The Water Footprint of Irish Meat and Dairy Products

Cranfield UNIVERSITY

Bord Bia Irish Food Board

Department of Environmental Science and Technology

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Report by
Tim Hess
Julia Chatterton
Adrian Williams

Contents

Executive summary

The water consumption of a range of dairy and beef production systems was estimated for four locations in Ireland using the Cranfield Life Cycle Assessment (LCA) systems model. This included direct water consumption (for drinking, washing, cleaning, etc.) as well as virtual water in the diet (that is, water that had been used to grow grass and concentrate feedstuffs). This was partitioned into "blue" water that is abstracted from rivers or groundwater, or taken from mains water supplies, and "green" water that is rain water used by growing plants at the place where the rain falls. The water consumption is shown in the tables below.

Total water consumption for Irish dairy systems, litres per litre fat and protein corrected milk.

System	Calving	Yield level	Blue water	Green water	Total
Dairy	Spring	Low	8.6	635	643
		Medium	8.2	607	615
		High	7.8	584	592
	Autumn	Low	8.0	589	597
		Medium	7.6	565	573
		High	7.2	541	548

Total water consumption for Irish beef systems, litres per kg edible carcase weight *.

System	Calving	Finishing	Blue water	Green water	Total
Dairy-beef		Extensive	14.3	6,560	6,574
		Intensive	16.8	6,710	6,727
Suckler Beef	Spring	Extensive	42.4	9,850	9,892
		Intensive	40.6	9,890	9,931
	Autumn	Extensive	50.7	10,700	10,751

* Live weight multiplied by killing out percentage

In general, intensive systems have a lower water consumption per unit of output than extensive systems as the higher water consumption per head is offset by high output. The water consumption of dairy-beef systems is lower than for suckler beef because most of the water use by the dairy cow is allocated to the dairy system, whereas for suckler systems, the water use of the suckler cow is included for the first year.

It is clear that the vast majority of the total water consumption for all the systems studied is green water. It can be argued that green water use has negligible environmental impact as it has a low, or negligible opportunity cost. The rain water consumed by growing grass or feed crops could only be used for growing alternative vegetation, that is, it could not be used to substitute for water for domestic or industrial consumption for example. Therefore, there is no water benefit in saving green water.

The blue water consumption is very small for both milk and beef under all systems. Drinking water accounts for almost half of the blue water used by dairy systems, and almost all of that consumed by beef systems. Therefore, technologies that reduce the wastage / leakage in on farm drinking water systems can reduce the overall water consumption. For dairy systems the remainder of the blue water consumption is associated with milk cooling and cleaning of the milking parlour and yards. The amount of blue water associated with growing feed is trivial. For dairy, twice as much blue water is consumed in the processing of milk compared to the livestock and feed systems. For dairy-beef and suckler beef, blue water consumption on the farm 2.5 and 7.4 times as much as used in the processing stage respectively.

Most water use on Irish livestock farms is from groundwater (≈90%) and mains water (≈10%). Generally, widespread abstraction pressures on groundwater are not significant in Ireland and the impact of water use would be expected to be small, however, there are some localised cases where abstraction pressures are impacting on groundwater levels (EPA, 2008). This highlights the very local scale of hydrological impacts and suggests that even though the average water consumption of Irish beef and dairy production is very small, in certain places it may be contributing to depletion of groundwater resources and water conservation may be encouraged.

The Water Stress Index can be used to normalise the blue water consumption and to derive an index of water equivalent (H_2Oe) that reflects both the volume of blue water consumed and relative stress on water in the producing region. For dairy systems, the normalised water footprint of milk production (at the farm gate) ranges from 0.12 litres H_2Oe/litre fat and protein corrected milk (FPCM) for high yielding autumn calving systems in the south of Ireland to 0.17 for low-yielding, spring calving systems in the south-east. For beef systems, the normalised water footprint of milk production (at the farm gate) ranges from 0.24 litres H_2Oe/kg for extensive dairy beef systems in the south of Ireland to 0.98 for autumn calving, extensive finishing systems in the south-east. These figures are very low compared to other livestock producing regions.

Introduction

Globally, agriculture is the biggest user of freshwater resources, accounting for approximately 70% of freshwater withdrawals. Unlike many domestic and industrial water withdrawals, much of which are returned to the environment, much of the water withdrawn for agriculture is either consumed (that is, evaporated or transpired from plants) or degraded, such that globally, agriculture has a huge impact on the quantity and quality of freshwater resources and aquatic ecosystems. Hoekstra and Mekonnen (2012) estimate that agricultural production contributes 92% to the global water footprint, of which meat and milk products are second and third in importance respectively.

The impact of meat and dairy production on the water environment may be considered under the headings of water quantity and water quality. Water quantity impacts occur where water consumption in the meat and dairy supply chain is reducing water availability for other domestic, industrial or environmental uses. For example, use of water from an aquifer may cause a lowering of local water tables and lead to desiccation of wetlands, or abstraction from a river may lead to dry weather flows that are unsuitable for fish. Water quality impacts may occur where the activity results in a degradation of chemical or biological status of the source water body.

Recent stories in the mass-media have discussed the amount of water required to produce meat and dairy products. Large figures have been quoted for the amount of water required to produce a kilogram of meat or a litre of milk. For example, the Water Footprint Network quotes global average figures 15,400 litres of water per kg of beef and 1,000 litres/kg for milk (Mekonnen and Hoekstra, 2010). These convey an image of huge quantities of water being used to produce food from livestock and even suggestions that "promoting a dietary shift away from a meat-rich diet will be an inevitable component in the environmental policy of governments" (Mekonnen and Hoekstra, 2012, p.13).

With an annual Irish beef production of 559,000 t (Bord Bia, 2011) and dairy production of 5,600 million litres (FDII, 2012), the total water use of the beef and dairy industry could be considerable. Such numbers may, or may not be useful. If correctly elaborate, an understanding of the water footprint of a product may help drive best-practice to reduce environmental impacts of production. However, there is a danger that such numbers, in isolation, are difficult to interpret and can send misleading messages to consumers.

There are several limitations to this simple analysis;

1. The proportion of freshwater abstractions used in agricultural production vary considerably. In Ireland, freshwater withdrawals for agriculture represents a tiny fraction of available freshwater resources[1]
2. These global averages in water footprint conceal significant regional variation. For example, (Hoekstra and Chapagain, 2007) quote figures for beef ranging from 11,000 litres/kg in Japan to 37,800 litres/kg in Mexico.
3. The water consumption varies according to the production system. (Ridoutt et al., 2010) note the variability in water footprints between dairy production systems and products.
4. The total volume of water consumed does not reflect the impact of this water use on the environment or other water users. For example, if livestock are fed on concentrates

[1] FAO Aquastat. http://www.fao.org/nr/water/aquastat/main/index.stm

produced under irrigation in water stressed environments, this water use may have a significant impact, however, if they are fed on grass grown under rain-fed conditions, the impact of water use may be negligible. In this respect, Irish livestock production is very different to drier regions, such as parts of North America, where much of the diets are sourced from crops grown in dry areas and irrigation is more common.

Aims & objectives

The aim of this study is to estimate the volumetric water consumption and water footprint of Irish beef and dairy production in relation to its potential environmental impact. The specific objectives are;

1. To estimate the volumetric water consumption and water footprint of a range of meat and dairy production systems, for different locations in Ireland.
2. To partition this according to the source of water, in particular "green" water (i.e. water from rainfall used at source) and "blue" water (i.e. water abstracted from freshwater resources).
3. To identify where blue water is being used in relation to the areas of water stress and vulnerability (both within Ireland & overseas).

Methods

Framework for analysis

The meat and dairy system can be envisaged as three sub-systems; a feed system; a livestock system; and a processing system (Figure 1). Each of these sub-systems uses physical water. For example, water is used to grow fodder, to wash cows and to process meat. However, each of these systems also discharges water. For example, water used for washing dairy parlours is returned to the environment (through spreading on land or discharge to ditches) after treatment. The water **consumption** at each stage is the difference between the water withdrawn (or falling as rainfall) and water discharged to the same water body and in the same condition. Some water is physically transferred from one sub-system to another as **incorporated** water. For example, a litre of milk leaving the farm contains nearly 0.9 litres of water, however, each sub-system inherits the water consumption from upstream sub-systems as **virtual** water. For example, the water used to grow fodder is a virtual water flow from the feed system into the livestock system. Compared to the virtual-water flows between sub-systems, the incorporated water flows are very small and are often ignored. Throughout the system from feed to product, there are also small contributions of virtual water from minor inputs, such as water used in the electricity generation; water used in the production of fertilisers; or water used in the production of animal bedding. Compared to virtual water flows in the feed, livestock and processing systems, these are usually small and are often ignored.

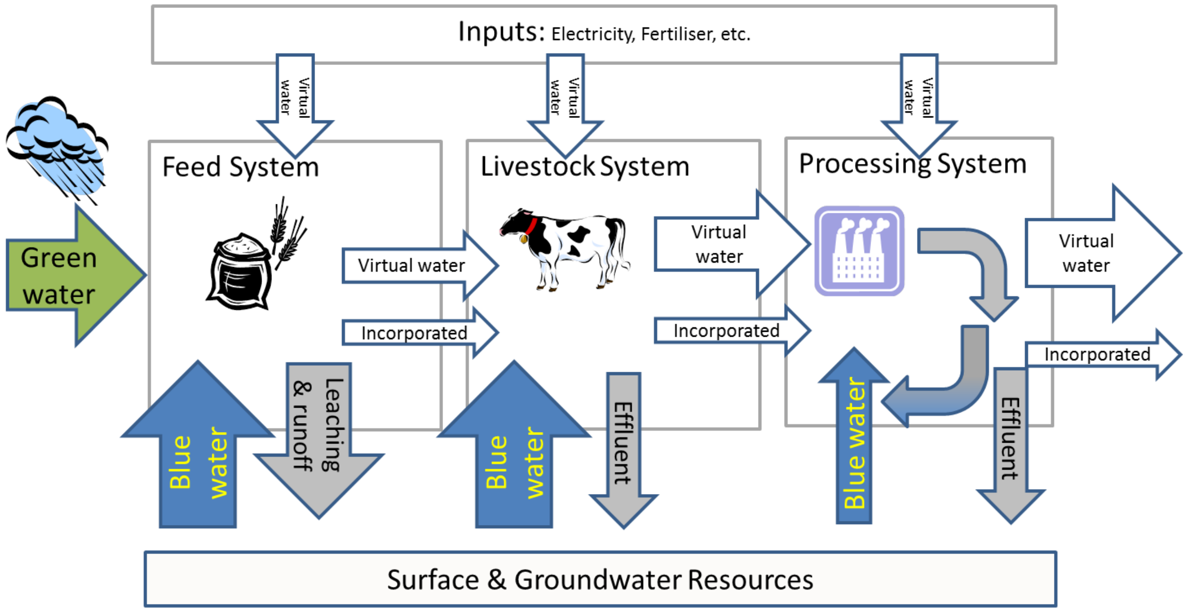

Figure 1 Physical and virtual water flows in the meat and dairy system.

Water consumption assessment

The water consumption of the meat or dairy system is the sum of the water consumed in all three sub-systems. By far the largest component is generally from the feed sub-system, accounting for approximately 98% of the total consumption (Mekonnen and Hoekstra, 2012). In this study, we are concerned with the consumption to the farm gate. As such, only the feed and livestock systems will be considered, although some comments will be made about water use in the processing system. The water consumption of minor inputs has been ignored.

The water consumption can be expressed per unit of output, e.g. m^3/litre milk. This concept is more simply applied to agricultural crops and commodities where there is a linear growth cycle and a single product. However, livestock systems are more complex. For example, a dairy herd is continually producing milk, plus there are other, non-milk outputs, such as male calves that may go into the beef sector. There are therefore issues of allocation of the water consumption. Mekonnen and Hoekstra (2012) used different approaches for meat and dairy systems. For meat, they summed the direct and indirect water-use by an animal from birth to slaughter and allocated the water between the various final outputs (such as meat and leather) on the basis of relative value. For dairy, they summed the direct and indirect water-use by an animal over a year (averaged over its lifetime) and allocated this to the annual output of milk.

The "colour" of water

Water used in the production of livestock products may be "blue" or "green". Green water use is the evapotranspiration of rainwater at the place where it falls and is the most significant component of the water consumption of feed production in most environments. In general, green water use has negligible environmental impacts as green water has a low opportunity cost. Therefore it is important to isolate the green water use in the total water consumption. Blue water is that which is taken from renewable water resources (rivers, lakes and groundwater) and in this case is primarily mains water or water pumped from rivers and wells.

Water used for livestock drinking, sanitation and processing is blue water. In Ireland, pasture and home-grown fodder is likely to be rainfed and so the blue water consumption is negligible, however, imported feed may be grown under irrigated conditions, and therefore have a blue water component (Table 1).

Table 1 Green and blue water in the various components of water use in the livestock production system.

Source	Green water	Blue water
Virtual water in diet	✓	✓
Feed processing		✓
Drinking water		✓
Washing and cleaning		✓

Water consumption and "grey" water

There is a lack of consensus on what water should be considered as "consumed". From a hydrological perspective, of the water that is drunk by a cow, only that proportion that contributes to the metabolism of the animal or is evaporated from sweat is consumed. The rest returns to the environment in the form of urine and faeces. Similarly, water that is used for cleaning dairy parlours is not "consumed" but returns to the environment in an altered state. Some studies have dealt with this in terms of a "grey water footprint" by expressing the water used, but not consumed in terms of the volume of freshwater required to assimilate the pollutant load.

In Ireland, most water used on the farm is withdrawn from wells or taken from the mains supply, and waste water is discharged to land or surface water courses (after storage and cleaning). That is, the destination of the waste-water is generally not the same water body as that from which the freshwater was taken. Consequently, all water pumped from the well, or taken from the mains has an impact on the source water body, even if, in the long term, waste water applied to land may eventually recharge the aquifer. Therefore, in this study we have considered drinking and cleaning water to be consumed.

Whilst it is clear that emissions from beef and dairy systems may play a significant role in degradation of the quality of fresh water bodies, we have not considered this within the present study and have therefore not calculated "grey" water footprints.

Selected livestock systems

The dairy industry in Ireland is mainly based in the South and East, Table 2, systems were modelled for spring and autumn calving herds for each selected location. For both spring and autumn calving, low, medium and high yielding systems were parameterised, with yields ranging from 4,000 – 5,000 litres per year for spring calving systems and averaging 5,500 litres per year for autumn calving.

Irish beef production is a combination of dairy beef calves from the national dairy herd and suckler beef production systems. Much of the production is extensive and grass-fed for up to 8 months of the year. Some beef is finished intensively on a mainly silage and concentrate-based diet. Therefore it was decided to model both dairy and suckler beef systems at different intensities - Extensive finishing systems were modelled for beef at four representative locations across Ireland, for both spring and autumn calving. Extensive systems were modelled to finish over approximately 24 months.

Four locations were chosen to focus on during the study (Table 2) with a representative site and weather station.

Table 2 Representative study locations

Region	% National dairy herd†	% National beef slaughterings†	Typical location	Representative weather station
South Ireland	59%	36%	Cork	Cork Airport
East Ireland	17%	28%	Meath/Louth	Mullingar
West Ireland	9%	18%	Roscommon / Mayo	Claremorris
South East Ireland	15%	18%	Kilkenny	Kilkenny

† Bord Bia, Pers. Com.

For dairy beef calves, both intensive, silage-based finishing (for bulls and steers) and extensive grazing-based finishing systems were modelled for each of the locations.

Water use in the feed system

The water used in the feed system depends on the mix of grazing, conserved grass, fodder crops and concentrates in the diet. Livestock in Ireland are mainly grass fed, but this is supplemented by a wide range of feeds depending on location, price and availability. Apart from grass, the main feeds are derived from domestically produced barley, distillers' grains, and imported soya and maize.

The feed given to animals contains 'virtual' or 'embedded' water that includes all the physical water embodied in the harvested crop and the water used by the growing plant (evapotranspiration). Evapotranspiration (ET) accounts for more than 99% of the total water use of most plants and very little water (relatively) is physically embodied in the harvested product. Therefore, the specific water use is determined from the total crop water use (ETc) over the growing period of the crop and the crop yield, thus

$$WU = 10\frac{ETc}{Y}$$

Where WU is the specific water use, m^3/t, ETc is crop water use, mm, Y is the crop yield, t/ha and 10 is a scalar to ensure consistent units.

Water use of grazing and conserved grass

The water use of grass grown in Ireland was estimated from a water balance. Average rainfall exceeds potential ET in all months in all four chosen locations, therefore, the water use of grass is not limited by drought stress, as it may be in dryer locations. Therefore, for Ireland, it is appropriate to assume that the water use of grass is equivalent to the reference evapotranspiration, ETo (

Table 3). Evapotranspiration is highest in Kilkenny due to higher air temperatures and wind speeds than the other regions (see Appendix 2 - Climate data used in the study).

Table 3 Estimated grass water use for four locations in Ireland.

Region	Location	Rainfall mm/year	ETo mm/year	Water use m^3/ha/year
South Ireland	Cork	1207	553	5,530
East Ireland	Mullingar	932	527	5,270
West Ireland	Claremorris	1136	503	5,030
South East Ireland	Kilkenny	823	573	5,730

Grass yield estimation

Data on grass yields for various locations in Ireland was obtained from Teagasc and extrapolated to fit the selected locations by combining with data from O'Mara (2009). Grass yields in Ireland appear to be reasonably similar across the country. Silage yields were assumed to be proportionally higher in each instance. Water use per hectare was then converted into water use per tonne grass and conserved forage dry matter ranging from 480 – 560 m^3/t DM (Appendix 3 – Grass and concentrate feed water use). The Cranfield LCA model calculates dry matter intake requirements of both grazed grass and silage for each production system.

Water use of concentrated feeds

Typical concentrate mixes were provided by Bord Bia (Appendix 3 – Grass and concentrate feed water use). Water consumption values for locally produced crops (e.g. barley), were determined using the same meteorological data as for grass with local crop yield values. The water consumption of crops produced in the UK and some overseas were taken from Chatterton et al. (2010). For other overseas crops, water consumption values were taken from Mekonnen and Hoekstra (2010a). Where the country was specified, average country values were used, for other crops world average values were used (Appendix 3 – Grass and concentrate feed water use). Economic allocation was used to partition the water consumption of crops that are processed before feeding to cattle (e.g. distillers' grains).

Water use in the livestock system

Water consumption in the livestock system was derived using the Cranfield Life Cycle Assessment (LCA) systems model for dairy and beef production (Williams et al., 2007), adapted for Irish systems. The model takes a systems-based approach to modelling the environmental burdens associated with meat and dairy production, accounting for all inputs and outputs crossing a defined system boundary, in order to produce a given quantity of a commodity, known as the functional unit. In the case of Irish beef and dairy production, the functional units used were a kg of expected edible carcase weight at the farm gate (slaughter house water use is excluded) and a litre of fat and protein corrected whole milk respectively. Edible carcase weight is live weight multiplied by the killing out percentage (KoP).

The model calculates the physical resources needed to produce the functional unit. In this case, the critical terms are the feeds coming from grazed grass, conserved forage and concentrates. The systems LCA model was thus used to quantify these feed inputs and hence to calculate the green water consumption of these inputs. The feed requirements of different types of stock were also used in deriving theoretical drinking water needs. The systems-based approach enables the complexity of agricultural systems to be captured and ensures that additional requirements and by-products of the systems are accounted for, such as replacement heifers and male dairy calves. By taking this approach, as opposed to an empirical approach, production systems are defined by sets of equations that describe their characteristics and these ensure that any changes in a production system are reflected throughout to ensure consistency of analysis. This gives much greater flexibility as it enables each characteristic to be changed individually and sensitivities to be explored. During the study, the Cranfield LCA systems model for dairy and beef production was adapted to fit representative Irish dairy systems, based on data for cow weights, calving indices, milk yields and feed composition. For dairy production a physical allocation method was used to partition the footprint between milk and cull cows and beef crossed calves in keeping with the International Dairy Federation methodology for carbon footprinting (IDF, 2010). For dairy beef animals no further allocation is required, as dairy beef calves are a by-product of the dairy industry and there are no further co-products. In the case of suckler beef, the pragmatic LCA method of economic allocation was used to allocate a small proportion of the burdens to cull cows. It is worth noting that economic allocation is used by the IDF (2010) for co-product feeds, because physical allocation is less suitable here.

Drinking water

As no local farm survey data exists for Ireland, drinking water consumption was based on standard texts. The drinking water intake of lactating cows was derived from the following relationship which was based on farm study measurements (Thomson et al., 2007):

$$I_w = 2.15\, I_d + 0.73M + 12.3$$

Where:
I_w = water intake, kg/day
I_d = dry matter intake, kg/day
M = milk yield, kg/day

Drinking water for beef animals and replacement heifers was calculated using suggestions from the Agricultural Research Council (ARC) review of water (cited in Thomson et al., 2007) based on dry matter (DM) intake and ambient temperature.

Ambient temperature (*T*), °C	Water intake, litres
≤ 10	$3.5 \times I_d$
10 < *T* ≤ 15	$5.4 \times I_d$
15 < *T* ≤ 20	$6.1 \times I_d$
20 < *T* ≤ 25	$7.0 \times I_d$

It was estimated from Irish meteorological data (Met Éireann, 2011, Appendix 2 - Climate data used in the study), that for all the representative locations, average ambient temperatures would be approximately 10°C and therefore a value of 3.5 l kg^{-1}DM ingested was used. Drinking water, and thus abstracted blue water, was taken to be the balance of this less the water content of feed.

Washing and cleaning water

Wash water for lactating dairy cows was also taken from Thomson et al. (2007) and assumed to be 25 L animal^{-1} day^{-1}. There are no available data on wash water for non-lactating cattle and it has been assumed to be negligible.

On-farm processing water

It was assumed that a ratio of 2:1 water to milk is used by the plate cooler to achieve optimum cooling (from DairyCo, 2009). Plate coolers require additional water for washing, so that a total ratio of 3:1 was assumed to include both milk cooling and washing functions. It should be noted that this water is frequently reused for washing down yards and cattle drinking water, but the extent of this and the amount lost to waste water is highly uncertain so has not been modelled. In some cases more traditional water-based alternatives are still used for cooling and may consume less water, however all newly installed cooling systems are plate coolers and these were therefore modelled to avoid underestimating blue water use.

Milking machine wash water was estimated from a small number of farm visits and adjusted to give a per cow value. It was assumed that the milking machine was washed twice a day. Bulk tank washing was assumed to be 100 litres per day for a herd of 60 cows.

Water consumption in feed and livestock systems

Dairy

Water consumption was calculated for each system in each of the four regions of Ireland. Table 4 shows averages for Ireland, weighted according to the national distribution of dairy cows. Results are presented on a functional unit basis, that is, the water consumption per litre of fat and protein corrected milk (FPCM)[2]. Total water consumption ranges from 550 – 650 litres water per litre FPCM with the higher yielding systems having a lower water consumption per litre FPCM. In all cases blue water accounts for ≈1% of the total water consumption.

Results for each of the four representative regions modelled are given in Appendix 4.

Table 4 Total water consumption for Irish dairy systems, litres per litre FPCM.

System	Calving	Yielding	Blue water	Green water	Total
Dairy	Spring	Low	8.6	635	643
		Medium	8.2	607	615
		High	7.8	584	592
	Autumn	Low	8.0	589	597
		Medium	7.6	565	573
		High	7.2	541	548

[2] That is milk normalised to 4% fat and 3.3% protein content

Beef

Dairy-beef systems were separated into intensive (concentrate/silage-based) finishing systems (for bulls and steers) and extensive grass-based systems. Again, water consumption was calculated for each system in each of the four regions of Ireland.

Results for each of the four representative regions modelled are given in Appendix 4.

Table 5 shows averages for Ireland, weighted according to the national distribution of slaughtered beef cattle. Results are presented on a functional unit basis, that is, the water consumption per kg. Total water consumption ranges from 6,570 – 10,800 litres water per kg edible carcase weight. In all cases blue water accounts < 0.5% of the total water consumption.

Results for each of the four representative regions modelled are given in Appendix 4.

Table 5 Total water consumption for Irish beef systems, litres per kg edible carcase weight.

System	Calving	Finishing	Blue water	Green water	Total
Dairy-beef		Extensive	14.3	6,560	6,574
		Intensive	16.8	6,710	6,727
Suckler Beef	Spring	Extensive	42.4	9,850	9,892
		Intensive	40.6	9,890	9,931
	Autumn	Extensive	50.7	10,700	10,751

Water consumption per kg is much lower for dairy-beef than for suckler beef because dairy-beef calves are a by-product of the dairy industry and therefore water use by the dairy cow is not accounted for. For suckler beef production, requirements of the suckler cow also need to be accounted for and therefore water consumption by the suckler cow over the first year, both for drinking water and water in feed, is included.

Discussion

For dairy, higher yielding dairy systems have lower water consumption (both green and blue) per litre of milk, by about 8% - 10%. Therefore although lower feed inputs suggest that low yielding cows require less drinking water, production of one litre of milk will require a greater number of cows. Similarly the blue water consumption for autumn calving systems was slightly lower than for spring calving, as average yields would be higher.

Intensive beef systems also have lower water consumption than extensive systems, although the difference is small. Intensive suckler beef have slightly lower drinking water requirements because they finish more quickly (so will drink less over their lifetime) and also because the killing out percentage will be higher. However, the green water consumption is higher due to the higher proportion of concentrates in the diet. Autumn calving systems have higher water consumption for both blue and green water, due to slightly longer finishing times and greater use of concentrate feed.

Green water consumption

It is clear that the vast majority of the total water consumption for all the systems studied is green water. For the systems studied, >98.5% of the dairy and >99.5% of the beef water use is green water. It can be argued that green water use has negligible environmental impact as it has a low, or negligible opportunity cost. The rain water consumed by growing grass or feed crops could only be used for growing alternative vegetation, that is, it could not be used to substitute for water for domestic or industrial consumption for example. Therefore, there is no water benefit in saving green water (there may, of course, be other benefits from increasing the productivity of land).

Blue water consumption

Dairy systems

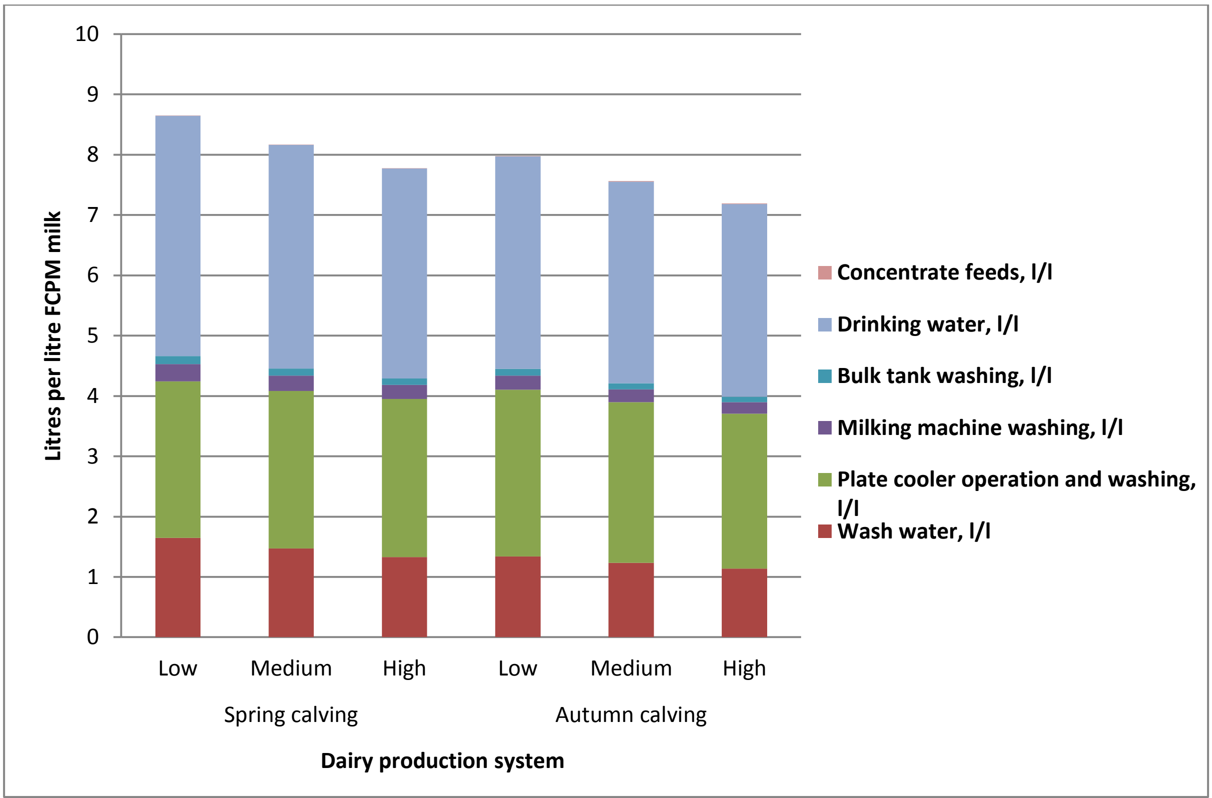

Figure 2 shows the breakdown of blue water use for dairy systems. Drinking water accounts for 45% of the total blue water use. As these estimates have been modelled, rather than surveyed, there is considerable uncertainty over the amount of water used for drinking. The values presented are based on farm measurements, but do not include estimates of wastage or estimates of between animals variation. However, these figures equate to 48 to 56 litres per head per day, which would be reasonable.

Plate cooler water accounts for 33% of the blue water consumption. In the worst case, this is all consumed, although much of this could be reused and it has been shown that cows may prefer to drink the warmer water (DairyCo, 2009). Drinking very cold water also adversely affects rumen protozoa. However the extent to which, and how this is reused is unknown and, if not used immediately, warm water is more prone to supporting microbial growth.

The remainder of the blue water is split between wash water for the animals and machinery. The virtual blue water associated with feed makes an insignificant contribution to the total blue water consumption, because most of the concentrate feed mix is from un-irrigated crops and is a by-product of other systems.

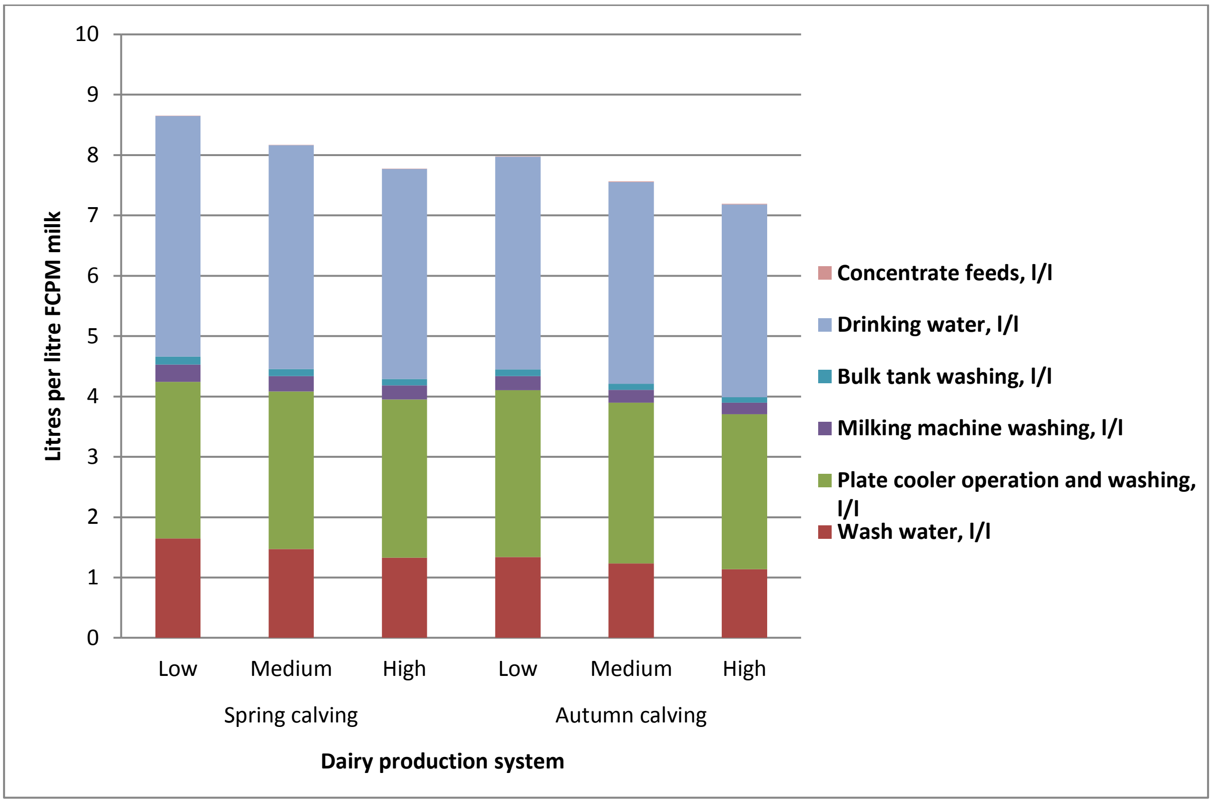

Figure 2 Breakdown of blue water consumption for Irish dairy systems, litres per litre FPCM

Enterprise Ireland (2011) studied 15 dairy processing plants. They found a mean water use of approximately 15l/l. Thus a greater volume of blue water is used in processing milk than is used on the farm.

Beef systems

Blue water for beef production is almost entirely drinking water, with a very small amount of virtual water associated with imported concentrate feed. Drinking water requirements for beef cattle are related to dry matter (DM) intake, therefore animals fed on concentrate-rich diets will require a greater proportion of their water intake as drinking, and thus blue water. However, the additional output per head offsets this and the overall water consumption per kg edible carcase weight is similar in all systems.

Enterprise Ireland (2009) studied 16 beef processing facilities. They found a mean water use of 2.02 m^3 per head, equivalent to 6.2 l/kg edible carcase weight.

Summary

The blue water consumption, including the feed and livestock systems and processing, is small for both milk and beef under all systems. The ranges are shown in Table 6. For dairy, dairy-beef and suckler beef, 66%, 29% and 12% of the blue water consumption is in the processing stage respectively.

Table 6 Summary of blue water consumption for Irish livestock products

System	Feed & livestock	Processing	Total†	Unit of output
Dairy	7.2 – 8.6	15.0	23	litre FPCM
Dairy-beef	14.3 – 16.8	6.2	22	kg ECW*
Suckler beef	40.6 – 50.7	6.2	52	kg ECW*

* ECW = edible carcass weight

† Average of range for feed & livestock system

Comparison with other studies

The estimates of water consumption in the livestock system are generally lower than found in other published reports. Green water consumption for both milk and beef is slightly lower than values quoted by Mekonnen and Hoekstra (2010b). Grass yields in Ireland are high, thus the water consumption per tonne of grass dry matter is low. Additionally the relatively low proportion of concentrates in the diet may reduce the green water consumption in comparison to feed from overseas locations where water consumption is higher.

However, our estimates of blue water consumption are considerably lower than those of Mekonnen and Hoekstra (2010b). This is probably due to a number of reasons, as follow.

- The high proportion of grass in Irish cattle diets. Drinking water requirements are likely to be lower for grass-fed animals than for cattle fed on more cereal or concentrate based diets where the dry matter content is higher, and thus less water is supplied in food so more of the daily water intake requirement must be met through abstracted drinking water.
- There is very little virtual blue water in concentrated feeds as most grain comes from rain-fed crops, as opposed to irrigated crops.
- A large proportion of concentrated feeds are low-value by-products (e.g. distiller's grains) and therefore little virtual water is allocated to the feed.
- This study does not include water for industrial processing of milk and carcasses, which is included in some other studies.

Water Footprint

The estimates of water consumption do not provide any information on the impact of water consumption on the source water bodies. Clearly, the same volume of water abstracted from a plentiful water resource, for which there is little competition, will have a lesser impact than that taken from an over-exploited resource. Therefore, many suggest that the water footprint should reflect the impact of water consumption on the source water body, rather than simply a volume of water consumed[3].

As green water cannot be diverted to other uses (except alternative vegetation) the green water consumption is often excluded from water footprint studies. The water footprint is therefore estimated from the blue water consumption only.

[3] NB. This differs from the definition of water footprint used by the water footprint network, but is compatible with the draft ISO on Water Footprints.

Anecdotal evidence suggests that most blue water-use on farms in Ireland is from farm wells with some mains water. The significance of blue water use depends upon the status of the water resource from which it is taken.

The Water Stress Index (WSI) is often used to reflect blue water scarcity in water footprint studies (Pfister et al., 2009). This reflects the ratio of water used to water available in a region and ranges from 0.01 (lowest) to 1.00 (maximum water stress). All of Ireland has a Water Stress Index <0.1 (very low) with values ranging from 0.01 (Galway) to 0.03 (Dublin)[4]. Similar levels of Water Stress Index are found in N Ireland, SW England, Wales and Scotland.

Table 7 Water Stress Index (WSI) for four regions in Ireland.

Station	WSI
Cork	0.0102
Mullingar	0.0110
Claremorris	0.0104
Kilkenny	0.0117

In order to estimate the water footprint of livestock in New South Wales, Australia, Ridoutt et al., (2012) used the WSI to normalise the blue water consumption and to derive an index of water equivalent (H_2Oe) that reflects both the volume of blue water consumed and relative stress on water in the producing region.

Blue water consumption is normalised as follows:

$$\text{Normalised water footprint} = \text{Blue water use} \times \text{WSI}/0.602$$

Where 0.602 is the global average WSI (Ridoutt and Pfister, 2010)

For dairy systems, the normalised water footprint of milk production (at the farm gate) ranges from 0.12 litres H_2Oe/litre FPCM for high yielding autumn calving systems in the south of Ireland to 0.17 for low-yielding, spring calving systems in the south-east.

For beef systems, the normalised water footprint of milk production (at the farm gate) ranges from 0.24 litres H_2Oe/kg for extensive dairy beef systems in the south of Ireland to 0.98 for autumn calving, extensive finishing systems in the south-east. These are considerably lower than the water footprint values ranging from 3.3 to 221 litres H_2Oe/kg LW derived for New South Wales, Australia, by Ridoutt et al. (2012). This is not very surprising given the very different climates.

Uncertainties

Drinking and sanitation water requirements were estimated from standard figures and simple models relating to diet and ambient temperature. These may not reflect actual water use on Irish farms. A protocol was drafted for collection of on-farm blue water-use (Appendix 1) that could be used to determine more locally applicable values.

[4] http://www.ifu.ethz.ch/ESD/downloads/EI99plus

The water footprint has been estimated on the basis of the Water Stress Index (in accordance with similar studies), which reflects surface water availability. However, it appears that most water use on Irish livestock farms is from groundwater (≈90%) and mains water (≈10%). Generally, widespread abstraction pressures on groundwater are not significant in Ireland and the impact of water use would be expected to be small, however, there are some localised cases where abstraction pressures are impacting on groundwater levels (EPA, 2008)[5]. This highlights the very local scale of hydrological impacts and suggests that even though the average water footprint of Irish beef and dairy production is very small, in certain places it may be contributing to depletion of groundwater resources and water conservation may be encouraged.

The calculation of the water footprint includes terms with varying degrees of uncertainty. A formal calculation of the statistical uncertainty requires access to data that is outwith our scope, e.g. the uncertainties in the meteorological data in Ireland, the third party estimates of the water footprints of imported crops. A range of water use values is inevitable, resulting from statistical uncertainties as well as farmer choices, between animal variation and the lack of actual measured data on Irish farms.

It is very likely the uncertainties are smaller than those in carbon footprinting and we believe that the calculations are correct to within ± 25%. While some might regard these error bands as large, they are within the range of the uncertainties found in other environmental analyses of agriculture, such as national inventories of greenhouse gases or ammonia. It is also important to recognise that the uncertainties are internally correlated and so the uncertainties are not totally independent between production systems, e.g. between extensive and intensive beef. So, the significance of differences between systems actually depends on the differences in activity data (e.g. days to finishing or weight of feed consumed) rather than in the uncertainties in, say, the evapotranspiration of water from grass. It is thus quite possible for small differences between values for the water footprints of similar products to be significant despite the large overall uncertainty. Without access to the underlying data on uncertainty, we cannot be sure if this actually is the case or not, but from similar analyses of the carbon footprint, it seems likely.

[5] http://www.epa.ie/downloads/pubs/other/indicators/irlenv/43366%20EPA%20report%20chap%206.pdf

Conclusions

The water consumption of a commodity by itself currently gives no indication of the relative importance of the type or geographical location of the water. This study shows the importance of considering water use in context and highlights the risk of considering the total water consumption involved rather than the impact of that water use. For both beef and dairy production the total water consumption, viewed out of context may be considered excessively high. However, for both commodities, less than 2% of the total water consumption is actually abstracted blue water, that has an opportunity cost elsewhere. Combined with the low levels of water stress in Ireland, the resulting water footprint is very small for all the livestock systems studied in comparison to other regions of production.

However, there are localised situations where groundwater resources are being depleted and dairy and beef production may be contributing. In these cases particular attention should be paid to the efficiency of livestock drinking water systems to reduce wastage and water recycling in dairy parlours should be considered. Using water from alternative sources, such as rain water harvesting, would reduce pressure on groundwater resources in these situations.

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Appendix 1 - Farm water use data collection protocol

1. Where do you get your water for the farm? (please tick the box that best describes each water source)

	Most of my farm water	Some of my farm water	Farm house	Not used
Mains water (metered)				
Mains water (not metered)				
Own well				
Shared well				
Spring				
Collection of roof water				

2. Do you know how much water you use for your livestock enterprise on an annual basis?
   - ☐ Yes
   - ☐ No

   If yes, how much do you use? ______________________m^3 or litres per year

3. How do your animals get drinking water when in the field?
   - ☐ River / stream
   - ☐ Troughs
   - ☐ Bowser
   - ☐ Nose bowls
   - ☐ Bite ball-valves
   - ☐ Other (specify _____________________________)

4. How do your animals get drinking water when housed?
   - ☐ Troughs
   - ☐ Nose bowls
   - ☐ Bite ball-valves
   - ☐ Other (specify _____________________________)

5. What do you use for washing down parlours and yards?
   - ☐ Volume hoses
   - ☐ Pressure hoses
   - ☐ Buckets

6. What happens to the waste water from washing down?

- ☐ Runs off to a ditch / stream (without treatment)
- ☐ Treated on-farm before discharge to a ditch / stream
- ☐ Collected with manure and spread on the land
- ☐ Collected for re-cycling as water on the farm
- ☐ Discharged to a sewer
- ☐ Other (specify ____________________________)

7. What happens to rainwater falling on yards and roofs?

- ☐ Runs off to a ditch / stream (without treatment)
- ☐ Treated on-farm before discharge to a ditch / stream
- ☐ Collected with manure and spread on the land
- ☐ Collected for re-cycling as water on the farm
- ☐ Discharged to a sewer
- ☐ Other (specify ____________________________)

8. How regularly do you check your farm water points for leaks?

- ☐ More than once a month
- ☐ Once a month
- ☐ A few times each year
- ☐ Once a year
- ☐ Never

9. Which of these water saving measures are you using? (please tick all that apply):

- ☐ Reducing pressure from water hose (e.g. using a pressure washer)
- ☐ Plate cooler water re-use (dairy)
- ☐ Triggers on hoses
- ☐ Water meters to monitor water use
- ☐ Building/finding alternative water sources (e.g. wells, springs)
- ☐ Use of new water technologies (e.g. solar powered pump system)
- ☐ Other (please specify)

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Appendix 2 - Climate data used in the study

Source: http://www.met.ie/climate-ireland/30year-averages.asp

CLAREMORRIS	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	***year***
mean daily max. °C	7.2	7.6	9.6	12	14.5	17	18.4	18.2	16.1	13.2	9.5	7.9	**12.6**
mean daily min. °C	1.4	1.3	2.3	3.3	5.5	8.2	10.2	9.8	8.1	6.3	3	2.3	**5.1**
mean RH at 0900UTC	91	91	88	84	80	81	84	87	89	92	92	92	**88**
mean daily sunshine, h	1.45	2.11	2.87	4.4	5.08	4.64	3.79	3.81	3.1	2.39	1.81	1.11	**3.05**
mean wind speed, knots	10	10	10.2	8.7	8.3	7.9	7.5	7.3	8	9	8.7	9.7	**8.8**
mean monthly rainfall, mm	121.1	82.9	95.8	61.7	77.5	71.7	63.4	96.9	104.2	125.9	111.8	123.5	**1136.4**

CORK	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**year**
mean daily max. °C	7.6	7.5	9.3	11.3	13.8	16.6	18.5	18.2	16	13.1	9.9	8.5	**12.6**
mean daily min. °C	2.6	2.5	3.1	4.2	6.5	9.2	11.1	10.9	9.4	7.5	4.5	3.7	**5.1**
mean RH at 0900UTC	90	90	88	83	81	81	83	86	88	91	90	90	**87**
mean daily sunshine, h	1.7	2.28	3.51	5.21	6.02	5.73	5.4	5.14	4.13	2.8	2.16	1.56	**3.8**
mean wind speed, knots	12.9	12.6	12.3	11	10.6	9.5	9.1	9.2	10.3	11.2	11.6	12.4	**11.1**
mean monthly rainfall, mm	148.3	115.9	97.1	70.2	84.1	67.7	65.4	89.9	97.4	125.8	108.7	136.5	**1207**

KILKENNY	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**year**
mean daily max. °C	7.7	7.9	10	12.4	15.1	18.1	19.9	19.6	17.2	13.9	10.1	8.4	**13.4**
mean daily min. °C	1.4	1.6	2.3	3.4	5.6	8.4	10.4	9.9	7.9	6.1	2.8	2.1	**5.2**
mean RH at 0900UTC	88	87	85	79	76	76	78	82	85	88	89	89	**84**
mean daily sunshine, h	1.71	2.29	3.32	4.85	5.47	5.15	4.65	4.5	3.82	2.71	2.22	1.48	**3.51**
mean wind speed, knots	7.4	7.4	7.7	6.7	6.4	5.8	5.6	5.6	5.9	6.4	6.4	7.1	**6.5**
mean monthly rainfall, mm	87	65.7	62.8	51.6	61.9	50.5	52.7	70.7	72.5	85.5	74	88	**822.9**

MULLINGAR	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**year**
mean daily max. °C	6.8	7.2	9.4	11.8	14.7	17.5	19	18.6	16.4	13.2	9.1	7.5	**12.6**
mean daily min. °C	1.2	1.2	2	3.3	5.6	8.5	10.3	9.8	8.1	6.1	2.7	2	**5.1**
mean RH at 0900UTC	92	90	89	83	79	80	82	85	88	91	92	92	**87**
mean daily sunshine, h	1.73	2.31	3.3	4.83	5.56	5.17	4.57	4.39	3.7	2.74	2.18	1.53	**3.5**
mean wind speed, knots	9.7	9.7	10	8.5	8	7.4	7.3	7.2	7.6	8.4	8.5	9.3	**8.5**
mean monthly rainfall, mm	92.4	66.3	72.6	59	70.9	67	61.2	82.9	85.1	94.1	87.9	92.2	**931.6**

Appendix 3 – Grass and concentrate feed water use

Table 8 Grass water use data for representative locations

Region	Location	Rainfall mm/year	ETo mm/year	Water use m^3/ha/year	Estimated grass yield, t DM/ha	Water use m^3/t DM
South Ireland	Cork	1207	553	5,529	10.41	531.2
East Ireland	Mullingar	932	527	5,270	10.42	549.9
West Ireland	Claremorris	1136	503	5,032	10.41	483.2
South East Ireland	Kilkenny	823	573	5,734	9.41	560.0

Table 9 Representative‡ concentrate mix (provided by Teagasc) with water use values

Beef	%	Blue water m^3/t DM	Green water m^3/t DM	Dairy	%	Blue water, m^3/t DM	Green Water, m^3/t DM
Maize gluten feed (N. America)	30		286†	Distillers' grains (local)	20	10†	307†
Maize distillers (N. America)	26	10	270†	Soya bean meal (Argentina)	15.5†		2638†
Barley (local 66%, N Europe 34%)	35		829†	Unmollassed beet pulp	15	1*	80*
Rapeseed meal (imported)	6.5		733†	Citrus pulp	15	18.5*	342.5*
Mineral/vitamin mix	2.5			Barley (local)	13.5†		829†
				Soya hulls	7.5†		2385†
				Palm kernel meal	6	0.2*	802*
				Molasses	5	43*	139*
				Mineral/vitamin mix	2.5		

*Derived from WFN values (Mekonnen & Hoekstra, 2010a).
†Derived from agroclimatic modelling and Cranfield LCA systems model.

‡These mixes were used within the model as representative, however other combinations will be used for both sectors.

Appendix 4 – Detailed results

Dairy production

Aggregated numbers for Irish dairy production were based on the 2010 Agricultural Census, grouped by region,

Table 10.

Table 10 Estimated distribution of dairy production across Irish regions

Region	Representative location	Proportion
South	Cork	59%
South East	Kilkenny	15%
East	Mullingar	17%
West	Claremorris	9%

Water consumption per litre of fat and protein corrected milk (FPCM) for each of the representative locations, Table 11, Table 12, Table 13 and Table 14.

Table 11 Total water use per litre FPCM milk for dairy systems in South Ireland (Cork)

Cork		Blue water use, l/l	Green water use, l/l
Spring calving	Low yielding	8.6	631
Spring calving	Medium yielding	8.2	604
Spring calving	High yielding	7.8	581
Autumn calving	Low yielding	8.0	587
Autumn calving	Medium yielding	7.6	563
Autumn calving	High yielding	7.2	539

Table 12 Total water use per litre FPCM milk for dairy systems in South East Ireland (Kilkenny)

Kilkenny		Blue water use, l/l	Green water use, l/l
Spring calving	Low yielding	8.6	651
Spring calving	Medium yielding	8.2	622
Spring calving	High yielding	7.8	597
Autumn calving	Low yielding	8.0	600
Autumn calving	Medium yielding	7.6	575
Autumn calving	High yielding	7.2	550

Table 13 Total water use per litre FPCM milk for dairy systems in East Ireland (Mullingar)

Mullingar		Blue water use, l/l	Green water use, l/l
Spring calving	Low yielding	8.6	662
Spring calving	Medium yielding	8.2	631
Spring calving	High yielding	7.8	606

Autumn calving	Low yielding	8.0	608
Autumn calving	Medium yielding	7.6	582
Autumn calving	High yielding	7.2	556

Table 14 Total water use per litre FPCM milk for dairy systems in West Ireland (Claremorris)

Claremorris		Blue water use, l/l	Green water use, l/l
Spring calving	Low yielding	8.6	579
Spring calving	Medium yielding	8.2	557
Spring calving	High yielding	7.8	540
Autumn calving	Low yielding	8.0	552
Autumn calving	Medium yielding	7.6	532
Autumn calving	High yielding	7.2	511

Table 15 Breakdown of blue water consumption for Irish dairy systems, litres per litre FPCM

	Spring calving			Autumn calving		
Yield level	Low	Medium	High	Low	Medium	High
Wash water, l/l	1.65	1.47	1.33	1.34	1.23	1.14
Plate cooler operation and washing, l/l	2.59	2.61	2.62	2.76	2.66	2.56
Milking machine washing, l/l	0.29	0.26	0.23	0.23	0.21	0.20
Bulk tank washing, l/l	0.13	0.12	0.11	0.11	0.10	0.09
Drinking water, litre/litre	3.98	3.71	3.48	3.52	3.35	3.19
Concentrate feeds, litres	0.002	0.004	0.006	0.010	0.010	0.009
Total blue water	8.6	8.2	7.8	8.0	7.6	7.2

Beef production

Water consumption per kg edible carcase weight beef for dairy beef systems at each representative location, Table 16, Table 17, Table 18 and Table 19.

Table 16 Total water use per kg edible carcase weight for dairy beef systems in South Ireland (Cork)

Cork	Blue water use, l/kg	Green water use, l/kg
Extensive finishing	14.3	6531
Intensive finishing	16.8	6697

Table 17 Total water use per kg edible carcase weight for dairy beef systems in South East Ireland (Kilkenny)

Kilkenny	Blue water use, l/kg	Green water use, l/kg
Extensive finishing	14.3	6684
Intensive finishing	16.8	6786

Table 18 Total water use per kg edible carcase weight for dairy beef systems in East Ireland (Mullingar)

Mullingar	Blue water use, l/kg	Green water use, l/kg
Extensive finishing	14.3	6767
Intensive finishing	16.8	6834

Table 19 Total water use per kg edible carcase weight for dairy beef systems in West Ireland (Claremorris)

Claremorris	Blue water use, l/kg	Green water use, l/kg
Extensive finishing	14.3	6138
Intensive finishing	16.8	6469

Water use for Irish suckler beef systems, aggregated and at representative locations, Table 20, Table 21, Table 22, Table 23 and Table 24.

Table 20 Water use per kg of beef, for suckler systems, aggregated for Ireland

Suckler beef		Blue water use, l/kg	Green water use, l/kg
Spring calving	Extensive finishing	42.4	9850
Autumn calving	Extensive finishing	50.7	10700
Spring calving	Intensive finishing	40.6	9890

Table 21 Water use per kg of beef, for suckler systems, for South Ireland (Cork)

Cork		Blue water use, l/kg	Green water use, l/kg
Spring calving	Extensive finishing	42.4	9800
Spring calving	Intensive finishing	40.6	9850
Autumn calving	Extensive finishing	50.7	10600

Table 22 Water use per kg of beef, for suckler systems, for South East Ireland (Kilkenny)

Kilkenny		Blue water use, l/kg	Green water use, l/kg
Spring calving	Extensive finishing	42.4	10100
Spring calving	Intensive finishing	40.6	10100
Autumn calving	Extensive finishing	50.7	10900

Table 23 Water use per kg of beef, for suckler systems, for East Ireland (Mullingar)

Mullingar		Blue water use, l/kg	Green water use, l/kg
Spring calving	Extensive finishing	42.4	10300
Spring calving	Intensive finishing	40.6	10200
Autumn calving	Extensive finishing	50.7	11100

Table 24 Water use per kg of beef, for suckler systems, for West Ireland (Claremorris)

Claremorris		Blue water use, l/kg	Green water use, l/kg
Spring calving	Extensive finishing	42.4	9070
Spring calving	Intensive finishing	40.6	9220
Autumn calving	Extensive finishing	50.7	9890

The water footprint of Irish meat and dairy products

Hess, Tim M.

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