Chapter 1

Sustainable irrigation: Setting the scene

Henning Bjornlund
University of South Australia and University of Lethbridge, Alberta, Canada

1 Introduction

Including the words “Sustainable Irrigation” in the title of a book necessarily raises the question *what is sustainable irrigation?* The terms sustainability and sustainable development have entered our language over the past 30 years and have gained increased use, often leaving the impression that they have become fashionable “buzzwords” used by politicians and companies because it is the “right” thing to say to increase votes or sales. The terms have also found their way into modern legislation, usually in the context of preambles or objectives, rather than in operational clauses. They are therefore less likely to have an impact on outcomes and can give rise to confusion and litigation.

This book will not weigh into the debate over definitions of sustainability or sustainable development or the difference between the two. That literature is already waste with an overwhelming array of often contradictory definitions (Van pelt *et al*., 1992; Flint, 2004). The purpose of this book is to discuss incentives and instruments which can be used to promote sustainable irrigation or assist irrigation to stay within sustainable limits as discussed in this chapter.

Sustainable development is a kind of overarching or parent concept which among its offspring has sustainable agriculture and sustainable water management; sustainable irrigation is a lower order concept relative to these two. Sustainable irrigation cannot exist without sustainable agriculture and sustainable water management. Most discussions of sustainable development and lower-order concepts make reference to the Brundtland Report *Our Common Future* (WCED, 1987), which refers to sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The ability to achieve this is closely linked to the state of the resource base (Csurgo *et al*., 2008); in the case of sustainable water management, a core issue is healthy ecosystems. Without healthy ecosystems, water resources cannot continue to meet a constant or growing level of needs into the future. The “needs” of current and future generations can also not be dealt with in isolation; but they have to be seen in the context of a certain watershed

WIT Transactions on State of the Art in Science and Engineering, Vol 37, © 2010 WIT Press
www.witpress.com, ISSN 1755-8336 (on-line)
doi:10.2495/978-1-84564-406-2/01

and the social, economic and environmental aspirations of its stakeholders and within a framework of higher order priorities as expressed in state or national water plans. Viewed at the national level, it might be desirable to define healthy ecosystems and environments differently for different water sources as some have already been worked so hard that parts of ecosystems have been permanently destroyed. For example, in Australia a distinction is made between working rivers and wild rivers with very different interpretation of what a healthy river looks like, and hence what constitutes a healthy ecosystem.

From this discussion, it is apparent that sustainable water management must

1. be the joint responsibility of governments, communities and water users such as farmers (Blomquist *et al.*, 2005);
2. be seen in the context of a specific location, at a specific period in time, while acknowledging that it is subject to dynamic environmental and socio-economic forces requiring flexibility and adaptive management (Brierley *et al.*, 2006);
3. be seen in the context of a specific set of stakeholder interests (Brierley *et al.*, 2006) and
4. reflect the local environmental, social, economic and cultural values (Elliott, 2004). It has been argued that society must determine to what extent ecosystem needs will be met in a particular watershed (Gleick, 1998a.; Postel & Richter, 2003).

Hence, sustainable water management involves a compromise that balances environmental, social and economic needs and is acceptable to the parties involved; the watershed is therefore the most appropriate level for water planning within the context of subsidiarity (Walmsley, 2002; Henriksen & Barlebo, 2008; Jordan & Jeppeson, 2000). Devolving the decision-making processes of water management to the watershed level and involving local stakeholder groups have therefore been central parts of both national and international water policies since Agenda 21, the program for action for sustainable development (UNCED, 1992).

Sustainable agriculture includes the use of agricultural practices, including irrigation techniques and on-farm water management practices, which enable current land and water resources to meet the needs of current and future generations. To do this, such techniques and practices cannot degrade the on-farm resource base or the resource system supporting it. The United States Congress defines sustainable agriculture as "… an integrated system of plant and animal production practices having a site-specific application that will, over the long-term: (1) satisfy human food and fiber needs; (2) enhance environmental quality and the natural resource base upon which the agriculture economy depends; (3) make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; (4) sustain the economic viability of farm operations; and (5) enhance the quality of life for farmers and society as a whole (USDA, 2008)".

2 Sustainable irrigation in the context of this book

In the context of sustainable irrigation, it has to be understood that irrigation in any specific location depends on a water resource system which yields an annual flow of water of a certain quality. Sustainable irrigation requires that extraction for consumptive use is kept at a level where sufficient water is left in the resource to ensure an aquatic ecosystem which can maintain a level of water quality sufficient for crop growth. This level of extraction might be significantly lower than what other stakeholders require to satisfy their needs. Therefore, stakeholders must first define sustainable water use within their watershed, that is,

1. define the acceptable level of water quality, thereby defining which environment or ecosystem they want to sustain and therefore how much water will need to be left in the river to meet in-stream flow needs in the form of base flow as well as to create environmental events such as flooding of wetlands (Postel & Richter, 2003);
2. define other required cultural, social and public good outcomes such as setting water aside for minority groups or previously disadvantaged groups as in South Africa (Backenberger, 2005);
3. establish how much water the system yields;
4. define the pool of water which can be sustainably used for extractive purposes by subtracting one and two from three above. In Australia, this is called the consumptive pool;
5. allocate the consumptive pool among competing users; and
6. acknowledge that sustainable water and land management cannot be separated and both have to be dealt with as part of an integrated watershed management approach (Blomquist *et al*., 2005). Hence, the foundation for sustainable agriculture is also defined as part of the planning process.

These are issues which are most appropriately dealt with by governance structures (de Loe and Bjornlund, Chapter 3). Issues such as conflict resolution, consensus building, water allocation and defining community, cultural and environmental needs have to be dealt with in adaptive watershed planning processes. These, in turn, have to be seen in the context of basin, state and/or federal policies/plans defining sustainable water management at the national level. These processes might include tradeoffs between wild rivers and working rivers to achieve national- or state-level environmental objectives.

Once the consumptive pool has been defined, the issue of sustainable irrigation can be considered. Sustainable irrigation has at least two main aspects: (1) irrigation must be supported by sustainable irrigation development which is capable of delivering a constant and reliable supply of sufficient-quality water for irrigation to support a constant or increasing level of food production while keeping its impact on the environment within sustainable levels as defined in the watershed plans (Easter and McCann, Chapter 3) and (2) individual irrigators must adopt land and water management practices which do not degrade the land resource and keep their impact on the river and groundwater environment within acceptable levels while allowing a constant or increasing level of food production. This includes a process of adopting more efficient and productive irrigation technology and water management practices as they are developed (Nicol *et al.*, Chapter 12).

In many water-stressed areas of the world, the consumptive pool is likely to be smaller than the pool of water which has previously been used by consumptive users. This is particularly likely to be the case with respect to irrigators' share. Under scarcity, the planning process is likely to give higher priority to human needs for drinking water and sanitation and to the needs of ecosystems than the needs of irrigation (Gleick, 1998b; Postel & Richter, 2003). The challenge then becomes "how can irrigation maintain its production output with access to less water while preventing negative environmental impacts".

If we look at "irrigation" in a broader sense, by also including what we could term the irrigation communities whose existence is dependent on irrigation for continued viability, the question also becomes "how can these communities continue to be viable under a sustainable water use regime". The successful outcome of this process is determined by the combined actions of individual irrigators. Do they have the financial and human capital to make the necessary adjustments? Do they adopt new technologies, management practices and crop varieties to maximize yield so that economic output can be maintained by the use of less water? These questions are relevant for both individual irrigators and irrigation developments or districts. The latter case also includes financial viability and the ability to collect fees, carry out maintenance, etc. (Easter and McCann, Chapter 3). When it comes to the irrigation communities, the issues are much the same. Do they have sufficient social capital to successfully navigate the adjustment process?

Irrigators and their communities, however, do not do this in isolation. Institutional structures have a significant role in facilitating and encouraging this process. Governments can introduce a number of incentives, instruments and policies that will assist the process of adjusting the irrigation industry towards sustainability by (1) encouraging and supporting some irrigators to become viable for long term while encouraging and supporting others to exit the industry and (2) supporting irrigation authorities' ability to maintain sustainable irrigation systems. Some of the policies introduced for these purposes are water pricing, water markets, water user organizations, subsidies for technology and management adoption, structural adjustment assistance, information and education campaigns, and funding research and development. To increase the effectiveness of these policies, the government can put institutions in place which facilitate their adoption (see Chapters 3, 4 and 5). For example,

- For water markets to operate efficiently, the following are needed: (1) well-defined property rights to water so that buyers and sellers know what they are trading in; (2) flexible and secure trading mechanisms to facilitate fast, reliable and secure transactions with minimum transaction costs; (3) properly regulated market intermediaries to facilitate the process; (4) secure water rights registers to provide irrigators with security of ownership and buyers with security of market outcomes and (5) transfer processes, or other regulatory institutions such as water use right, to ensure that trade in water does not have negative environmental impacts so that potential externalities associated with the transfers are internalized. Within some watersheds, special attention needs to be paid to rural-to-urban transfers to make sure that these take place with minimum impact on irrigation (Byrne *et al.*, Chapter 10).

- For water prices to be efficient in contributing towards sustainable irrigation, they need to be set at a level where the necessary infrastructure can be adequately maintained and renewed, and adequate funds are available to properly monitor, enforce and administer water allocations, water scheduling and delivery, fee collection and water trading. They also need to send proper signals to water users. If prices are kept low using subsidies, inefficient and low-value users will continue to irrigate. Full cost recovery prices are more likely to communicate the message to inefficient and low-value users that they need to either become more productive or sell their water to more efficient and higher value users. Water prices could also be structured so that they internalize the externalities associated with water trading out of individual supply systems and thereby help to maintain financial sustainability, as is the case in Australia (Chapters 4, 5 and 11).
- Subsidies have been widely used in the context of irrigation; most large-scale irrigation projects would not exist had it not been for subsidies. In the context of sustainable irrigation, subsidies have been used to encourage the adoption of more efficient irrigation technology. However, great care has to be taken to design such programs so that the efficiencies gained do not result in a net increase in water use with the effect that less water is returned to the river and the environment. There is a growing body of literature illustrating that this has often been the case (Scheierling *et al.*, 2006; Bjornlund *et al.*, 2009).

3 An outline of the book

This book is written within the context of the above-mentioned discussion. Chapters 3–5 deal with the issues of governance and institutions, and, as such, set the backdrop for Chapters 6–15, which deal with individual elements or aspects in more detail.

Chapter 2 (Bjornlund and Bjornlund) provides a historical perspective on sustainable irrigation by discussing some old irrigation cultures and highlighting how some were sustainable while others were not. In some instances, similar irrigation technologies and approaches were sustainable for thousands of years in one location, while they were unsustainable in another, highlighting the location-specific aspect of sustainable irrigation.

Chapter 3 (Easter and McCann) discusses institutional arrangements for sustainable irrigation developments as one of the essential components of sustainable irrigation. It argues the importance of financial sustainability and the need for strong water user organizations to ensure that water charges are paid, allocations are enforced and maintenance work is carried out to keep the systems up to acceptable standards, which limits the environmental impact of irrigation so that the affected water source stays within ecologically sustainable levels as locally defined.

In Chapter 4, de Loe and Bjornlund discuss the governance structures needed to ensure sustainable water management which needs to underpin sustainable irrigation in a contemporary society. They also discuss the inevitable link between sustainable irrigation, water security and food security.

Young and McColl (Chapter 5) then discuss how a robust framework for water allocations can be designed so that it can cope with the change. In the sustainability literature, the need for flexibility and adaptive capacity of institutions has been widely acknowledged. The ability of water resources to meet the need of future generations is dependent on current and future generations' ability to respond to climate change, improved knowledge about environmental needs and changing community values towards water.

To achieve sustainable water management and sustainable irrigation at the watershed level will require a change in human behaviour (Cullen, 1997; GACGC, 1997). The role of the governance and institutional arrangement discussed in Chapters 3, 4 and 5 is to try and facilitate such a change. However, people's behavioural changes in response to such governance and institutional arrangement and instruments will be influenced by the values, norms and beliefs that they hold (Kuehne *et al.*, 2008; Kuehne & Bjornlund, 2007) as will their perceived legitimacy (Contandriopoulos *et al.*, 2004). Kuehne and Bjornlund (Chapter 6 analyse the values, beliefs, norms and attitudes that influence irrigators' behaviour in response to new policies or instruments and discuss their implications in the context of recent offers to buy water from irrigators within the Murray–Darling Basin to provide environmental benefits.

The next three chapters deal with various aspects of water markets. There have been divided opinions on water markets and their ability to facilitate sustainable irrigation in terms of their environmental and social impacts. It has been argued that water trading has negative social and community impacts by favouring larger and more powerful farmers and moving water out of communities depending on it. Others have argued that markets have provided an important mechanism for weaker farmers to stay in business during periods of financial difficulty. In Chapter 7, Shanahan *et al.* analyse water market prices and activities within the Goulburn–Murray Irrigation District in Victoria, Australia to identify whether water markets help to sustain irrigation during periods of drought. They find that markets have significantly increased both big and small irrigators' ability to deal with drought and financially survive at least the first years of a drought period. Markets have helped irrigators with long-term investments to get enough water to keep their businesses going, keep their dairy herds, maintain their vines and fruit trees and fulfil contractual obligations to deliver produce to processors. In this process, these buyers help many smaller and lower value growers to stay on the farm by purchasing their water for far more than the profit they could have made by using it.

In Australia and the United States, increased emphasis has been placed on using the market to buy water to achieve environmental outcomes. In the context of this book, it is considered that acceptable environmental outcomes are ensured at the watershed level as part of the planning process (Chapter 4). In this context, governments can buy water from irrigators to achieve this objective. Individuals and non-government organizations could also be allowed to use the water market as a mechanism to achieve environmental outcomes in addition to the locally defined acceptable outcome. In Chapter 8, Hadjigeorgalis analyses the outcome of water trusts and environmental water transfers in the United States to evaluate their potential impact on sustainable irrigation.

Water transfers out of irrigation to satisfy increased urban and industrial needs have caused some of the major conflicts over water trading in the United States. However, such transfers are likely to play an increased role in water markets as urban centres expand and water scarcity intensifies. It is therefore important to find mechanisms by which such transfers can be implemented with least possible impact on irrigation and food production. Byrne *et al.* (Chapter 9) discuss the possible mechanisms for inter-sectoral transfers and analyse the potential for water options contracts within the Murrumbidgee Valley, Australia.

Water pricing and water markets are often considered to be the key economic instruments in communicating appropriate market signals to water users to encourage them to use water more productively. Also in Chapter 3, Easter and McCann argue the need for appropriate pricing policies to ensure sustainable irrigation systems. In Chapter 10, Young *et al.* pay particular attention to the issue of water pricing in the light of irrigators' ability to pay for irrigation water.

The price of other inputs into irrigation as well as the opportunity to produce more valuable crops also communicates economic market signals to irrigators to use water more wisely. Recently, the price of energy has increased significantly. As energy is a major input in irrigation, the cost of energy has proven a major factor in driving the adoption of more efficient irrigation technology and management practices (Bjornlund *et al.*, 2009). In Chapter 11, Schoengold *et al.* provide an in-depth analysis of the impact of increased energy cost as well as the increase in biofuel production on sustainable irrigation and food security.

The last three chapters discuss sustainable irrigation within the context of three national settings: Alberta, South Africa and India. In many parts of the world, strategies, plans and policies are introduced to resolve problems associated with scarcity, to ensure increased efficiency and productivity of water use so that new demand for water can be met and economic activity can be maintained or increased while more water is set aside to secure healthy ecosystems and environmental outcomes. Given that agriculture uses more than 70% of water extracted for economic use worldwide, irrigation has to play a pivotal role in achieving such objectives. The province of Alberta in Canada introduced its Water for Life Strategy in 2003. In Chapter 12, Nicol *et al.* analyse the strategy's likely success in achieving its efficiency and productivity goals.

Irrigation in South Africa is associated with a unique set of challenges balancing social, environmental and economic interests within the concept of sustainable water management. Nieuwoudt and Backnberger (Chapter 13) discuss how economic instruments and governance structures are being implemented to provide safe drinking water and water for sanitation and subsistence farming to members of previously disadvantaged groups while protecting economic water use and keeping total extraction within sustainable levels.

More than 30% of all water used for irrigation worldwide is groundwater. This has caused significant aquifer depletion in many places such as the United States, China and India, indicating that sustainable irrigation from that resource is not possible at current levels. This has significant implications for sustainable agriculture and food security. In the last chapter, Msangi addresses this issue.

References

Backenberger, G.R. 2005. Water institutional reforms in South Africa. *Water Policy,* 7: 107–123.

Bjornlund, H., Nicol, L. & Klein, K. 2009. The adoption of improved irrigation technology and management practices—a study of two irrigation districts in Alberta, Canada. *Journal of Agricultural Water Management,* 96: 121–131.

Blomquist, W. & Schlager, E. 2005. Political pitfalls of integrated watershed management. *Society and Natural Resources,* 18(2): 101–117.

Brierley, G., Hillman, M. & Fryirs, K. 2006. Knowing your place: an Australasian perspective on catchment-framed approaches to river repair. *Australian Geographer,* 37(2): 131–145.

Contandriopoulos, D., Denis, J., Langley, A. & Valette, A. 2004. Governance structures and political processes in a public system: lessons from Quebec. *Public Administration,* 82(3): 627–655.

Csurgo, B., Kovach, I. & Kucerova, E. 2008. Knowledge, power and sustainability in contemporary rural Europe. *Sociologia Ruralis*, 48(3): 292–312.

Cullen, P. 1997. Issues in the transfer of R&D outcomes to wetland management. In: Williams, W. (Ed.), *Wetlands in a Dry land: Understanding for Management*. Environment Australia, Land and Water Resources Research and Development Corporation, Canberra, Australia.

Elliott, L. 2004. *Global Politics of the Environment (2nd edition)*. Palgrave Macmillan, Hampshire.

Flint, R.W. 2004. The sustainable development of water resources. *Water Resources Update,* 127: 41–51.

German Advisory Council on Global Change (GACGC). 1997. *World in Transition: Ways Toward Sustainable Management of Freshwater Resources. Annual Report 1997.* Springer-Verlag, Berlin.

Gleick, P. 1998a. Water in crisis: path to sustainable water use. *Ecological Applications,* 8(3): 571–579.

Gleick, P. 1998b. The human right to water. *Water Policy,* 1: 487–503.

Henriksen, H. & Barlebo, H. 2008. Reflections on the use of Bayesian belief networks for adaptive management. *Journal of Environmental Management,* 88(4): 1025–1036.

Jordan, A. & Jeppeson, T. 2000. EU environmental policy: adapting to the principal of subsidiarity? *European Environment,* 10: 64–74.

Kuehne, G. & Bjornlund, H. 2007. One size does not fit all—recognizing heterogeneity in Australian farmers. *Proceeding from the Conference of the US Commission on Irrigation and Drainage.* Sacramento, California, September.

Kuehne, G., Bjornlund, H. & Cheers, B. 2008. Identifying common traits among Australia irrigators using cluster analysis. *Water Science and Technology,* 58(3): 587–595.

Postel, S. & Richter, B. 2003. *River for Life: Managing Water for People and Nature*. Island Press, Washington DC.

Scheierling, S., Young, R. & Cardon, G. 2006. Public subsidies for water-conserving irrigation investments: hydrologic, agronomic, and economic assessment. *Water Resources Research,* 42: W03428.

The United Nations Conference on Environment and Development (UNCED). 1992. *Agenda 21: Program for Action for Sustainable Development.* UNCED, New York.

United States Department of Agriculture (USDA). 2008. *Sustainable Agriculture*. http://www.usda.gov/oce/sustainable/agriculture.html accessed on 20 August 2008.

Van pelt, M.J.F, Kuyvenhoven, A. & Nijkamp, R. 1992. *Defining and Measuring Sustainability*. Serie Research memoranda. Vrije Universiteit, Amsterdam.

Walmsley, J. 2002. Framework for measuring sustainable development in catchment systems. *Environmental Management,* 29(2): 195–206.

World Commission on Environment and Development (WCED). 1987. *Our Common Future*. Oxford University Press, Oxford, UK.

Manual subsurface drip irrigation avoids the high capillary potential of traditional surface applied irrigation, which can draw salt deposits up from deposits below. Introduction. Factsheet Block Body. Manual irrigation systems are easy to handle, require no technical equipment and are therefore generally cheap (in contrast to high-tech systems such as sprinkler irrigation or subsurface drip irrigation). But they need high labour inputs.Â Cagayan de Oro: Sustainable Sanitation Center Xavier University (XU), the Philippine Sustainable Sanitation Knowledge Node, the Philippine Ecosan Network, and the Sustainable Sanitation Alliance (SuSanA) URL [Accessed: 07.05.2019]. Technical Manual for Ideal Micro Irrigation Systems. Technical Manual for Ideal Micro Irrigation Systems. Sustainable methods of irrigation evaluation and collection of fees must be considered in light of Nyanyadzi's economic and technical environment. The research noted that water use efficiency is required in order to maximize the benefits farmers derive from the irrigation projects and extraordinarily high user fees should be avoided in the project development stages, where the payment capability is much less at the beginning than at the maturity stages of irrigation projects.Â The research will assist stakeholders to see the advantages which can be derived from setting up clear cost recuperation and water pricing methods. Here we investigate the sustainability of irrigation, balancing farmers' profit generation objectives and the needs of ecological systems. We ask the question â€œsustainability of what?â€ to stress how the sustainability of irrigation is often evaluated with respect the opposing needs of humans and nature.Â In the last few decades, the growing demand for agricultural commodities has translated into an increasing pressure on the global freshwater resources, often leading to their unsustainable use. Here we investigate the sustainability of irrigation, balancing farmers' profit generation objectives and the needs of ecological systems. We ask the question â€œsustainability of what?â€ to stress how the sustainability of irrigation is often evaluated with respect the opposing needs of humans and nature. Setting the scene. Chapter 1 Sustainability in South Africa. Chapter 2 What affects our environment?Â the concept of sustainable development has generated debate and has become a convenient hook onto which to hang divergent value systems. Simply put, it advocates behaviour that makes current development efforts to raise the quality of peoplesâ€™ lives sustainable into the future. It has to do with adopting a long-term development path that improves life for current generations and that at the same time leaves future generations with the same capacity and options for development that we have at present. Sustainable development recognizes the interdependencies and links between the natural environ Setting the scene. An overview of demographic and environmental issues in sustainable agriculture in sub-Saharan Africa. M.A. Mohamed-Saleem and H.A. Fitzhugh.Â Fresh water is a very vital but limited resource. In SSA rain water is available for only part of the year and irrigation water is scarce. Soil may be considered as a bank in which water and essential crop nutrients are stored. Rain water can be harvested and held in tanks or earthworks while runoff can be restrained by maintaining ground cover, ridging and terracing hillsides. However, the way water is replenished, maintained, protected and controlled depends on soil conditions and demographic demands.