

# Sector: Field Vegetables

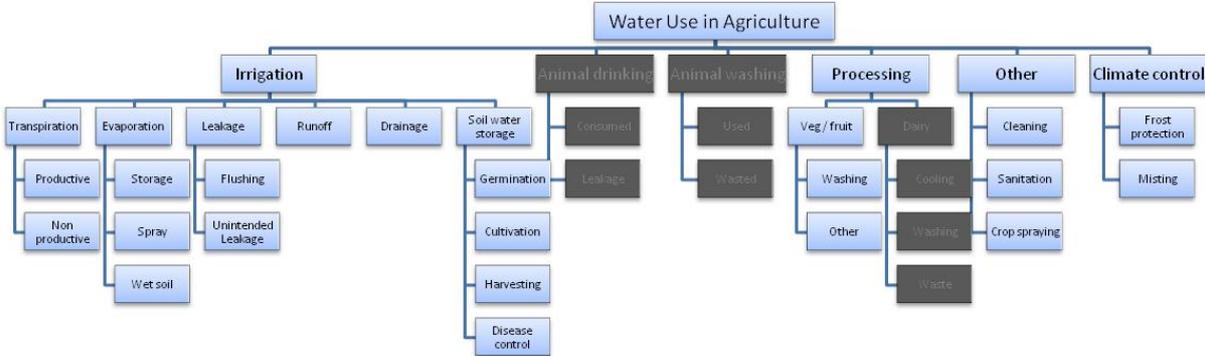
## 1. Introduction

This sector covers field vegetables grown in the open, including root crops (e.g. carrots), brassicas (e.g. cabbages), legumes (e.g. beans) and other speciality crops (e.g. asparagus, lettuce). Within field vegetables, the most important irrigated crops include carrots, onions, lettuce, and baby leaf salads. These are all dependent on supplemental irrigation to maximise yield and quality. A significant proportion of agricultural and horticultural holdings involved in field vegetable production, both large and small scale, traditional and organic, are dependent on water to provide the high quality continuous supplies of premium quality produce demanded by the major multiples (supermarkets), processors, and retailers. Restrictions in the availability and reliability of water supplies for field vegetable irrigation can have major consequences on crop yield, quality and farm income (Knox et al., 2000). For other field vegetables, such as brassicas and legumes, irrigation is also important, but not so extensive, as these are grown on more moisture-retentive soils, are less prone to drought stress, and have quality criteria that are less sensitive to water stress (Knox *et al.*, 2010).

## 2. Hydrological pathways

Water use in the field vegetable sector occurs for four main purposes: crop irrigation, crop processing, climate control and other (spraying, equipment washing) uses (Figure 1). The purpose for which the majority of water is abstracted and used is for crop irrigation.

**Figure 1** Possible water use pathways in field vegetable production.



Most irrigation water is abstracted from surface sources and used direct, with relatively little on-farm storage. In contrast, crop processing (washing) relies on direct mains water supplies which are then treated and discharged, or increasingly often cleaned and then recycled. Cleaning equipment, sanitation and crop spraying activities generally all use small volumes of direct mains water supplies. Water use for climate control and misting is very crop specific (e.g. orchard fruit, blackcurrants) and accounts for only very small volumes of water abstracted between February to April.

When considering opportunities for water saving, it is important to differentiate between the individual ‘hydrological pathways’ and identify those that can be considered as “losses” (Carter *et al.*, 1999). For example, leakage of water from irrigation pipes or spray drift may be considered as non-productive losses and any technologies that can reduce these losses would be beneficial. Other

pathways, such as crop transpiration are productive and cannot be reduced without impacting on plant performance (unless the plant physiology can be modified to use less water for the same plant growth, through for example, genetic modification).

### 3. Field vegetables – cropped areas and value

The estimated area and value of UK field vegetable production is summarised in Table 1. In 2008, the total cropped area was reported to be 116315 ha. The most important in terms of area were peas (processing), followed by carrots and cauliflower. However, processing peas are the lowest in terms of production value (£/ha). The crops with the highest production value (£/ha) are carrots, leeks, green (salad) onions, cabbage, beans, celery and lettuce. For all these high value crops (except cabbage) product quality is a major determinant of crop price, and timely and reliable irrigation supplies are essential.

**Table 1** Estimated cropped areas and farm gate values for UK field vegetable production based on data from 2008 (Source: Defra, 2009).

FV category	Crop type	Cropped area (ha)	Production ('000 tonnes)	Production value (£'000)
Roots and Onions	Beetroot	1,564	55.0	24,510
	Carrots	11,028	719.3	129,885
	Parsnips	3,273	90.1	29,400
	Turnips and Swedes	3,105	105.3	32,877
	Onions, Dry Bulb	8,575	349.2	46,097
	Onions, Green	1,702	15.3	25,054
Brassicas	Brussels Sprouts	3,029	44.5	35,535
	Cabbage, Spring	2,556	29.4	14,222
	Cabbage, Sum and Aut	1,423	55.7	17,711
	Cabbage, Winter	3,038	149.1	38,093
	Cauliflower	9,440	116.2	51,761
	Calabrese	7,232	77.2	65,942
Legumes	Beans, Broad	2,024	9.9	3,648
	Beans, Runner and Dwarf	1,765	15.8	17,472
	Peas, Green for Market	901	5.9	3,029
	Peas, Green for Processing	34,930	153.0	39,652
	Peas, Harvested Dry	5,378	14.3	2,768
Others	Asparagus	1,435	3.2	12,106
	Celery	850	47.9	24,375
	Leeks	1,647	42.6	35,154
	Lettuce	5,592	116.8	98,043
	Rhubarb	296	15.6	15,939
	Watercress	60	2.0	11,099
	Other	5,470	106.5	40,040
<b>TOTAL</b>		<b>116,315</b>	<b>2,339.7</b>	<b>814,413</b>

## 4. Irrigation

King *et al.* (2006) conducted a baseline assessment of agricultural water use in England and Wales, and estimated total on-farm water abstraction to be in excess of 300 million m<sup>3</sup> year<sup>-1</sup>. Almost half (128 M m<sup>3</sup>) was used for field-scale agricultural (and horticultural) spray irrigation. Livestock rearing accounted for a further 119 M m<sup>3</sup>, mainly for consumption (drinking), but also for cleaning housing and yard assembly areas. The third largest sector was for protected and nursery cropping, which accounted for 53 M m<sup>3</sup>. A minor but significant use was for spraying pesticides on field crops, which accounts for nearly 3 M m<sup>3</sup>. Over the past 20 years, there have been significant changes in the range of crops irrigated. Nationally, the proportion of irrigation of grass, sugar beet, and cereals has declined steadily. In contrast, there has been a marked increase in the irrigation of high value crops, notably potatoes and field vegetables. National surveys of irrigation are undertaken periodically by Defra, usually every three years, and most recently in 2005. Information on the areas irrigated and volumes of water (and derived average depths applied) are given in Table 2.

**Table 2** Estimated areas irrigated (ha), volumes of water applied (m<sup>3</sup>) and average depths (mm) applied between 1995–2005 for field vegetables grown outdoors in England and Wales.

Survey year	1990	1992	1995	2001	2005
Irrigated area (ha)	25250	20200	27300	39180	32202
Volume applied ('000 m <sup>3</sup> )	18450	12180	25500	34120	24740
Average depth applied (mm)	73	60	93	87	77

In 2005, irrigated field vegetables accounted for 28% of the total irrigated area, and 27% of the total volume of irrigation water applied nationally. This trend is driven, at least in part, by supermarket demands for quality, consistency, and continuity of supply, which can only be guaranteed by irrigation. It should be noted that the average depths are calculated by allocating the total volume evenly over the gross area reported; however, irrigation practices range from full water replacement to small applications to ensure plant survival. The areas irrigated and volumes of water applied vary significantly from year to year depending on summer weather (notably summer rainfall) so this needs to be taken into account when assessing trends. In irrigation terms, 2005 was considered to be one of the wettest in the last 35 years, whereas 1995 was a very dry year in irrigation terms.

Using irrigation survey data for the period 1982 to 2005, Weatherhead (2006) analysed the underlying growth rates in the areas irrigated, volumes and depths applied for various horticultural crops as linear functions over time after allowing for annual weather variation, using multiple regression techniques. Assuming linear growth, the data suggests that the total irrigated area of vegetables has been growing strongly at 3% per annum over the period. The volumes of water used on vegetables have also been rising steadily (3.9% pa), reflecting the increased depths of water being applied to obtain higher crop quality.

The field vegetable sector is generally very progressive in terms of technology uptake, whether it relates to improving security of water resource supplies (water harvesting, reservoirs); application equipment (switching technologies to more efficient irrigation systems) or to in-field water management (monitoring equipment to aid/improve irrigation scheduling). Many of the novel and emerging in-field water management technologies and control systems are usually developed overseas for more arid and semi arid environments (e.g. Australia) and then modified for UK temperate/humid cropping conditions.

A brief description of water use within each 'hydrological pathway' for field vegetable production is provided below and opportunities for novel and emerging technologies to be developed to improve water efficiency are identified.

## 4.1 Transpiration

Transpiration is the evaporation of water from living plant tissue. For most crops there is a linear relationship between plant growth and transpiration (under constant temperature and relative humidity) therefore transpiration cannot be reduced without reducing plant growth. Genotypes may differ in their transpiration efficiency (dry matter per unit of transpiration) and there is scope for plant improvement to select more efficient plants. Over the years, selective breeding has increased the water use efficiency of crops and the partitioning of dry matter to the harvestable parts of the plant. Most research in this area appears to be focussed on grain crops and in particular, rain-fed crops grown in semi-arid areas.

It is important to recognise that in the field vegetable sector, the goal is not to maximise dry matter production, but to maximise revenue, which is crucially related to qualitative aspects of the crop. Although restricting water use by the plant may result in less dry matter production, it may lead to better quality of produce that can secure a higher market price. Two approaches to limiting water uptake by plants are deficit irrigation and partial root-zone drying.

Deficit irrigation (DI) involves giving plants slightly less water than they would otherwise use if it were freely available so that a moderate soil water deficit is maintained. This has been shown to increase water use efficiency, particularly in crops that are typically resistant to water stress (Costa et al., 2007) such as grapes, however, it has also been shown to be effective in temperate field crops. For example, Liu et al. (2006) showed that deficit irrigation increased the dry matter in roots and tubers of potatoes compared to leaves and stems, thus increasing the water use efficiency over the fully irrigated crop. However, deficit irrigation requires very careful water management and too much stress at the wrong stage of growth can result in significant yield and quality losses. Under outdoor conditions in the UK, deficit irrigation is difficult to manage, especially as unpredictable rain can interrupt drying cycles. It therefore relies on precision irrigation.

Partial root-zone drying (PRD) involves alternately wetting and drying two spatially distinct parts of the plant root system. It has shown potential to increase irrigation water use efficiency and to maintain crop yields. Shahnazari et al. (2007) found that when potatoes were irrigated with a PRD regime, 30% of irrigation water was saved while maintaining tuber yield, leading to a 61% increase in irrigation water use efficiency. They concluded that PRD is a promising water-saving irrigation strategy for potato production in areas with limited water resources. However, as with deficit irrigation, it is difficult under UK field conditions to control root drying when rainfall can occur at any time.

There are opportunities to limit non-productive transpiration, i.e. transpiration of unwanted vegetation (such as weeds). Mechanical and chemical weed control to remove non-productive vegetation will reduce total transpiration, but this may not result in water saving, if it is replaced by evaporation from the exposed soil (see below).

## 4.2 Evaporation

This section considers technologies that could reduce the evaporation losses from water storage (reservoirs), from overhead spray irrigation (e.g. switching from overhead to drip irrigation) and from wet soil (e.g. using buried drip or mulching).

### 4.2.1 *Reducing evaporation losses from storage reservoirs*

The loss of stored water from surface water reservoirs through evaporation is inevitable and can be significant in arid and semi-arid climates. Water will evaporate from open water surfaces much faster than the surrounding landscape. Additionally, research has shown that smaller water bodies evaporate at a faster rate than large water bodies in the same climatic conditions due to turbulence

and edge effects (Harbeck, 1962; Sweers, 1976), therefore, evaporative loss per unit area is also greater from farm dams compared to large reservoirs. It is important to note that the impact of farm dams on storages will be greatest during times of drought. The application of hard covers, wind breaks or monolayers to farm dams has the potential to reduce evaporation.

Evaporation rates are affected by latitude of the water body (solar energy input), air and water temperatures, air pressure, wind velocity over the water surface and turbulence in the water. In low rain years, evaporation loss may exceed the amount of gain from rainfall. Evaporation rates are also affected by the plant coverage on a lake's surface. In general, evaporation decreases as immersed plant (e.g., cattail) and floating plant (e.g., water hyacinth) coverage increases.

Floating covers eliminate algae growth and contamination from airborne pollutants. They reduce evaporation losses and assist in temperature stabilisation. Covers maybe modular or may fully encapsulate the upper surface of the reservoir by being mechanically fixed and sealed around the perimeter. They can be designed to cater for fluctuating water levels, rainwater drainage, and routine access. Floating covers are usually manufactured from reinforced polypropylene.

Aquatain is a silicone based liquid which can be poured on to the surface of water stores to greatly reduce evaporation. Trials have shown that evaporation can be reduced by over 50%. Aquatain self spreads across the surface and forms a monolayer which limits the escape of water vapour. The effects on water quality are unknown.

#### 4.2.2 Reducing spray evaporation

Most UK field vegetable irrigation is still applied through overhead irrigation methods, mostly hose-reel systems fitted with rainguns (Weatherhead, 2006). These systems are widely acknowledged to be inaccurate and inefficient in water and energy use. However, they are robust, versatile, and fit well onto typical UK mechanised arable farms. They cope particularly well with the flexibility required by rotational cropping patterns (e.g. following potatoes around a farm with non-standard field sizes). Despite the criticisms there is surprisingly little hard data on the efficiency of water application from overhead systems under UK conditions. Agronomists scheduling commercial crops by neutron probe have reported that, in hot dry weather, sometimes only 60% to 70% of the water reportedly applied from hose-reel-gun systems appears to be accountable for in their soil moisture measurements. However, these measurements have not been controlled by simultaneous catch-can or gun discharge measurements. Incorrect settings or low pressure could have meant less water was applied than intended, or the poor uniformity and limited number of probe sites could have distorted results.

In France (CEMAGREF, 1997) water distribution measurements at temperatures up to 31° C and a range of wind speeds, showed that 85% to 90% of the water discharged from guns was collected in catch-cans at canopy level. Evaporation from foliage could account for another say 2 mm loss, i.e. 8% of a typical 25 mm application. This suggests at least 80% should reach the soil in daytime summer conditions, and more at night (probably over 90%). Given that other overhead systems have similar foliage losses, plus daytime aerial losses of say 5%, switching between overhead methods may not drastically improve application efficiency. Indeed, the very fine drops from some spray nozzles are more likely to evaporate and drift than the large drops from guns. These estimates need experimental corroboration under UK climatic conditions for the range of overhead systems likely to be used in the future (Weatherhead *et al.*, 1997).

Evaporation from foliage and the soil surface could be reduced by minimizing the area wetted, e.g. by irrigating only between alternate rows on a bed. This would be possible with precision hose-reel-booms and linear move systems, using drop tubes or sub-canopy sprays, which also avoid aerial evaporation and drift losses. The higher application rates could be a problem on some soils, necessitating the use of special tillage or small basins. Some research and product development has already been undertaken in the USA along these lines, with application efficiencies of over 95%

claimed (Hoffman and Martin, 1995), and would be worth investigating further for use under UK conditions.

Another alternative is to switch application technology, from overhead spray to localised micro or trickle irrigation. Trickle is often considered to be the irrigation of the future – accurate, energy efficient, easily automated and producing high yielding, quality produce. Its potential to save water is particularly attractive when water is scarce or expensive. Trickle irrigation can potentially use less water than spray irrigation. However, the crop water use (transpiration) from a fully irrigated crop is similar whatever the method of water application. Using trickle, however, spray evaporation, wind drift, and leaf interception are avoided, and soil evaporation is reduced. As a static (solid-set) system, it allows smaller and more timely applications, and is easier to automate than portable or moving overhead irrigation systems. This permits more accurate scheduling. Potentially, trickle can also give a high uniformity of application, reducing the need to over-irrigate to compensate for dry spots.

#### 4.2.3 Reducing evaporation from soil

During the early part of the cropping season a considerable amount of water is lost from the soil by evaporation. If the water could be conserved in the soil for later use, irrigation water requirements for certain vegetable crops could be reduced. Indeed studies outside the UK have shown that considerable reductions in soil evaporation can be achieved, increasing water availability later in the season (Todd et al., 1991; Yunusa et al., 1994). Weatherhead et al (1997) assessed the potential water savings in a ‘design’ dry year from using varying degrees of mulch on selected field crops. The modelling considered different sites to account for varying agroclimatic conditions and differing amounts of summer rainfall (Table 1).

**Table 1** Estimated water savings in a design dry year from mulching with 50% and 100% mulch for maincrop potatoes at three sites in UK.

Met Station	Dry year irrigation need (mm/annum)		
	No mulch	50% mulch	100% mulch
Wattisham, Suffolk	258	38	66
Mepal, Cambridge	174	32	49
Rosewarne, Cornwall	131	25	40

The modelling showed that the water saving due to mulches may be equivalent to one or two irrigations (25 mm to 40 mm). These savings are similar in different agroclimatic regions of the country, i.e. there is no correlation between saving and annual need. For potatoes, the savings were concentrated in May and June when crop cover was low; similar responses would be expected for other root vegetable crops, but for those vegetable crops with shallow rooting and more frequent irrigation intervals, the effect of mulches would be quite different. For potatoes, if May and June are sufficiently wet then irrigation is not needed, and hence there is no water saving.

The findings presented here and undertaken by Weatherhead et al (1997) are entirely dependent on modelling, due to the lack of experimental data. They appear to disagree with the public perception of the benefit of mulches. The use of mulches on spray irrigated crops is less effective than on rain-fed crops, because of interception and loss of some of the irrigation applied and because rain-fed crops are more dependent on retaining winter water in the soil.

The practical feasibility for reducing irrigation water demand through a reduction of soil evaporation by the use of mulches on field vegetable crops therefore appears limited.

### 4.3 Leakage

Leakage can occur in the underground distribution network (infrastructure) or from the in-field equipment itself. Leakages from the distribution network do occur, due to burst pipes or failing manifolds and evident by a high pressure drop in the system. They need to be repaired before irrigation can continue and are therefore a short-term problem. Gradual seepage from aging pipes is harder to ascertain. All modern irrigation systems are usually fitted with pressure controls which shutdown the system when very low pressures occur, but this may not detect small leaks.

The most serious problem in trickle irrigation schemes is the risk from emitter clogging. Maintenance programmes which include water filtration, chemical treatment, pipeline flushing, and field inspection are all necessary to maintain performance. Some “losses” are thus unavoidable and needed to maintain equipment, for example the regular flushing of trickle (drip) irrigation laterals to avoid accumulation of sediment or precipitates in the water, which if not removed would block the emitters.

### 4.4 Runoff

Surface runoff of irrigation water can be considered as a ‘non-productive’ loss. Although the runoff water may find its way into drainage channels and eventually into watercourses or the groundwater, it may be returned at a time, place or quality that makes it less useful. Runoff during irrigation can occur when the application rate exceeds the soil infiltration rate or when irrigation occurs on soil that is already wet and cannot receive the amount of water being applied. Where irrigated fields are on steep slopes and cultivation practices create preferential pathways for water flow (e.g. furrows running up and down slope), the excess water will quickly leave the field and find its way into drainage channels and water courses. Reducing surface runoff not only saves irrigation water, but also reduces soil erosion, phosphate and other chemical losses (and contributes to satisfying Good Agricultural and Environmental Condition, GAEC) and increases the effectiveness of rainfall (reducing the need for irrigation).

Modifications to soil structure, changes in application technology and better in-field management can help reduce the risks of runoff and thereby help save water.

#### 4.4.1 *Modifying soil surface condition*

Practices that encourage local retention of water on the soil surface will reduce surface runoff rates. Blocking furrows (“furrow diking” in the USA) has been advocated in semi-arid agriculture for many years (e.g. Dagg and Macartney, 1968), but more recently the technique has been tried with supplementary irrigation in more temperate environments. For example, Nuti et al. (2009) evaluated the use of furrow diking for supplementary irrigated cotton in Georgia, USA. It was shown to reduce irrigation requirements and improved yield and net returns when rainfall is periodic and drought is not severe. Special rollers are now available in the UK to maximise water retention. For example, the “Aqueel<sup>1</sup>” creates multi small depressions (up to 200,000/ha) on raised beds, ridges or over the whole soil surface and these act as mini reservoirs each holding about a litre of water. They reduce runoff and aid slow water percolation through the soil (ADAS, 2007). Patrick et al. (2007) estimated that surface run-off could be reduced by 95% on some soils using this technique.

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<sup>1</sup> Aqueel, Simba International Ltd.

#### 4.4.2 *Switching irrigation technology*

Clearly matching irrigation application rates to soil infiltration characteristics is fundamental to system design. Irrigation technologies for very low application rate may be useful in particular problem soils. Subsurface drip irrigation (SDI) effectively eliminates surface runoff compared as water is applied within the root zone. This however, does not automatically result in water savings as drainage may be substituted for surface runoff if scheduling is poor.

However, most irrigation in the UK takes place on light soils with moderate to high infiltration capacities and application rates are rarely a problem. Use of overhead irrigation systems with small droplet sizes, such as micro-sprinklers, can reduce runoff and the risk of capping of fine textured soils (which can lead to runoff from both irrigation and rainfall). Water saving potential exists through better control on irrigation equipment (development of smart technologies) to improve uniformity, and switching from overhead to micro (drip) irrigation potentially offers water savings, but only on appropriate soils and for selected crops. On-farm trials would help quantify the water saving potential and help identify the practical operational challenges.

#### 4.4.3 *Good agronomic practices*

Maintaining good soil structural condition is important to maintain infiltration capacities and is a fundamental aspect of Good Agricultural and Environmental Condition (GAEC). Similarly, agronomic practices that encourage rapid and complete ground cover reduce the expose of bare soils and risk of capping on silty soils.

#### 4.4.4 *Better irrigation scheduling*

Accurate knowledge soil the soil water status prior to irrigation means that applications can be scheduled to reduce the risk of runoff. On light soils, surface runoff from irrigation due to saturation overland flow is unlikely as light soils will accept water even when wetter the field capacity (although this may be lost due to drainage).

### 4.5 Drainage

On light soils and gentle slopes, drainage of water downwards from the root zone may be much more significant than surface runoff. As it is not visible, it does not raise immediate concerns and can continue unnoticed. Drainage of water out of the root zone will occur when the root zone soil water content is raised above the field capacity water content. If drainage is unimpeded, this water is effectively lost (unless it is captured and recycled) and with it, nutrients dissolved in the soil water. If drainage is impeded, it will lead to water-logging. Good scheduling of irrigation timing and amounts will aim to maintain soil water conditions drier than field capacity in order to minimise drainage losses from irrigation. However, keeping the soil close to field capacity will increase the risk of drainage losses from unpredictable rainfall. Good irrigation practice in the UK is to not to return the soil to field capacity with irrigation, but to maintain some storage capacity (buffer) for unexpected rainfall. This maximises the effectiveness of rainfall and reduces the need for subsequent irrigations.

An equally important problem, particularly with rainguns, is the poor uniformity of water application. This can result in drainage losses even where part of the crop is not fully irrigated, particularly where a farmer tries to compensate by applying even more water. Scheduling by point measurement methods, such as neutron probes, is also potentially inaccurate if the water is not uniformly applied, again leading to wasted water. The use of booms should help significantly here by applying water accurately, saving water and helping provide a more uniform and higher quality crop.

## 4.6 Soil water storage

Some irrigation is applied not to meet the plant water requirements, but to maintain the soil in a suitable condition for mechanical or plant protection purposes. For example, when varieties of potatoes that are susceptible to common scab (such as King Edward, Majestic and Désirée) are grown, it is necessary to maintain moist conditions in the root zone for a period after tuber initiation (Lapwood, et al., 1973). In a dry spring, this can be a significant proportion of the over-irrigation requirement of the crop. Increased scab resistance; growing scab resistant varieties (such as Record) or shortening of period during the soil is kept moist could reduce the volumes of water used at this growth stage. Also, by allowing larger soil water deficits (typically soils are kept below 15mm deficit for scab control of potatoes) there is less chance of rainfall causing drainage, therefore the use of rainfall is more effective. However, by allowing more soil drying early in the crop cycle, more water would be required later and the net saving would be less.

Water is also required in some years to wet the soil prior to cultivation or for harvesting. For example, in 2009, many potato growers were irrigating in late autumn to aid lifting and prevent bruising and skin damage to potatoes. In the UK, dry springs and autumns do not occur frequently, therefore demands for such irrigation is not high. Also, there is little that can be done to reduce this water need.

## 4.6 Processing

### 4.6.1 *Vegetables and fruit, washing, other*

Fruit and vegetables can be processed in many different ways depending on the type of raw material and end product. There are two major sectors, fresh packed products and processed products. The techniques most frequently used for processing are: canning or bottling accompanied by heat treatment; refrigeration or freezing; fermentation; drying; pickling; and chemical preservation. In most cases the aim is to lengthen the shelf life (reduce the perishability) of the product, but there are often secondary objectives such as to make the product more convenient to use, to improve the packaging and presentation, to improve the eating quality, or to produce a new product such as juices, purees, or jams. Water is used in a variety of stages including primary cleaning, sorting and grading, product preparation, and processing. In order to identify possible water savings in vegetable processing, it is necessary to undertake a water balance of the facility, to quantify the water in the product, water used for cooling, water used for washing down, any recycled water streams, any known losses (evaporative losses etc), water in sludges leaving site, and any other known process uses.

Fruit and vegetable processing operations can use large quantities of fresh water for cleaning process areas and equipment, cleaning raw fruit and vegetables, and as process water in peeling, sorting, transporting and canning operations. But nearly all this water is returned via discharge consent back into the environment and thus a non-consumptive use. Large volumes of effluent (wastewater) containing high organic loads, cleansing and blanching agents and suspended solids may also be produced. The effluent may also be contaminated with pesticide residues. The volume of effluent flow may vary substantially by season, and as the quality of the effluent, after primary treatment to remove solids, is usually suitable for discharge to a municipal wastewater treatment system, it is not usual for further treatment to be carried out on site, unless the peak volumes would cause a problem. Here, water minimisation programmes can help achieve water savings. For example, Envirowise ([www.envirowise.gov.uk](http://www.envirowise.gov.uk)) provides guidance to fruit and vegetable processing companies to help them reduce water use. Their website contain four tools, the Monitoring tool (to record water use data), Water Account (to benchmark business water use with others in the sector), WaterNet (a search engine for water efficiency information) and the Mogden Formula tool (calculates charges for effluent discharged to sewer). Most information relates to providing

businesses with guidance on how to prepare an overall water balance for the site, how to produce process maps and identify sources of waste, calculate the true cost of waste, look for opportunities to reduce water and waste costs, and implement no-cost and low-cost measures to improve environmental performance.

Opportunities to reduce water use in food processing include:

- Improve product conveying systems to reduce/eliminate wet transportation of products and waste;
- Reduce water usage for primary product cleaning where appropriate by using dry methods such as vibration with sieving and sifting devices; improved washing techniques;
- Adopt tank and equipment cleaning-in-place (CIP) procedures to reduce chemical, water and energy consumption;
- Use taps with automatic shut-off valves and high water pressure and optimised nozzles;
- Separate cooling water from process water to enable recycling of wastewater and recirculation of cooling waters;
- Effluent strength increases if solid wastes - such as trimmings - come into contact with water. Removing the solid waste avoids having to pay unnecessary effluent treatment and disposal costs.
- Select equipment and techniques that reduce water use, solid waste, and effluent volume and strength. Consider using separate water systems to achieve better control of treated water use.
- Consider using spray systems to minimise water use during processing. Delivering water to an integrated blancher-cooler tunnel system with a spray system uses much less water than blanching and cooling baths. The system is also less labour intensive.

Water can also be cost-effectively re-used from fruit and vegetable processing in various ways:

- Water used in flumes (for conveying solid waste) can be reused following suitable treatment
- Screening water to remove grit, stones and other debris allows it to be reused (e.g. rinsing)
- Ultra filtration can filter out larger molecules – for example, proteins and fine colloidal material, while nanofiltration takes out smaller molecules such as sugars
- Used water can be stored and then reused for irrigation
- Produce can be rinsed in a series of tanks or stages - lower rates of water use are achieved with counter-current rinsing because the produce is rinsed initially in dirty water and then in progressively cleaner water

## 4.8 Other

### 4.8.1 *Cleaning equipment and sanitation*

Relatively small volumes of water are required for cleaning equipment in this sector, in contrast to, say dairy farming.

The vegetable sector is one of the larger employment sectors in agriculture, particularly during the planting and harvest periods, when large numbers of casual labourers are employed in the field and in the processing facilities. Water use for sanitation can be significant where conventional water closets are used. The water used is frequently from the mains supply.

Water use can be reduced by standard water savings measures such as low volume and dual-flush toilets, electronically operated urinals or even water-less urinals (particularly useful for field sites

where mains water is not available). Toilet flushing operated on a fixed time interval basis (e.g. cisterns that slowly fill and then flush automatically) should be avoided.

Harvested rainwater can be used for toilet flushing, though the economics and water storage needed require consideration. Re-use of sanitation water is technically feasible but the volumes may not be sufficient to make this worthwhile.

#### 4.8.2 Crop spraying

Crop spraying requires water to dilute the chemicals being applied and obtain better coverage. Volumes are relatively small per application, since the water must be carried in the crop sprayer, but could mount up over a large area with repeated spraying. The water used is frequently from the mains supply.

### 4.9 Climate control

#### 4.9.1 Frost protection

Irrigation can be used as a method of frost protection. It has been used in the UK on top fruit and soft fruit. The water falling on the plants freezes at a slightly higher temperature (0°C) than the sap in the buds (typically -4°C), protecting the plant. To be successful, the irrigation system must be capable of applying water at a relatively high rate to the whole crop simultaneously. However, this effectively requires a solid set sprinkler system with special sprinklers and larger pumps and pipes than required for normal irrigation, which makes it expensive. The practice, early in the year, can also lead to crop damage through water logging and the weight of the ice formed.

Data on the areas protected and volumes of water used is not readily available. Although technically it is a separate “purpose” for water abstraction licences, the returns show that the water allocated was in fact being used throughout the summer; similarly water on normal spray irrigation abstraction licences could have been used for frost protection. The volumes will however be included in the total irrigation abstraction statistics. The Defra Irrigation Surveys included a question on frost protection until 1995, but this was subsequently dropped because it was a minor use.

The authors believe it is now a relatively limited use, and becoming less common due to the cost and associated problems. Climate change will reduce the number of frost days, and hence further reduce the future need.

#### 4.9.2 Misting

Misting is a specialised form of irrigation whereby high pressures and small nozzles are used to create a fine mist. This rapidly evaporates in the air, increasing humidity. Mist irrigation is normally used within greenhouses when high humidity is required, for example to root cuttings propagate seedlings. This is a specialised application, and the volumes of water used for this in the field vegetable sector are very small.

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