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Learning from Water Footprints

who loses, who wins, and who cares?

Abstract

The 'footprint' concept is widely used as an indicator to assess CO_2 emissions and the water embodied in crop production. A comparison of key features reveals that CO_2 footprints are a global concern no matter their location or source; water footprints only have local relevance, being locally generated and impacting only at local levels. As such, addressing excessive water use is a local concern. Where excessive use is not managed, a process of 'chaotic disallocation' from irrigated agriculture ensues, resulting in reduced local production and, through market mechanisms, increased demand elsewhere. Those areas where water scarcity is managed sustainably will see more profitable opportunities for irrigated production, though the impact on prices will be of little concern to consumers in the developed world.

Keywords footprints, sustainable water resources management, chaotic disallocation

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In 1993, Tony Allan introduced the phrase 'virtual water' (Allan, 1993), setting out the concept that all goods – but, most importantly, agricultural products – utilise water in their production. Thus, trade in agricultural commodities can also be viewed as a trade in the water embodied in the production process – 'saving' the importing country from allocating its own water resources. This concept of virtual water provided the underpinning for the development of water footprints (Hoekstra et al., 2011).

Water for agriculture dominates demand in most water-scarce regions (Richter et al., 2017), so that the primary focus of attention has been on crops and trade in agricultural commodities. Crop water footprints – the water that a crop transpires through its foliage as part of the process of biomass formation – have gained acceptance as a revealing indicator of the pressure on a resource that is overexploited in many countries. Many see a parallel between carbon footprints and water footprints (Ercin and Hoekstra, 2012).

At first glance, the parallel with carbon footprints seems obvious: reducing our carbon footprint reduces the damaging impact of CO_2 on the world's climate. Good! Similarly, reducing our water footprint alleviates pressure on a scarce and critical resource. Good? Not necessarily.

Water is more complicated than carbon in several respects. CO_2 emissions are an unambiguous and universal metric: one gram of emissions from a car driven in Canberra equates to one gram of emissions from a power station in Cape Town. In contrast, the water footprint of a crop is typically composed of one or more of several diverse components: non-renewable water pumped from a fossil aquifer; water diverted from a river; water 'harvested' from local run-off; and/or water that landed directly on a field as rainfall. And the water that landed as rainfall would, in the absence of a crop, have been utilised just as fully by natural vegetation, so that the 'footprint' of the crop when compared to the natural alternative may be zero.

In sum, where water comes from is complicated; how we use it is complicated; and where it goes after use is complicated. These complexities have profound implications for the relevance of water footprints to water policy at local, regional and global levels, which are explored in more detail below. Using the attributes of carbon footprints provides important insights into what the future holds for areas where water is currently overexploited.

Carbon footprints are global; water footprints are local

Perhaps the most important difference between carbon footprints and water footprints is that water is a *local* resource whose use has local impacts. Scarcity or excess, seasonal supply and demand, the customs and institutions governing allocation are all local variables and the range of possible combinations of these is almost infinite. No doubt the domain that constitutes 'local' may range from two neighbours sharing a well to several countries sharing a basin, but the 'water' domain is never global, and in that sense is always local. In contrast, CO_2 emissions are CO_2 emissions no matter what the source, where they occur, or when; they are always global and never local.

The fact that water footprints are local has important implications: 'my' local water use for washing, cooking or watering my garden does not affect a water user anywhere outside my 'locality'. More generally, if I give up sugar in my coffee, the resulting fall in global demand for sugar will result in reduced production, somewhere. It may result in reduced production in Maharashtra, where sugar cane production depends heavily on unsustainable groundwater use. If so, pressure on the local groundwater resources will be reduced, which is a good outcome for the local water economy. Alternatively, if the reduction in production occurs in the West Indies, where sugar cane production is based on rainfall that will wet the ground and vegetation, there will be no benefits to the local water economy: the rain will continue to fall, and vegetation of some type will capture and transpire a proportion of that rainfall. There is no guarantee that the reduced global demand for sugar will result in an economically or environmentally rational response. The local and the global are not logically connected (Perry, 2014).

> Mismanagement of water … is leading … to chaotic disallocation of water from agriculture.

This is not to say that widespread failure of water systems (aquifers too saline or too deep for exploitation; rivers seasonally dry causing environmental collapse, etc.) will not have implications for global food production; there is clearly a link, but disaggregating the local impacts of water management from global concerns about food security and the ecosystem reveals the heterogeneity of the likely losers (and winners) from problems in the water sector.

Water (mis)management is case by case

If a country, like New Zealand, mismanages its water, the sectors that currently depend on that water will eventually and inevitably suffer 'disallocation' of water – first from the environment, which is what we already commonly observe, and then, typically, from irrigated agriculture. Human interference in the water cycle, especially to support irrigation, has as its objective the increased local consumption of water by crops. This artificially induced increase in consumption, supported by abstraction from an aquifer, or diversion from a river, affects the balance between inflows and outflows, and will have consequences. Mother nature will combine forces with the law of conservation of mass to ensure that this happens: wells will go dry, or saline, or too deep for economic exploitation; downstream abstractors from rivers will increasingly frequently find the river is dry or too saline for use. This process is already widely evident (Falkenmark, Lundqvist and Widstrand, 1989; Leblanc et al., 2011; MacDonald et al., 2016; Perry, Steduto and Karajeh, 2017).

As long as water demand is constrained to be well within the average renewable supply, with acceptable environmental outcomes, the water economy (and irrigated agriculture) can to some extent absorb shocks. On the supply side, aquifers can be over-drafted in times of drought and allowed to replenish in times of above-average precipitation; surface water reservoirs can be operated to carry over storage to mitigate low-flow years (for example, Aswan can retain about twice the average inflow to Egypt from the Nile). Equally importantly, on the demand side, if farmers plant a significant proportion of annual crops (grains, cotton, forage, etc.), they can reduce the area planted when advised that water is scarce, or even abandon a crop in mid-season at relatively minor cost. Once perennials are established (vines, orchards, nuts), this flexibility is severely constrained because farmers will protect their long-term investment using whatever water source they can access – usually unsustainable groundwater (Dinar, 1994). Similarly, irrigating forage for a dairy enterprise supports a demand that cannot be abandoned temporarily during a drought. Demand is thus less flexible, while the supply is at or beyond the margin of sustainability so that the capacity to absorb variations in precipitation is limited.

What we have observed over recent years is that water resources are being widely exploited beyond the renewable margin (Panda, Mishra and Kumar, 2012; Famiglietti, 2014; Leblanc et al., 2011; OECD, 2015; MacDonald et al., 2016). The observed depletion of aquifers and damage to river ecosystems – and farmers are tending to move to higher value, perennial crops that they are unwilling to abandon in times of drought – is almost universal. The consequence, inevitably, is shocks to the system – isolated, short-term and usually local shocks rather than the progressive global catastrophe envisioned in some global warming scenarios, which again highlights the difference between CO_2 emissions and water footprints.

Those most affected by chaotic disallocation ... are also those least able to afford the associated increases in food costs.

In the water sector, this local process is likely to be – indeed often is – chaotic. The sequence in which wells become unusable is determined in part by the resources of individual farmers – how deep is his well? What are the neighbours doing? – and in part by the specific hydrogeology of the location – one farmer sits over an area of fresh groundwater; the next has to tap a deeper aquifer. A similar process will unfold with surface water: upstream abstraction and consumption will render downstream areas dry or supplied sporadically, perhaps only with increasingly saline water. These processes will not be orderly, prioritised or predictable.

Add to this the short-term variations in the weather: Australia in 2018 was experiencing a severe drought; simultaneously, California was experiencing excessive precipitation. The previous year was essentially the reverse. Who will not have water next year? We really do not know.

And the process is already ongoing. In some regions, farmers, their families and the local economy are suffering badly. Migration from agriculture to cities has many drivers, but unstable and decreasing availability of water is certainly one of them. The 'environment' in many areas is already suffering, very badly. And the pursuit of individual and entirely rational self-interest when the resource is open-access ensures that the 'tragedy of the commons' (Hardin, 1968) is a powerful explanatory paradigm.

While this long-term imbalance between how much water there is and how much we would like to have is unavoidable, the process of chaotic disallocation as the law of conservation of mass plays out is primarily a *local* issue, depending on how close to the renewable margin the water system is operating, and how flexible the response to scarcity is. Does the system have the capacity to absorb short-term fluctuations in supply, complemented by some flexibility in demand? Increasingly, neither is the case.

Water management is also case by case

Mismanagement of water will lead – is leading – to chaotic disallocation of water from agriculture. An alternative process of *managed* disallocation driven by local policies, regulations and institutions is possible, however. Whether countries opt to adopt such approaches is within their own power. When implemented effectively, disallocation will be policy driven, transparent, prioritised and scheduled over time, thus minimising costs, allowing progressive adjustments, and providing compensation where appropriate.

If (for example) water consumption in specific irrigated areas must fall by 20% in order to re-establish the local average balance between renewable supply and demand, we can anticipate that agricultural production will fall. Chaotic disallocation will probably maximise the impact on production for several reasons: first, a given level of *uncertain* supply will be less productively used than the same average level of *assured* supply because the farmer will invest more in inputs to maximise the productivity of assured water. Second, disallocation will randomly remove water from all farmers, including the most productive. Managed disallocation, by contrast, can be planned over time, and targeted on the least productive farmers or crops, and will consequently have a lower impact, encouraging the most rational responses to reduced supply. These could include abandoning the least productive uses of water through adjusted commodity policies, market mechanisms such as buying out water rights, or allowing trade of water allocations among farmers.

Thus, we see that individual countries and regions have it largely in their own hands as to whether the water resources relevant to their livelihoods are managed sustainably – a clear and substantial difference from the global carbon economy.

Winners and losers

Looking beyond the local water economy and turning to the global picture, we see a second important difference between the water and the carbon economies: the potential for at least some winners to emerge (somewhere else) as a result of local water management failures.

The impact of reduced production in some areas will be an increase in crop prices both locally and, to a lesser extent, more widely. This will induce a new equilibrium as those farmers who still have access to water are incentivised to farm more productively, and some farmers who were previously uncompetitive, despite having access to renewable water supplies, are able to enter the market.

This last outcome is again a fundamental difference between the water and carbon footprint paradigms. Inadequate management of carbon emissions is bad for those emitting excessive levels of CO_2

and bad for everybody else in the world. There are no benefits and no winners – we all lose.

There will be winners from the disallocation of water from irrigated agriculture, and some of those winners are currently relatively poor rain-fed farmers. Consumers of agricultural produce will experience a small increase in prices; farmers 'captured' by the chaotic disallocation will suffer a large fall in income, while farmers involved in managed disallocation will also lose, but in a more predictable way (and still be farming as crop prices rise).

So the water crisis will have losers and winners, and a prime determinant of which category farmers fall into will be governance. Where governments fulfil their obligation to manage a nation's resources sustainably for the common good, the outlook for irrigated agriculture remains positive. Where governments fail in that duty, the prospects are poor, and the negative consequences are potentially very long-term.

Once an aquifer is exploited to destruction, some or all of three things can happen: first, the remaining water is so deep that recharge takes many years to reach it and initiate replenishment; second, the residual water is saline and depends on extensive recharge to re-establish a usable freshwater layer above the saline residue; and third, the previously porous aquifer-supporting soil structure compresses so that the storage potential and permeability are destroyed. This last condition is permanent. River ecosystems are perhaps more complicated, but again the challenges to restoring damage rise exponentially with the extent and duration of over-exploitation of upstream water.

And lastly: who cares?

If the climate does spiral out of control as a result of global warming, driven by excessive CO_2 emissions, few dispute that all of us will suffer severely, directly or indirectly, from the consequences of these events. The impacts will not be evenly distributed across nations or citizens, but the impacts will be dramatically negative for the vast majority of life on this planet. We all should care about this, and most people do.

How will water crises play out? Locally, as argued above, there will be substantial negative impacts for those directly affected, in terms of production and income. Elsewhere, some farmers will be better off, and, more generally, the global market for commodities will adjust.

The precise scale of the changes in commodity prices as a result of disallocation of water from irrigated agriculture is beyond the scope of this article (and this author). However, an IFPRI study (Rosegrant, Cai and Cline, 2002) provides helpful guidance, as interpreted by this author. The study concluded that eliminating over-abstraction from aquifers would reduce global irrigated cereal production by 35 million metric tonnes, which would be partially offset by an increase in rain-fed production of 17 million metric tonnes, stimulated by average price rises of around 7%. This *average* price increase is greatly ameliorated by the impact of world trade (Liu et al., 2014). In the areas where production is directly affected by reduced water availability – often remote and distant from markets – the impact will be much more severe.

At one end of the spectrum, for those urban and rural poor who depend on buying commodities for their staple diets, this will be a severe impact as they spend as much as 35% of their income on food – rice, wheat, vegetables, etc. At the other end of the spectrum, it is estimated that New Zealanders spend 14% of their after-tax income on food (Cronshaw, 2014), and that the commodity component of that food (i.e. excluding processing, packaging, transport, etc.) accounts for only 10% of the total cost of food. So a 7% rise in commodity prices would imply a 0.1% rise in food prices, corresponding to a 0.14% rise in the cost of living. The relevance of the 'who cares?' question becomes obvious.

To sum up, CO_2 emissions constitute a local contribution to a global concern, such that we 'all' care. Thus, there is obvious and effective scope to invoke peer pressure at a global scale. However, mismanagement of water is a local issue based on local failure of government to exercise its appropriate function for the specific benefit of those in that same domain of mismanagement. Beyond that domain, in areas where water is not scarce, or where it is properly managed, producers of agricultural commodities will benefit from failures elsewhere as demand for their production increases.

At the global scale, most consumers of agricultural produce will barely notice the change in prices induced by the progressive collapse of some water systems. Those most affected by chaotic disallocation of water from their agricultural incomes are also those least able to afford the associated increases in food costs. The priority is thus to promote good governance of water resources in advance of scarcity.

The upside of this gloomy picture is, of course, that local interventions can lead to better local outcomes independently of the wider picture of water mismanagement.

That more optimistic scenario is another contrast with the CO_2 story.

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