New irrigation scheduling techniques

Irrigation scheduling is the process by which the timing and volume of irrigation applications are planned to ensure the optimum use of water as a resource to achieve the required crop yield and quality. Under the variable rainfall conditions of the UK, this process requires the careful assessment of soil moisture and crop growth to plan applications. The objective of irrigation scheduling is to maintain optimum soil water conditions for crop growth in order to meet crop yield and quality targets with minimum water wastage. Under-irrigation is not desirable. It can cause plant water stress resulting in reduced yields. Poor timing of irrigation at key times can also impact on crop quality. Potatoes, for example, can develop scab during tuber initiation and reduced tuber bulking later in the season. This impacts on market grade, tuber quality and ultimately on contract price. Some growers over-irrigate to make sure their crops have enough water. But this too causes problems – wastage of water, labour and energy, and fertiliser leaching. It can also aggravate soil erosion. The techniques used to monitor soil moisture fall broadly into two categories:

(i) Direct measurements of soil moisture: There are various devices available that are capable of the continual measurement of soil moisture content at depth intervals down through the soil profile. These systems are normally based on capacitance or TDR/FDR technologies and require a power supply which is usually provided by battery or photovoltaic cells. Data are available electronically via manual downloads but are more frequently accessed through telemetry and software packages that deliver results directly to the grower's computer through web-based facilities. Other systems such as neutron probes and the Diviner™ can provide similar soil moisture data but rely on individual measurements taken by transportable probes during field visits. All these systems have been shown to provide accurate measurements of soil moisture but only measure a small volume of soil. It is therefore important to take sufficient measurements to accurately represent the moisture status of the whole field, and;

(ii) Indirect methods: Computer based water balance models area available that use soil, crop and weather data to estimate soil moisture and schedule irrigation applications. These systems are dependant of accurate weather data (either for the Met Office or from on-farm weather stations) and in particular require accurate local rainfall and irrigation data. These systems have been shown to be accurate provide the source data are reliable.

Current status and uptake

Whilst many of the techniques used to develop irrigation schedules are well established they are not universally employed within the industry. A Defra survey (2010) indicated that 78% of holdings used judgement not based on any measurements to plan applications with only 29% using direct soil moisture measurements, 19% computerised water balance methods and 16% manual water balance calculations.

Suitability and target use

Careful irrigation scheduling is likely to provide the best return when used on high value crops that are responsive to irrigation and where produce quality drives crop value. However, all irrigated crop species should benefit from accurate irrigation scheduling. Direct soil
measurements techniques are suitable for most situations (including protected crops grown in soil). Where water is not applied uniformly across the soil surface, as in drip systems, it is important to locate soil sensors appropriately to measure the moisture levels in the crop root zone. Indirect, computerised water balance methods do not perform well for protected crops or drip irrigated systems. Also, whilst they are able to calculate water demand for most common crop species in the UK, their performance for some less widely grown species may be less robust.

Investment cost

The investment costs vary with the chosen technology and the level of sophistication for data transfer, analysis and interpretation. Some sensors can cost as little as £10 with other fully integrated systems costing well over £10,000. In general, as price increases, more data are generated and less management time is required by the grower to interpret the results. Other systems such as the computerised water balance method do not require any upfront investment cost but are purchased as an annual package that often involves supplementary irrigation advice. A summary of estimated 'typical' scheduling costs is given in Table 1.

Table 1 Typical irrigation scheduling costs (Source: Knox et al., 2009).

<table>
<thead>
<tr>
<th>Method/technique</th>
<th>Estimated cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bureau water balance</td>
<td>£200-£250 per site per season</td>
</tr>
<tr>
<td>Consultancy service</td>
<td>£20-£25 per ha per year</td>
</tr>
<tr>
<td>Purchase scheduling software for use by farmer</td>
<td>£750-£1000 depending on number of fields requiring scheduling</td>
</tr>
<tr>
<td>Neutron probe service</td>
<td>£300 - £500 per site (based on 2 or 3 access tubes) per season</td>
</tr>
<tr>
<td>Capacitance probe service</td>
<td>£1750-£2500 for a basic system including sensors, logger and staff training</td>
</tr>
<tr>
<td>Automatic weather station</td>
<td>£1000-£3000</td>
</tr>
<tr>
<td>Atmometer (ETgage)</td>
<td>£300</td>
</tr>
</tbody>
</table>

A significant proportion of growers still do not schedule scientifically – why? Some believe that by over-irrigating they do not need to schedule. But the marginal cost of applying water is rising and over-irrigating can prove costly. Others have irrigation systems that are under capacity and cannot keep up with irrigation demand. Scheduling is of little value in these circumstances but reduced crop yield and quality will reduce farm profits.

Design and management issues

The key issue when scheduling using direct soil moisture measurements is the replication of measurements to ensure that the data used to plan irrigation applications are representative of the whole field. Most sensors measure soil moisture in a small zone (<200mm radius of the probe), so that multiple reading are often needed to obtain an accurate picture of irrigation need.

It should be noted that neutron probes are not well suited for use on very shallow rooted crops. For computerised water balance methods, the key management issue is the need to supply accurate local rainfall and irrigation data into the model. Without this information, the estimates of soil moisture can become increasingly inaccurate as the season progresses.
In all scheduling systems it is wise to get an accurate determination of field capacity as individual crop schedules are normally based on soil moisture deficits.

**Other issues (e.g. environmental, legal)**

Soil condition is an important factor to consider when planning irrigation as ‘capped’ soils or layers of compaction within the profile can impede water movement and may result in run-off and increase than risk of erosion. Other adaptations in this series consider how best to manage soils to optimise crop water availability.

**Documented case studies**

*Strawberry production (Hereford)*

For Stewart Alcock, Technical Manager at G and BB Houlbrooke, Ledbury (Hereford), the benefits of scheduling strawberries are clear. His main objective is to ‘add value’ – and being able to meet crop water requirements with small, frequent water applications using trickle irrigation is where scheduling pays dividends. The farm specialises in growing Grade 1 strawberries under polytunnels for the major supermarkets which rely on English fruit from mid-May to mid-Oct. Since 1993 they have used a commercial scheduling service (Agri-Tech NP) in order to match crop water demand with supply on 100 acres of main crop and everbearer varieties. At critical growth stages it is important not to over-water otherwise the fruit becomes excessively soft, and difficult to pick and pack. In the past, they have relied on neutron probes to monitor changes in soil water, but this year they tested IrriWise™ – a scheduling system that uses tensiometers buried at different depths. Soil water suction data are automatically relayed back to the farm office. This ‘real time’ soil water status meant that irrigation could be fine-tuned for different growth stages and weather conditions. The tensiometer data were compared with neutron probe data in order to build confidence in the new system. A Davis Vantage™ weather station keeps a daily check on evapotranspiration (ET) rates. Strawberries are short season, shallow rooting, and sensitive to drought – especially under polytunnels where water stress can quickly build up even at moderate outside temperatures. Stewart says "The benefits of getting irrigation right are substantial. Grade 1 strawberries can be worth £3,000/t. But if you get the irrigation wrong, then Grade 2 strawberries are not worth picking. For me, knowing daily crop water needs and keeping a close eye on changes in soil water makes my life much easier.

**Relevant references**


*Managing Water Better*  

*Irrigation best practice: A Water Management Toolkit for Field Crop Growers*  

*Irrigation Best Practice: Water Management for Potatoes, A Growers Guide*  
Irrigation Best Practice: Water Management for Field Vegetable Crops, A Growers Guide