2.8 SUSTAINABILITY CHALLENGES IN WATER MANAGEMENT

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Key concepts for sustainability education

- Water is a unique and finite resource that all users (humans, agriculture, and the environment) need to survive. However, supply is both diminishing and highly uncertain in the future due to climate change, driving intense competition between users. This situation demands we urgently teach and adopt sustainable water management for the benefit of all.
- Successful sustainable water management depends on careful measurement, good quality information, high levels of caution, and flexible arrangements that are challenging to design and implement. However, most of us are also unwilling to give our water up.
- Innovative sharing and reallocation of water resources offer a modern basis for teaching sustainable outcomes condensed to supply and demand concepts. Yet these concepts also face problems, which we discuss here for structuring effective teaching.
- Sustainable water management is a shared problem requiring shared adjustment, which has proven challenging to achieve in the past. However, the current pressures on inequitable supply, increasingly variable supply, and uncertainty are increasing the urgency for reform.

Introduction

The sustainable use of water resources is a particularly wicked problem for the world. Freshwater, the water we need for drinking, economic activity, and meeting freshwater environmental requirements, accounts for less than 2% of total water resources. This makes freshwater (water) scarce, increases the demand for access, and can create conflict between alternative users, especially between those that have access to water and those that do not. In the near future, water stressors around the world will be high to extremely high in many countries (Figure 2.8.1), highlighting a need for users and managers of water resources alike to arrive at sustainable solutions as a priority.

While individual countries will experience different water stresses, ultimately all will have to deal with a common set of problems and solutions. This is because water has unique

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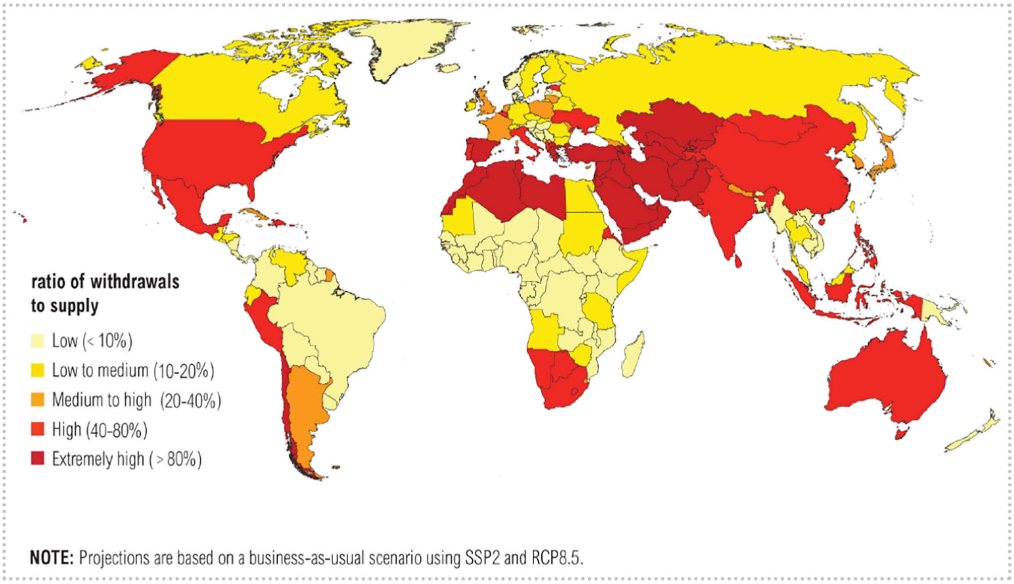

Figure 2.8.1 World water stress by 2040 (Maddocks et al. 2015).

So how do we assess our water resources, identify feasible management systems for water use, choose between competing demands for water resources, and shift our thinking and structures to sustainable use pathways? The aim of this chapter is to introduce the basics with respect to sustainable water management, typical solutions suggested for improvements, and some ideas about the problems that arise when we look at *water.*

properties such as being highly mobile, highly variable in availability (i.e. droughts and floods), in very high demand, and legally/politically complex within and between nations that affect all users equally. As a result, the global development of water supply infrastructure and demand patterns have followed broadly similar stages throughout the world such that today many contexts struggle to achieve sustainable use challenges.

Water's unique characteristics

Water is not a standard good. It is essential to life, commerce, ecosystems, and social or cultural activities. Therefore, water is highly sought by all users but is inequitably shared, with irrigation accounting for around 70% of water use globally. Water is also very heavy and bulky to capture, store, and deliver, making it an expensive good to manage. That said, water is also quite mobile such that the use of water by one user (e.g. in a lake for recreational purposes) does not necessarily exclude other uses (e.g. hydropower generation). This creates complexities and nuances when managing water. Further, water supply is highly variable and when systems periodically experience drought or flood events there can be catastrophic consequences. This highlights a need to build infrastructure to curb such catastrophic consequences (e.g. dams and weirs), but these choices subsequently create new problems such as disrupted river habitat and fish movement, reduced downstream flows, inundation of land, and changed river morphology which lowers sustainability. Finally, the importance of water to large-scale food production, trade, employment, and regional economies drives legal and political issues that complicate the management of water further, especially when irrigated land displaces wetlands. These complexities often serve to confuse users, analysts, and observers alike.

Water's unique characteristics in turn drive many countries to develop laws, infrastructure, management systems, and reallocation mechanisms – that is, a means to move water between users – in broadly similar ways. Early periods of low water use and need are often followed by a sharp growth in demand which often exceeds the actual supply. This creates shortages and tension among users that may be addressed technologically or via reallocation mechanisms. But ultimately, the limits to water supply are reached and a reduction in total use must be achieved to create a sustainable future where users can adapt to absolute scarcity (Figure 2.8.2). The question is, how do we get there?

As shown at the bottom of Figure 2.8.2, groups of solutions are also typically experienced in the water context. Building more storages, extending supply delivery networks, and pumping water farther afield can provide access to more users (i.e. Stage 1 – Supply-side solutions). Then, as the limits to further new infrastructure arise, investments in less leaky delivery pipes, water-saving technology (e.g. low-flush toilets), and other engineering improvements may stretch the resource further (Stage 2 – Demand-side using technical

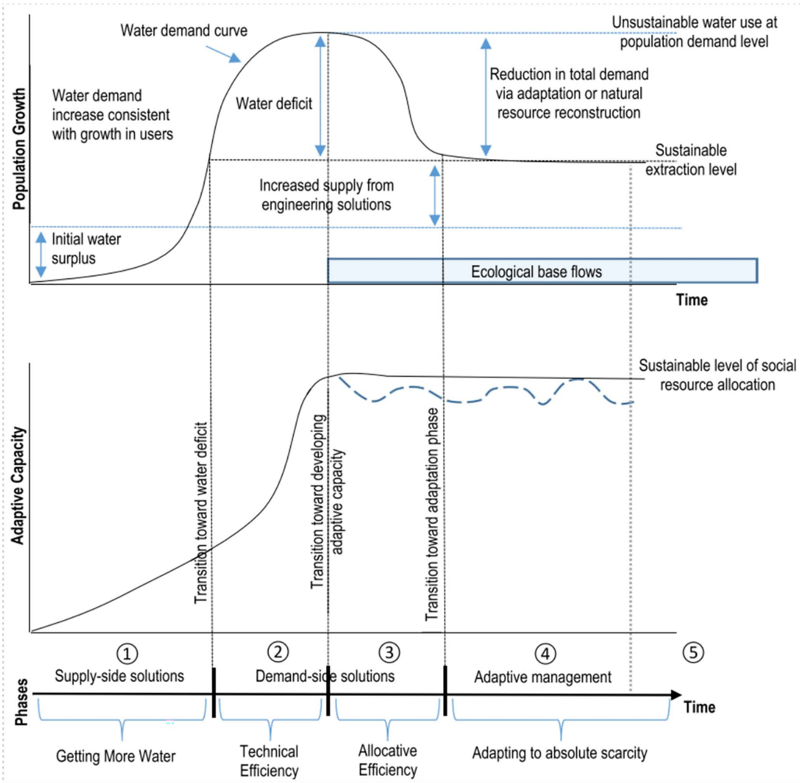

Figure 2.8.2 Links between increasing water scarcity and achieving sustainable use over time (Loch et al. 2020).

Assessing the total resource

efficiency). Efficient uses of water may motivate increased consumption of other inputs (e.g. fertilizers), making their sustainable status increasingly tenuous.

However, as we reach the limits to use and technology, we may have to introduce increased pricing, charges, or other cost incentives to change the demand for water and ensure users value the resource (Stage 3 – Demand-side using allocative efficiency). Finally, if we have exceeded the sustainable level of use – possibly because we did not factor in a need for environmental base flows as a minimum system health driver – we may have to reduce total use (potentially quite dramatically) so that we are aligned again with system limits (Stage 4 – Adapting to absolute scarcity). After that, we will need management arrangements capable of maintaining that sustainable use in light of the unique characteristics of water already discussed (e.g. high variability of supply and demand). Typically, this resembles some form of adaptive management (Stage 5 – Sustainable use).

Ideally, we would recognize this common water resource development pathway ahead of exceeding sustainable limits to avoid Stage 3/4 outcomes. However, many contexts have already reached such outcomes or are close to them. In that light, what must we think about to achieve sustainable water management?

Water resources need to be managed conjunctively; that is, we need to understand all of the water resources that are available. We need to understand the alternative surface water and groundwater reserves available and the limitations associated with their use to prevent the overallocation of resources to consumptive uses. Therefore, a first step is to measure the total system and its limits – ideally with a healthy margin of error as a precaution to address uncertainty to deal with the inherent variability/uncertainty in future supply. This process serves to identify i) a realistic range of total supply under variability; ii) where water is available, how quickly water infiltrates into aquifers, and how it may be captured, stored, and moved elsewhere; iii) the point at which the resource will be exhausted; and, critically, iv) a capacity to monitor progress toward that point over time. Given a high degree of uncertainty that may be associated with system limits dependent on available data, and the likelihood of legal or political complexities as mentioned earlier, a high level of caution is also advised to ensure future flexibility as system limits grow closer. For example, in the case of groundwater, if we fail to understand the rate of infiltration into the aquifer and over-extract water resources, the aquifer can be degraded so that future infiltration is not possible. In that case, we turn a renewable resource into a non-renewable resource (Loáiciga 2003).

Once system limits are near to being achieved or at the point where resources have been completely allocated, it will be necessary to 'close' the water resource context (e.g. basin or catchment) to further uses (Gomez et al. 2018). This is akin to reaching the Stage 2 'plateau'; although in an ideal world this would be situated at the *sustainable use* level and not at one above system limits, creating a situation where water is over-allocated across all users and thus avoiding Stage 4 reductions at a future point as well as the costs that go with over-allocation reduction requirements.

Factoring in environmental base flows

As shown in Figure 2.8.2, the identification and inclusion of environmental base flows – the minimum volume of water in river systems needed to maintain ecological processes and refugia for critical species – typically occurs late in the development process. Clearly, this is far from ideal, complicates the sustainability outcome, and may in turn create social/cultural/economic and environmental harms. To counter this, following the total system resource assessment a critical second step should be to identify, quantify, and then prioritize minimum environmental base flow requirements across relevant river sites, if not all sub-systems. This would serve to extend the environmental base flow bar in Figure 2.8.2 back into Stages 1 and 2.

As a foundation volume of water needed to protect and ensure ecological functions, base flows also need the highest priority because they underpin the rest of the system. If those base functions fail, the entire system fails. Thus, base flows are often referred to as planned or regulated water, as they may be enshrined in law and provided in all states of nature. Achieving this level of protection for base flows is a critical requirement for sustainable water management. Some base flows may also be used to augment – or themselves be augmented by – conveyance water volumes, which are used to deliver consumptive resources (e.g. irrigation rights) to users. Given the high levels of losses of around 25% in most circumstances (Young 2005) that can be associated with system delivery, base and conveyance flows may constitute around 5–10% of prioritized total water resources.

Water rights, system characteristics, and information

After environmental base flows are established and set, all other users can be considered. But care is needed here as you must fully define the environmental context/conditions demanded by society both now and into the future. This then allows environmental use to be prioritized based on their respective levels of anticipated total demand and importance. For example, urban or household users – which may include livestock water – could be the next priority group due to their low, but critical, consumptive level (i.e. ~1–2% of total) needs for reliable drinking water. By contrast, irrigated agricultural users (60–70% of total) may be provided access to large-scale supply but have their use swiftly and heavily curtailed during periods of shortage (e.g. drought). Agricultural irrigation uses also tend to experience large losses between extraction from a delivery channel/river; that is, only around 50% of extracted water is used productively to achieve yield or other productive crop objectives (Young 2005). This necessitates agricultural irrigation sector access to large quantities of water, but also highlights the inefficiencies during low-supply periods that lessen the sector's priority ranking.

Therefore, within the group of higher prioritized rights should be another set of environmental rights, known as held or real water (i.e. ~10–15% of total). It is these rights that provide a set of actual water supplies for river basin management, which may be used to 'irrigate the environment' (Adamson 2019) and drive national benefits from ecological health. Again, as a basis for sustainable water management these rights may sit above agricultural uses, such that they can be relied upon to help smooth sustainable outcomes in response to variability and uncertainty (see Stage 4 in Figure 2.8.2).

What if total water use already exceeds maximums?

If, as shown in Figure 2.8.2, the total level of water use exceeds a sustainable level denoted by the system resource assessment mentioned earlier, then a range of supply-side and demand-side solutions may be suggested to reduce total usage. Supply-side solutions (e.g. dams) are quite common if an area is at earlier stages of development (i.e. Stage 1). But feasible options become harder to develop and justify over time as suitable sites diminish, and the financial and opportunity costs of new infrastructure works increase as society progresses through the development stages (i.e. Stages 3–4). As discussed, water infrastructure also has a high impact on its location, impeding fish movement and other species habitat, inundating large areas of land, creating siltation build-up over time, and disturbing natural flows downstream. Water infrastructure also has a limited life; it may be 100–150 years, but is still limited overall. As such, supply-side solutions are increasingly viewed as challenging to justify and argue in the sustainable water management space.

By contrast, demand-side solutions are now more commonly viewed as the answer to wicked water management problems in the literature. Demand-side solutions are aimed at reducing the claim for water by different users to obtain a sustainable level of consumption. In economics we identify two broad solution groups: technical and allocative efficiency. Technical efficiency involves making the most of available resources to extract as much productivity or output from a drop of water as possible. Thus, taking the agricultural loss example earlier, if we can reduce delivery losses to ~20% – and in-field application losses to ~40% – then we may be able to increase our water use elsewhere by 15%, provided those 'savings' are actual. Herein lies the problem though. Often in water management, assessments of efficiency losses are complex and difficult, making it hard to determine what is being 'lost' elsewhere in the system, and at what rate (e.g. seepage to groundwater, which may not be measurable). Further, if we 'save' water in order to try and reduce total consumption but then allow those 'savings' to be consumed elsewhere – a common requirement for investments in technical efficiency programs – then we will not move the system toward a sustainable objective (C. Dionisio Pérez-Blanco et al. 2021) via reductions in total use. Adamson and Loch (2021) contend that, knowing water savings are complex and rarely possible, farmers are often reluctant to invest in technical efficiencies themselves, only committing to such programs with government support (e.g. subsidies). Other reviews of public-supported investments in large-scale technical efficiency programs have found poor assumptions often used as a basis for program justification (Adamson and Loch 2014), huge spending for limited gains (Loch et al. 2014), and outcomes contrary to objectives (Pérez-Blanco et al. 2020). For these reasons, many analysts now dismiss general technical efficiency solutions for sustainable water management.

By contrast, allocative efficiency mechanisms are used to reallocate water resources between users via incentives to change behaviour. These include (i) cooperative agreements between users to alter decisions via payments (e.g. payments for ecoservices as in Maziotis and Lago 2015), (ii) social contracts between parties to establish rules for sharing water and reallocating scarce resources when needed (Nekhvyadovich et al. 2022), (iii) pricing and charges for water use to raise an appreciation of the value of water and its sustained use (Pérez-Blanco et al. 2016), and (iv) at the extreme end of such mechanisms water trading between users which can improve economic resilience and adaptability (Quiggin 2012).

Allocative efficiency mechanisms should increase motives to reduce water use at the margin and reduce water use over time as costs – including the opportunity costs of the next best alternative uses (Young 2005) – that are passed on to users. Selecting between allocative efficiency measures should be based on Stage 4–5 water development requirements; that is, those mechanisms that will facilitate a movement toward, and then the maintenance of, adaptive arrangements to preserve sustainable use. As one example, while expensive, complex to establish, and imperfect with respect to externalities (e.g. environmental damage may not be priced into a market trade – although it can be if structured correctly), water markets may provide an effective adaptation mechanism in more advanced economies.

Allocative efficiency can also be used to create 'common property' (Ciriacy-Wantrup and Bishop 1975). Here overallocation is dealt with by transferring rights from private users to an 'environmental manager' who utilizes those rights for the environment. In the case of water, by resorting to environmental flows negative externalities are reduced either by directly watering the environment and/or from increased water diluting pollution (including salinity issues) and/or preventing issues from developing (e.g. blue-green algae) (Adamson 2015).

Water markets and trade

There are always calls for water to be provided as a basic human right and, given the low total system requirements for human consumption outside of agriculture, this may be possible to achieve. However, the unique characteristics of water discussed earlier (e.g. bulky and costly to store/deliver) will require large-scale investment to provide such public benefits. After those investments are made, the question of who will bear the costs of that decision, and repay them over time, should be considered for sustainable system outcomes or else the system will fall into disrepair. Again, given the limited timeframes of water supply systems (e.g. 100–150 years), how replacement costs will be met in future should also be taken into current charges so that future generations are not disadvantaged.

One way to promote thinking about the benefits and costs of water resources is through accurate valuation – premised on any number of key objectives or strategic aims (e.g. sustainable outcomes). In economics, that which is valued tends to get managed, and where a system is approaching its upper limits of use effective management becomes highly important. Identifying progress toward system limits and designing/implementing management arrangements ahead of that to assist users adapt to inevitable change is an important phase to get right. Most systems will fail to achieve sustainable outcomes if they seek to impose reforms after limits have been breached, users have gotten used to supply/use conditions, and investments have been made to support that water use. This is where legal and political complexities will work against sustainable objectives, and may even make things worse.

For example, in Australia a period of drought between 2017 and 2020 motivated some water users – particularly irrigators – to blame high market prices on water hoarding and market speculation by external investors (e.g. investment funds from Canada), rather than viewing those high prices as a result of supply shortages. Their complaints triggered several costly public inquiries into those hoarding/speculation claims (Treasury 2019). Due to the complexities of modelling water market speculation (Loch et al. 2021), the inquiry generally found little evidence in support of either claim where data and analysis were challenging (ACCC 2021). Further, once system supply returned to more favourable conditions (i.e. 2021–2022), prices decreased dramatically and the suspected hoarders miraculously disappeared – along with irrigator complaints. The political complexities of water thus drove these costly inquiries, and there was ultimately little to no public benefit from that expense.

However, a similar investigation into the hoarding/speculation claims found many water market failures with respect to price signalling, data integrity, and information asymmetry via a range of analysis techniques (Loch et al. 2021). These studies show that water markets are far from a panacea and must be consistently reviewed and updated within a regulated environment – but preferably not self-regulated as recommended by the Australian Competition and Consumer Commission (ACCC 2021). Self-regulation introduces a lack of accountability and allows slippages of standards, which in the case of water will lead to poor water values, trade inefficiencies, and reserved (if any) sustainability drivers.

In the absence of water markets, surplus water can have no value and it can remain within the river system, providing a dilution effect. However, water markets provide the capacity to access previously unutilized water resources and trade it to those who need it. Water trade can then exasperate the negative externalities generated from using water. Beyond market transactions there are numerous ways to value water, and these are widely used (see Young 2005 for an excellent coverage of these techniques). However, an efficient water market is very hard to beat, as it provides the capacity to properly reallocate water resources between users. Again, those outside the market (e.g. environmental, cultural, or recreational users) may find it difficult to compete, and as such the 'true' price signal may be confounded. However, if all water uses can be included in a market, then water's true value can be easily, and quickly, determined at any given point in time or for different supply conditions (e.g. drought).

The main power of the market is in reallocation at the margin. If all opportunity costs of water can be considered and evaluated (which is tricky at best), the real value of water can be determined. Then, based on that value, water should flow to its highest-value alternative uses via market transfers. For example, if we value ecological use most highly in a drought to protect key species sites and functions, then we should see public authorities paying high market prices to secure that water. Alternatively, if we desire more water to be held aside for ecological support in the future, we may enter the market to buy rights off other users (e.g. irrigators) in the national interest. This will lower the total cost of achieving environmental gains in the long run (Horne et al. 2018; Loch et al. 2011, 2016).

Further, water markets are very good at reallocating rights between users in response to changed supply/demand conditions, where we will typically not have the political will or fortitude to reallocate scarce resources via regulatory reforms (e.g. legislation and compensation). As low political will is a common, and increasing, characteristic of governments globally, markets ironically provide at least some realistic means by which social preferences for sustainable water use may be achieved.

Finally, there are some other issues that are important to consider in the search for sustainable water management.

Groundwater substitutes and their risk

Unfortunately, many water analyses fail to consider the conjunctive nature of water resources. This then fails to understand how the alternative reliably of all resources (surface and groundwater reserves) can be utilized, and the risks associated with their utilization. In a great many contexts, groundwater may be the major source of water and, if so, it may already be heavily exploited. For example, despite massive land subsidence and irreversible damage to the aquifer, California is still grappling with groundwater management. Up until very recently there were no restrictions on groundwater use, and this comes with great private gains and significant social costs (Adamson and Loch 2021).

However, where surface water resources still dominate, increases in scarcity and pressure to find viable substitutes may motivate water managers to access and use more groundwater. An argument for this substitution may be made that groundwater is more sustainable as a resource given its relatively cheap access costs, lower evaporation exposure, next to no engineering infrastructure requirements, and larger volumes. Indeed, these were key arguments in Australia's Murray-Darling Basin (MDB) when the government agreed to release 927 gigalitres (GL = 1 billion litres) of groundwater rights to agricultural users as part of the new Basin Plan aimed at improving water resource sustainability (MDBA 2012). Groundwater was viewed as more reliable in its supply than variable surface water, prone to drought and intermittent availability. In turn, this perception of increased reliability may help transform agricultural irrigation producers – particularly in the northern MDB where dams and storages are limited – toward perennial plantings (Adamson et al. 2021).

It is anticipated that increased access to a perceived highly reliable groundwater resource will rapidly increase the value of those rights. However, there are associated risks attached to this groundwater use. Consistent with the key principle earlier, we should be able to know the resource limits and when those limits are being approached. In groundwater this is highly challenging given its nature; that is, underground and out of sight. Further, as climate change impacts grow, so too will the demand for groundwater testing political and legal barriers to maintaining already shaky resource limits. But when groundwater use is linked to higher-valued perennials, which require water in *all* states of nature (Adamson et al. 2017) as discussed later, the tendency to grow that resource use rather than sustain it in the face of high uncertainty (e.g. developing greenfield irrigation sites to take advantage of growing export markets) will diminish any potential that groundwater resources have for sustaining current water uses and their benefits. Therefore, a high level of precaution should be applied to groundwater and its access right provision/allocation.

The importance of minimum water requirements

With regard to perennial crops, the critical relevance of the distribution of these production systems within a water resource management area cannot be understated when sustainability is an issue. In short, perennials dramatically increase the risks associated with water as an input to production and can undermine sustainable objectives where the basics are not well appreciated. Water must be viewed as having two important functions: maintaining a capital base (e.g. tree stock) and generating agricultural outputs (e.g. fruit yield). In general, any sustained or uncertain variability of water supply can be particularly damaging to the capital protection values of water, where future uncertainty can be challenging to quantify and capture in models (see later).

For example, if perennial production systems comprise the majority of the water demanded, there may not be sufficient flexibility in that system to cope with future shortages. That is, perennial crops require a minimum amount of water (g) in all states of nature (i.e. droughts, floods, and normal years) just to keep trees/vines alive, after which more water (h) is needed to deliver crop yields that can be sold to cover costs (Loch et al. 2020). If water managers are oblivious to minimum (g) water requirements, then tipping points (i.e. system failure across all users) become highly probable, and these tipping points can be rapidly reached during supply shortages. This makes the sustainability of a system vulnerable to shocks, as well as the need for costly public interventions/supports in response. Further, because perennial crops often attract higher returns motivating transformations within a production area, economic and other justifications (e.g. perceived illegitimacy of other users such as environmental flows) may drive increased water theft to maintain perennial crop capital and the likelihood of profits (Loch et al. 2020). Once again, increased theft will do little to support sustainable water objectives and exacerbate tipping points in the system.

The problems of risk and uncertainty

As we have shown, it is necessary to look to the future to describe, assess, and ultimately determine how systems will be able to achieve sustainable use outcomes. Naturally, whenever we look forward, we encounter considerable *risk* (i.e. future events which we are aware of and might be able to assign a probability of occurrence to) and *uncertainty* (i.e. events of which we have absolutely no knowledge, and thus cannot be assigned a probability) (Knight 1921). Typically, we may select a course of action (e.g. build a dam) and then test the robustness of that choice to a range of plausible futures. But those futures are likely to alter our choice sets and final decisions as we continually learn about our choices and reflect on the outcome of those alternatives. It will therefore be useful to apply models that can take such learning and adaptation into account – for example, state contingent analysis techniques (Chambers and Quiggin 2000) – which can explore rare events and how decision-makers may reallocate resources (e.g. water inputs) as a consequence (see for instance drought adaptation responses in Adamson et al. 2017).

Such analysis coupled with sensitivity testing may be used to determine when existing knowledge, technology, or management responses may fail (i.e. tipping points are reached), providing lessons for on-going management adaptation at both private and public levels. Future research paths and questions will be informed by increased awareness of the full set of contingencies that may or may not be applicable under future climate change. However, in practice, the success of those choices will still be constrained by decision-maker bounds to awareness and any deeply uncertain events that may arise.

Australia as an example for the world

Many of the examples drawn upon here are from an Australian perspective. This is deliberate as Australia is one of the driest continents on Earth and has been forced to act earlier than some other countries to reform water management – sometimes not as well as might be hoped. That said, Australia is also expected to face severe water shortages in the future under climate change. Recent Intergovernmental Panel on Climate Change (IPCC 2018) estimates suggest that, by 2050, Australia will experience drought conditions in 75% of years – frankly, a terrifying prospect. In the MDB, for example, Australia's premiere agricultural production region, this will have dire consequences for water availability (Figure 2.8.3).

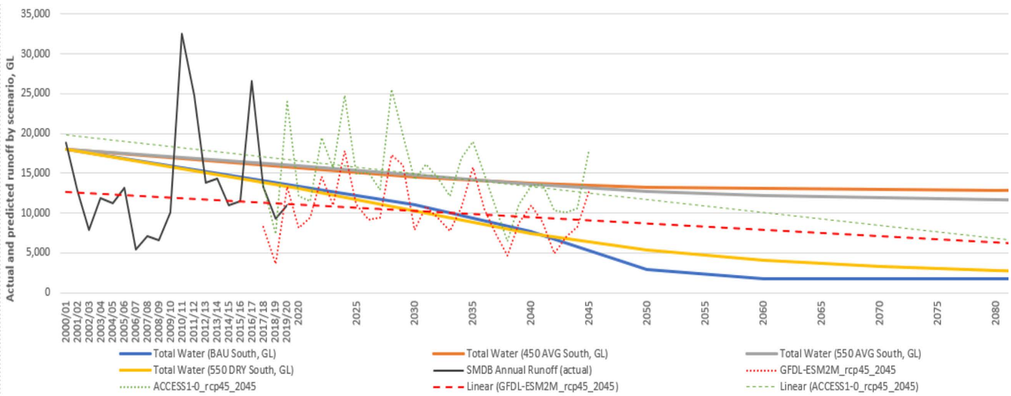

Figure 2.8.3 Garnaut climate change scenarios, actual runoff (2000–2020) and study climate model runoff predictions (2021–2080) for southern MDB based on last 20 years of climate history and CSIRO/BoM RCP45 scenarios.

Source: Author's own interpolation

In essence, Figure 2.8.3 depicts an update to the 2008 Garnaut Climate Change Review which assessed a number of possible pathways for water availability in the MDB with and without effective emission reductions (e.g. business as usual [BAU] in the southern MDB, or BAU South). Looking at actual runoff in the southern MDB (solid black line) and the trends for two Commonwealth Scientific and Industrial Research Organisation (CSIRO) climate model projections out to 2080 (red and green dashed lines), we can see a very clear expected decline in water availability by 2050 to around 10,000 GL (gigalitres, or a billion litres) on average. Note runoff is not inflows to storages, which will be a lower proportion, and total current water rights in the MDB exceed 19,000 GL – or roughly twice expected runoff. This clearly shows a need to arrive at sustainable solutions to water problems relatively soon in Australia, with lessons for other possibly more water-abundant (for now) contexts to then learn from.

The insurer of last resort problems

Finally, in view of future climate changes, it is necessary to consider who will be impacted by any failure to create sustainable water systems and who then should or will pay to address those failures and their impacts on users. In recent years we have seen a great many impacts on communities, farmers, businesses, and individuals as a result of extreme events (e.g. fire, drought, and flooding). These have significant economic, social, and cultural costs for society (Quiggin 2018) and typically require considerable private and public investments to achieve recovery (Moss 2002). These interventions logically also have a tipping point; that is, where the burden on public funds becomes so great and common that there is simply no capacity to continue. As climate change impacts increase (IPCC 2022) and – where we have failed to invest in flexible systems beforehand – the cost to change systems based on historical events is expected to increase due to urgency, multiple stakeholders competing for limited funds, and a need to address many concerns at once. This also is unsustainable. As such, we must investigate, design, assess, and select flexible production systems and water uses that are able to adapt to future uncertain conditions and provide the best basis for future sustainability (Adamson and Loch 2021).

Conclusion

In this chapter we have sought to provide a very basic set of issues to consider with respect to identifying and teaching the core concepts for sustainable management of water resources. The reality for water management is in many ways far more complex, but the issues raised herein give at least some understanding of, and structure to, what must be thought about when aiming to teach sustainable water use. Crops can only last around two to three weeks without irrigation, a human can survive about three days without drinking water, and most industries would cease almost immediately if their access to water was removed. These are the stakes involved in sustainable water management, why it is so important for us all, and what must be included in teaching about the concepts. The recent COVID-19 pandemic has shown us how fragile our food and consumable supply system is, but in a situation in which the underlying access to resources did not disappear. If we take water away from any single area the consequences will be immediate, challenging to address, and potentially costly in human lives. There will be little time or patience to try and get it right then.

As such, when teaching this subject we need to be aware of the risks we face and the complex nature of water sustainability issues to ensure the problem is taken seriously and addressed by those who can make a difference – we as teachers, students who will manage these issues in the future, policy makers/resource managers as instigators of change, and all of us as water users.

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