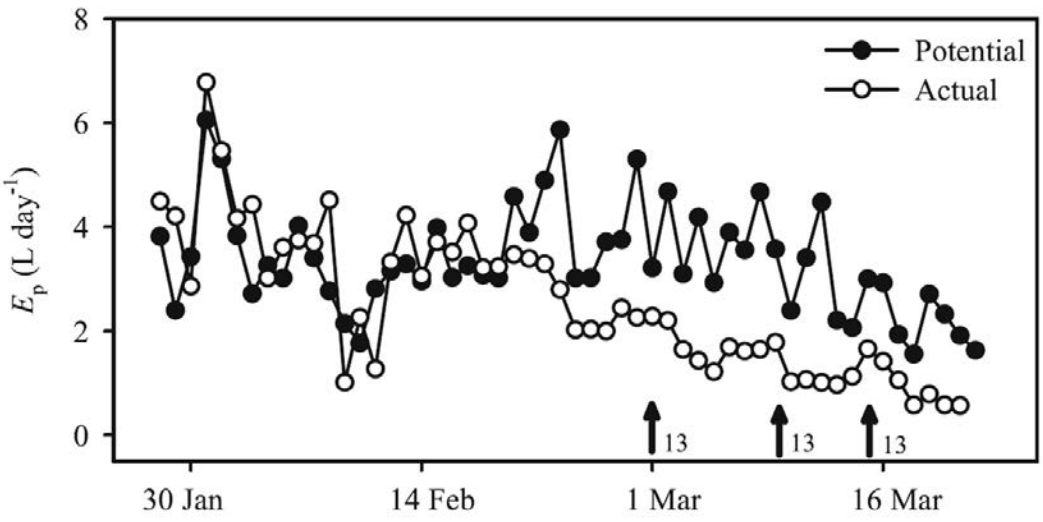

Figure 7. *Daily sap flow values (white circles) versus potential sap flow values (black circles) for a grapevine under RDI. The irrigation treatment was started around mid-February. The sap flow in the grapevine was maintained at approximately 30% of the potential daily water use. The arrows indicate days when irrigation was applied to the grapevine. (Figure source: Fernández et al (2008), Plant and Soil, 305, 91-104.)*

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