# Wetlands in Drylands

## Extending Rangelands and Ecosystem Services Thinking to Water Ecosystems in Dry Landscapes of the Murray-Darling Basin

Final Report

**Sarah Ryan and the Australian Rangeland Society**

**for the Murray-Darling Basin Authority**

**June 2009**

# Workshop participants

We thank all who attended the workshop, contributed freely to the discussion and made follow up contributions to the report.

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# Indigenous input

We acknowledge that there has been no Indigenous input to this discussion and that any further development of the ideas in this report should be enriched with Indigenous perspectives if possible.

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# Introduction

This report is the result of a joint project between the Australian Rangeland society and the Murray-Darling Basin Authority (MDBA). The Rangeland society is planning a Special Issue of their journal in 2010, which will focus on the Murray-Darling Basin. Their biennial conference will also be held in the region, in Bourke, in 2010. MDBA's interest stems from the new role of the Authority under the recent revisions to Federal-State agreements about the Basin and the need to review and reshape its activities in the natural resource management area.

In particular MDBA is keen to explore the implications of its new responsibilities in the drier parts of the Basin where it has previously had relatively small roles. The Authority recognises that differences in the climate, river systems and development history between the south and north of the Basin have combined to produce different linked socio-ecological systems in each case. The Rangeland society, with its long experience at developing an understanding of drylands as linked socio-ecological systems may have insights that could be usefully drawn on in developing plans for managing wetlands in a dryland setting, a setting that includes the people, their economic activities, their communities and their existing natural resource management governance and practices.

The agreed objectives of the project were to:

1) generate a synthesis of knowledge from recent research into the dynamic nature of arid/semi-arid river basins;
2) inform NRM strategies in arid/semi-arid river basins; and
3) increase understanding of natural resource management including:
    a. foster understanding how arid/semi-arid river basins function under present and future climatological scenarios
    b. develop an understanding of how arid/semi-arid river basins interact and connect between regions.
    c. develop understanding of the pressures on social systems in arid/semi-arid river basins and outline strategies to mitigate these pressures

The report draws on the contributions of members of the Rangeland society and others who attended a workshop on 3 June 2009 in Canberra and who subsequently contributed to and commented on the draft report.

# The Policy Context

The context of the project arises from the new Water Act 2007 (Commonwealth of Australia 2007) that now governs management of the water resources of the Basin and consequently shapes the work programs of the new MDBA. The legislation focuses on water resources and the sharing of that water for human, agricultural and environmental purposes (Box 1).

Compared to the scope of the previous Murray-Darling Basin Agreement, the new Agreement and the Water Act 2007 set the uses and values of water in a much broader context. The objectives of the Act (Box 1) make reference to this enlarged scope, recognising however that the States still retain their constitutional rights to govern “other” natural resources in the jurisdictions.

This project focuses on four aspects of the new Act where achievement of the purpose will be especially challenging. These derive from the references to:

1. optimising **economic, social and environmental** outcomes
2. within the context of (1), protecting, restoring and providing for the ecological values and **ecosystem services** of the Murray-Darling Basin
3. interactions between water management and the broader **management of natural resources**, and
4. efficient and cost effective **water management**.

It is notable that the objectives are couched much more in a sustainability (triple bottom line) framework than in any previous agreement. Australians have agreed conceptually that they want more sustainable outcomes from the use of water in the Basin, but the methodology for achieving the “balance” between economic, social and environmental outcomes is not well established (“balance” is the terminology in the National Water Initiative, the over-riding Council of Australian Governments agreement about water). Much of the rest of the Act deals with water in isolation from other considerations.

**Box 1. Objectives of the Water Act 2007.**

## 3 Objects

The objects of this Act are:

(a) to enable the Commonwealth, in conjunction with the Basin States, to manage the Basin water resources in the national interest; and

(b) to give effect to relevant international agreements (to the extent to which those agreements are relevant to the use and management of the Basin water resources) and, in particular, to provide for special measures, in accordance with those agreements, to address the threats to the Basin water resources; and

(c) in giving effect to those agreements, to promote the use and management of the Basin water resources in a way that optimises economic, social and environmental outcomes; and

(d) without limiting paragraph (b) or (c):

- (i) to ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused; and
- (ii) to protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin (taking into account, in particular, the impact that the taking of water has on the watercourses, lakes, wetlands, ground water and water-dependent ecosystems that are part of the Basin water resources and on associated biodiversity); and
- (iii) subject to subparagraphs (i) and (ii)—to maximise the net economic returns to the Australian community from the use and management of the Basin water resources; and

(e) to improve water security for all uses of Basin water resources; and

(f) to ensure that the management of the Basin water resources takes into account the broader management of natural resources in the Murray-Darling Basin; and

(g) to achieve efficient and cost effective water management and administrative practices in relation to Basin water resources; and

(h) to provide for the collection, collation, analysis and dissemination of information about:

- (i) Australia's water resources; and
- (ii) the use and management of water in Australia.

← economic, social and environmental outcomes

← ecosystem services

water in NRM context ←

← governance

# Paradigms, Knowledge and History

Ways of thinking and knowing shape what is possible. Raising them to a conscious level is helpful for constructing a context and a wider set of options for the future.

Indigenous beliefs and understandings about Australian landscapes are distinctively different from those of non-Indigenous Australians. The physical and spiritual health of their people is seen to be inseparable from the health of land and water. Box 2, although from the Ngarrindjeri people who live around the lower Murray, illustrates a contemporary Indigenous view of the importance of water in the Basin. Water is not just biophysical, it is also about the flow of culture. Cultural Flows have been a major concern of the Murray and Lower Darling Rivers Indigenous Nations (MLDRIN) (Weir 2009) and of the Lake Eyre Basin traditional owners who met in Birdsville in May 2009 (Luke Keogh, unpublished report).

**Box 2. Ngarrindjeri statement about water. (From MDBC 2006)**

*Ngarrindjeri lands and waters is a living body. It must be healthy for Ngarrindjeri people to be healthy. This is a human right. Ngarrindjeri people need to manage the health of Ngarrindjeri Ruwe (lands and waters) according to Ngarrindjeri laws and traditions. For example, cultural flows are essential for the continued breeding and health of Ngarrindjeri Ngartjis (totems). Ngarrindjeri people believe that the Ngarrindjeri Nations's health depends on the health of our Ngartjis. This cultural flow is also essential for our Ngarrindjeri cultural heritage sites. Some areas are of high Ngarrindjeri cultural significance but have not been be identified as being environmentally significant. Ngarrindjeri leaders need access to cultural flows to maintain the health of those places. Ngarrindjeri people wish to be actively supported in determining the priorities and allocations for cultural water flows and in continuing Ngarrindjeri research into Ngarrindjeri Ruwe.*

People's experiences in places shapes their understanding ('local knowledge") and scientific and other academic studies draw on and contribute to global developments in knowledge. Disciplinary studies benefit from a very structured approach to knowledge and coalescence around agreed explanations of why things are the way they are; but these can act as straitjackets as well.

What societies value has also affected what is studied and understood. The importance of agriculture to Australia's early development led to large investments in agricultural R&D over the past century. "Bogs" and "swamps" were little valued by society until recently (eg 'between Mannum and Wellington, the flat shores of the river have all been reclaimed from useless swamp' (Hill 1937) – and have been little studied in comparison. Box 3 shows some workshop examples of how changing values are reflected in the language used to describe water ecosystems (eg Giblett 1996).

**Box 3. Paradigms and language. Points from workshop.**

- We now talk about "wetlands" when in the past people referred to them negatively as bogs and swamps.
- Floods are seen as highly beneficial in drylands (but as threats in coastal areas).
- The Ramsar international convention for classifying wetlands accords 'wetlands' a world heritage status, rather than treating them as places that need improvement by engineering.

Partly as reflection of past values, and partly due to the inherent difficulty of studying complex natural systems, ecology has a short history as a scientific discipline and the understanding of how water ecosystems work has lagged understanding of other aspects of land and agricultural systems. Due to the high variability in Australia's rainfall and therefore stream flows, ecosystem theories developed from research on temperate perennial streams elsewhere in the world are not necessarily applicable in Australia (Thoms and Sheldon 2000).

Wetlands in drylands have been particularly under-studied world-wide and particularly in Australia where their ephemeral qualities make them unpredictable. Thoms and Sheldon (2000) estimated that only 25% of papers published on Australian freshwater systems between 1978 and 1998 were about lowland systems, despite lowland rivers being the dominant river form in Australia, accounting for 97% of the total river length. Much of wetlands research to date has focussed on understanding dynamics at a local scale over short time frames and there are substantial knowledge gaps about the relationships between wetlands at catchment and Basin scale and over longer time frames at all spatial scales. This is recognised in the current MDBA project, Narran Science Application Project, which is working on applying current knowledge about the function of the Narran floodplain ecosystem to management implications at local, landscape and regional scale.

In contrast, a combination of 150 years experience and scientific research has led to a good understanding of what is required for sustainable animal production in the arid and semi-arid rangelands of Australia. Given that the wetlands that are the focus of this project occur in the same drylands, and both wetland and grazed land productivity are highly governed by the same variable rainfall, a goal of the project is to test whether there are "lessons" or ways of thinking about rangeland variability that might be applicable to wetlands.

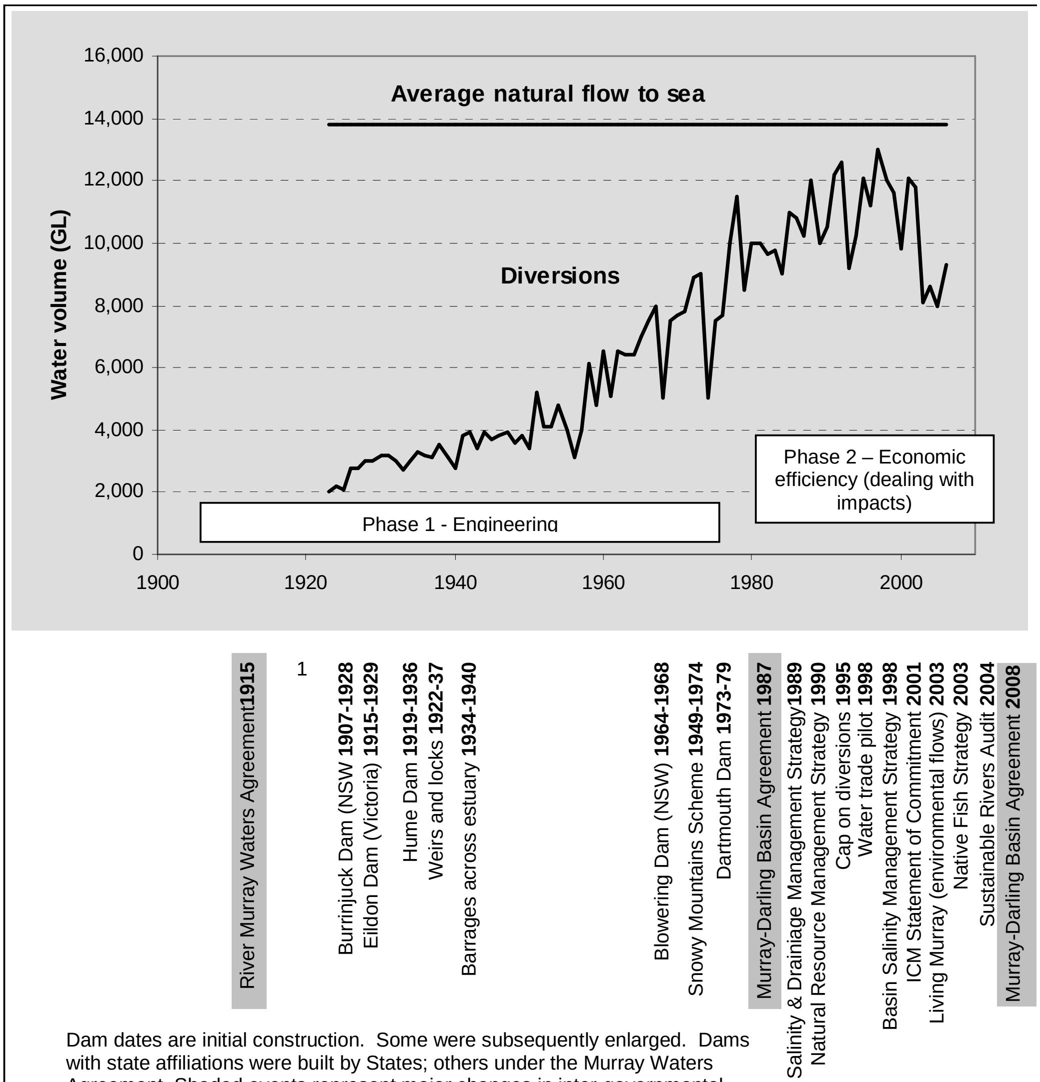
Environmental historian Robin has traced the development of scientific ideas about what we now call biodiversity and how the language and concepts have impacted on conservation practices in Australia (Robin 2007).

In common with the history of river basin development in other parts of the world there have been distinct shifts in the ways of thinking about water as the resource has been developed in the MDB. Figure 1 from Ryan (2010 In press) maps the history of water resource development and institutional development in the MDB. In Phase 1 (using a framework from Woolfe and Brooks (2003)) a technical paradigm dominates (in the MDB there was a focus on controlling variability – providing water "security"). In Phase 2, when there's no more resource to develop, increasing the efficiency of use dominates. Policy responses then rely heavily on economic mechanisms (and in the case of MDB, addressing the environmental impacts of Phase 1). In Phase 3, which we are just entering, the focus is on why water is used in this way at all and policy responses depend much more on new options and reallocation, for which social capacity is the most important.

Raising the paradigms to a conscious level is also important when developing a systems view that spans more than a generation of human time. "Unless we understand some history, we are often limited by what is currently fashionable, what has been called *presentism*."(Robin and Connell 2005).

Even younger than ecology is the science of sustainability. This has arisen from the change in paradigm of western science, technology and governance that formerly (and still in many situations) placed people outside and separate from the ecological systems upon which their lives depend.

**Figure 1. Changes in governance and paradigms in water development of the mostly regulated portions of the Murray-Darling Basin.**




Dam dates are initial construction. Some were subsequently enlarged. Dams with state affiliations were built by States; others under the Murray Waters Agreement. Shaded events represent major changes in inter-governmental arrangements. Diversion data are from Close (1990) and MDBC (2007).

Methods for assessing, measuring, managing and governing for sustainability are being rapidly developed but have a short history of use. They are challenging to use, because of the basic premise that people who are in the social-ecological system in question must be involved in their study or planned development; and because they required multi-disciplinary studies and integration that crosses many traditional academic as well as government structural divides. Embracing sustainability thus implies questioning some significant current paradigms. A resilience approach to understanding and managing sustainability is the youngest of the scientific developments and is especially relevant to the objectives of the MDBA.

Three basic concepts underpin the resilience approach to thinking about linked social-ecological systems (Box 4). These will be important components of new thinking to underpin achievement of the **"economic, social and environmental**" objective of the Water Act.

**Box 4. Concepts underpinning the resilience framework for thinking about sustainability (from Walker and Salt 2006).**

- *Concept 1: We all live and operate in social systems that are inextricably linked with the ecological systems in which they are embedded; we exist within social-ecological systems. Whether in Manhattan or Baghdad, people depend on ecosystems somewhere for their continued existence. Changes in one domain of the system, social or ecological, inevitably have impacts on the other domain. It is not possible to meaningfully understand the dynamics of one of the domains in isolation from the other.*
- *Concept 2: Social-ecological systems are complex adaptive systems. They do not change in a predictable, linear, incremental fashion. They have the potential to exist in more than one kind of regime (sometimes referred to as "alternative stable states") in which their function, structure, and feedbacks are different. Shocks and disturbances to these systems (eg fires, floods, wars, market changes) can drive them across a threshold into a different regime, frequently with unwelcome surprises (such as a lake suddenly going from a state of clear water to a persistent state of murky water).*
- *Concept 3: Resilience is the capacity of a system to absorb disturbance; to undergo change and still retain essentially the same function, structure, and feedbacks. In other words, it's the capacity to undergo some change without crossing a threshold to a different system state – a state with a different identity. A resilient social-ecological system in a "desirable" state (such as a productive agricultural region or industrial region) has a greater capacity to continue providing us with the goods and services that support our quality of life while being subjected to a variety of shocks.*

Historians well understand Concept 2. Robin and Connell (2005) point out "History's chief lesson is a humbling one: human life is not ultimately amenable to reductive or predictive capacity". Even in the biophysical world, we are currently facing the limitations of empirical models based on past experience that are no longer predictive eg runoff models in the MDB that are based on correlation with past rainfall are not predicting runoff in the current drought which is outside past experience; and fire models based on past experience that are not predictive in new extremes of temperature and aridity.

# Characteristics of the Drylands of the Murray-Darling Basin

## *Defining 'drylands'*

'Drylands' is a relatively new term used in some of the international literature to describe the arid and semi-arid regions of the world. (eg Reynolds *et al.* 2007). It is used here as shorthand for 'semi-arid rangelands' because it's a simpler term and in common language perhaps more inclusive of all the resources, values and uses of the region – and to recognise that landscape processes are highly interwoven, that enterprises might make livings from different mixes of resource use over time, and that communities want "healthy" landscapes regardless of institutional or scientific distinctions that are made between their component parts. Nevertheless, there is no fine distinction between 'drylands' and 'rangelands' for the purpose of this report and they are used interchangeably.

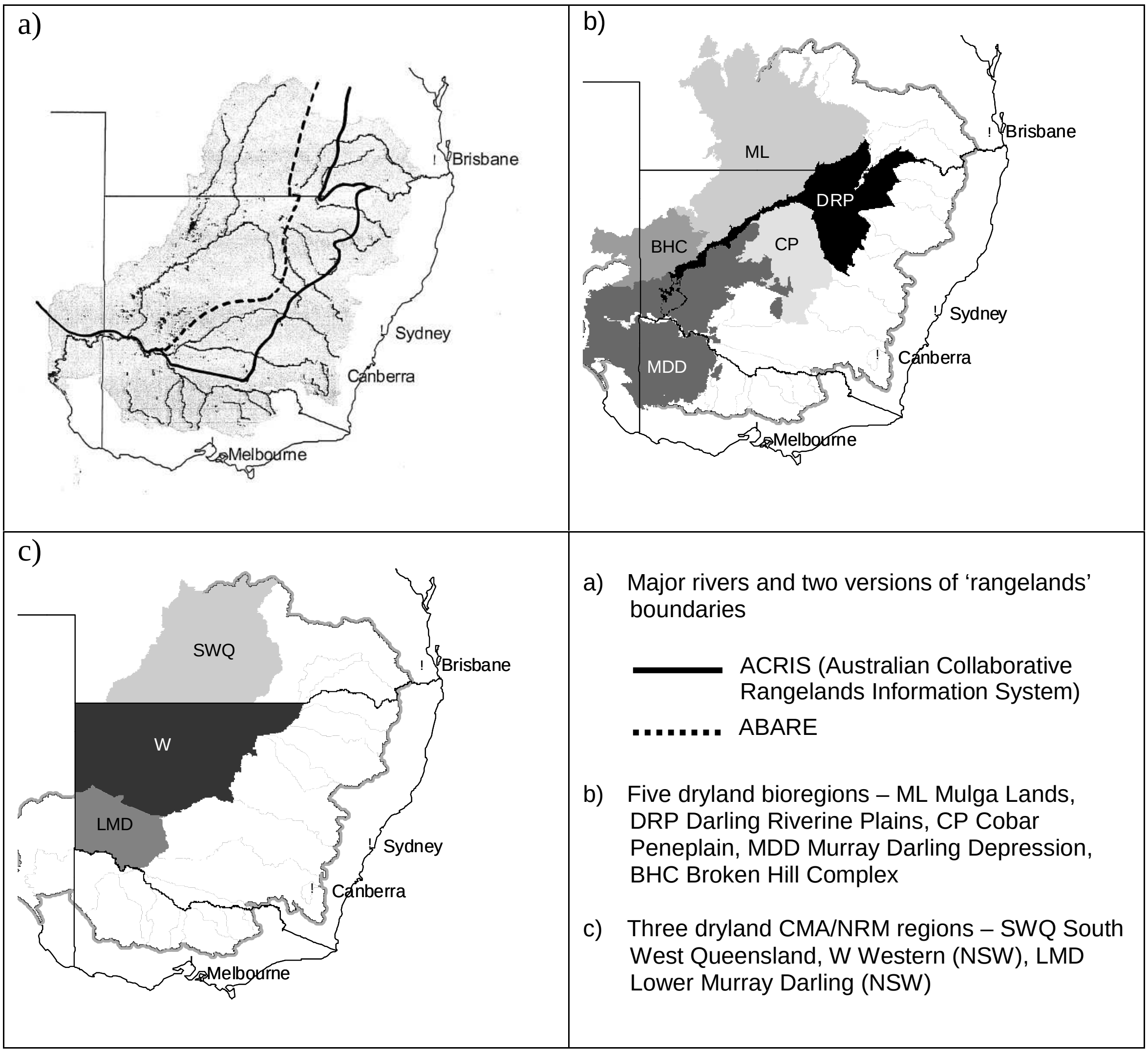
The drylands of the Basin are predominantly semi-arid, falling in the 250-350 mm rainfall pa range (arid is defined as <250 mm rainfall) so the 350mm rainfall isohyet is a rough guide to the eastern boundary of drylands in the Basin. Different organisations draw different boundaries to the drylands/rangelands to meet specific requirements (eg ABS, ABARE, ACRIS, NRM regions) but we can work with fuzzy boundaries to the geographic space because we are more concerned with conceptual approaches than spatial accuracy. We recognise also that the extreme variability in rainfall in this region means averages have little meaning: boundaries of a rainfall-defined region "move" with short and long term movements in rainfall, and may possibly move even further with climate change.

Figure 2 indicates two boundaries that have been used to define rangelands in the Basin and complementary maps showing NRM region boundaries and the bioregions of the drylands of the Basin.

## *Land use*

Grazing of sheep and cattle on natural vegetation (shrubland and woodland rather than the grasslands of the more arid and more northern regions of Australia) and nature conservation are the main land uses but opportunistic cropping in the eastern, wetter areas and some irrigation development along the rivers and where overland flows can be captured in farm dams also occur in the region and are economically important. Indigenous land use and mining also occur. Depending on where the boundary is drawn in the east more irrigation of cotton and grain crops and summer rainfed cropping would be included.

**Figure 2. A range of boundaries for the drylands in the Basin.**




## *Wetlands and lowland rivers in the drylands*

The rivers in the drylands of the Murray-Darling Basin are lowland rivers, broadly defined as those flowing through country less than 300m in altitude (Thoms and Sheldon 2000). They are mostly fed by rainfall falling outside the zone. Due to their length and the low rainfall, high temperatures and high evaporative demand in the drylands, these rivers lose considerable water due to evaporation, evapotranspiration and groundwater recharge.

Australian lowland rivers are globally unique, due to their extreme variability in flows. This hydrological variability shapes and maintains a complexity in the instream physical environment that is important for providing a range of aquatic habitats so that organic matter can be accumulated in a wide range of flow conditions. Once the river is flooded, flow variability physically reshapes wetlands and drainage patterns on the floodplain, creating a diversity of habitats. The variation in inundation frequency has shaped a diverse biota capable of maintaining ecosystem functions in an unusually wide range of conditions.

Habitats are characteristically patchy and connectivity in time and space is important as resources are meagre in low flow years and concentrated in refuges, but must be capable of rapidly recolonising more broadly in wet years (Thoms and Sheldon 2000).

Six of the sixteen Ramsar wetlands of international importance in the Basin are in the drylands: Narran Lakes, Currawinya Lakes National Park, Macquarie Marshes Nature Reserve, Riverland including Chowilla Floodplain System, Gwydir Wetlands and Paroo River Wetlands. Other large wetlands include Menindee Lakes, Narran Lakes, Talyawalka Anabranch and Teryawynia Creek, Yantabulla Swamp, Darling Anabranch Lakes and Lowbidgee Floodplain. Much of the area of these wetlands is in private ownership.

The structure and function of most of these wetlands have been considerably altered by human activities: diversion of water for irrigation, alteration of flow patterns by building banks and channels, grazing and introduction of pests and weeds. Improving their condition is a key objective of the Water Act 2007 (Box 1).

## *Socio-economics*

Pastoral and non-pastoral agriculture are the main economic activities in the drylands of the Basin. Each contributes roughly equally to the total agricultural activity of the region (based on the data in Table 1 from Chudleigh and Simpson (2004)) and assuming all the NSW drylands are in the Basin, but only a moderate fraction of Queensland's and only a small fraction of South Australia's.). The major contributors to the value of non-pastoral industries were cereals for grain ($50 million), cotton ($79 million), grapes ($51.1 million) and citrus fruit ($31.2 million). Apart from cereal production, some of which are irrigated and some not, all the remainder require irrigation when grown in drylands. The authors point out the high spatial clustering of irrigation activities around water sources and the consequential heterogeneity between income for SLAs.

**Table 1. Pastoral and non-pastoral economic values in Australian rangelands (from Chudleigh and Simpson 2004).**

| State | Value of pastoral industries in rangelands ($m) | Value of non-pastoral industries in rangelands ($m) | Total value of agriculture in rangelands ($m) | Non-pastoral agriculture as a percentage of total agriculture in rangelands |
|---|---|---|---|---|
| New South Wales | 197 | 271 | 467 | 58% |
| Queensland | 1,168 | 157 | 1,325 | 12% |
| Northern Territory | 198 | 72 | 270 | 26% |
| Western Australia | 189 | 91 | 280 | 32% |
| South Australia | 83 | 38 | 121 | 31% |
| AUSTRALIA | 1,835 | 628 | 2,463 | 26% |

Consistent with the idea of a desert syndrome (see next section) in which scarce natural resources and scarce social resources are functionally linked, Table 2 illustrates a challenge for the drylands of the MDB. Population density is low and Australian government investment per unit area is low, compared to the non-drylands regions, but the average NRM investment per person is higher in situations where joint effort is more difficult due to the sparse distribution of people and networks.

**Table 2. Population density and NRM investment and capacity in the drylands.**

| | **"Drylands" NRM regions in the MDB** | **"Non drylands" NRM regions in the MDB** |
|---|---|---|
| Total area km2 | 480,470 | 1,025,199 |
| Total population | 57,000 | 2,612,195 |
| Population density | 0.12 | 2.55 |
| Average NHT&NAP $/km2 | 14 | 186 |
| Average NHT&NAP $/person | 121 | 73 |
| Average ARIA index | 6.10 | 1.50 |

Calculated from Robins and Dovers (2007). The three 'drylands' NRM regions are South West Queensland, Western NSW and Lower Murray Darling NSW (two other NRM regions map partially into 'drylands' (see Figure 1) but they include considerable dryland agriculture and closer settlements.

Socio-economically, the regions in the drylands of the Basin are less well off than the Australian average. Almost all of them fall in the bottom two quintiles of the SEIFA (Socio-Economic Index for Areas) (see map in Alston and Witney-Soane 2008). This ABS compiled index combines measures of affluence, employment advantage and levels of skill and education to produce a summary spatial statistic of socio-economic well-being.

The sparseness and above-average age of people in this region tends to lower their capacities for self-reliant adaptation. Withdrawal of government services has often stretched these already-sparse capacities close to or beyond thresholds. Often community survival depends on a few leaders and some devoted followers who are willing to keep contributing time and energy to the community. But this is hardly resilient, given that community survival may quickly unravel once these individuals leave (Marshall *pers. comm.*)

# Climate and Climate Change

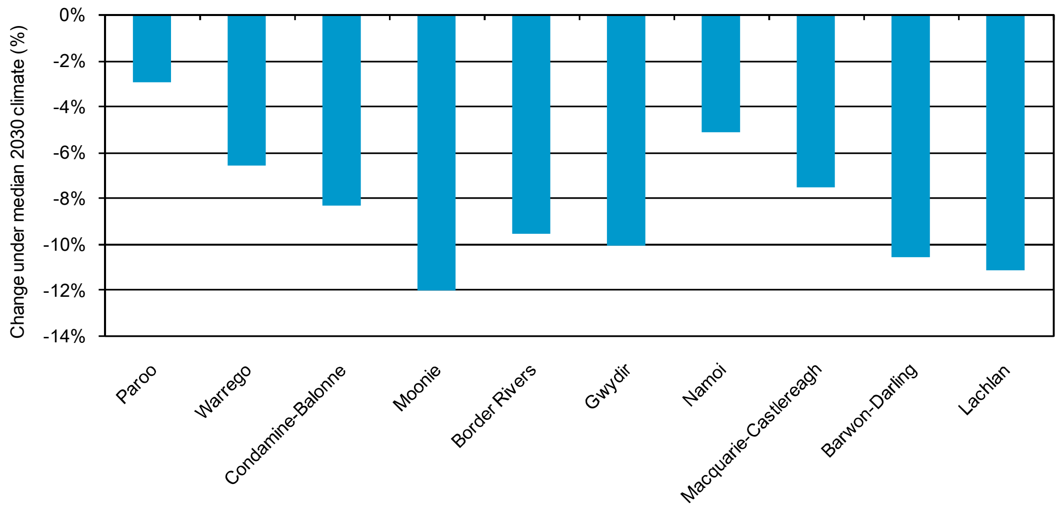
Climate, and particularly a low and variable rainfall, is a key driver of ecological processes and socioeconomic consequences in drylands (eg Stafford Smith 2008). The current understanding of how the linked socio-economic systems function today is based on climate interactions over the past but it is increasingly certain that there will be climate changes associated with global warming. Hydrological and biological responses to a changing climate are unlikely to be linear or fully within the bounds of past responses.

## *Climate change projections*

For the Murray-Darling Basin, the CSIRO Sustainable Yields project CSIRO (2008) modelled how climate might change by 2030 and the likely consequences for runoff and river hydrology. The project investigated three levels of global warming by ~2030 ranging from 0.45°C to 1.6°C based on the CSIRO and Australian Bureau of Meteorology (2007) study. These three levels of warming were used to scale the climate projections from 15 of the global climate models used in the latest IPCC assessments to give 45 possible future scenarios. Across these scenarios the median reduction in mean annual rainfall for the northern MDB is about 2%, with wet and dry extremes (both of which are associated with the highest warming) of around a 10-15% increase or decrease in mean annual rainfall.

These rainfall and temperature changes are predicted to lead to reductions in mean annual runoff of between 2% (Paroo, and Barwon-Darling) and 10% (Moonie and Lachlan) under the median future climate scenario, but with wet extreme scenarios of 20% to 50% increases in mean annual runoff and dry extreme scenarios of around 15% to 35% reductions in mean annual runoff. The changes in mean annual runoff for each of the northern MDB catchments under the median future climate scenarios are shown in Fig 3.

**Figure 3. Changes in mean annual runoff under the median 2030 climate change (CSIRO 2008).**




In addition to these changes in mean annual conditions, changes are likely in the magnitude and frequency of extreme events – thus further increasing the already very high natural variability of rainfall and streamflow. For example, in the Paroo under the median climate scenario, in spite of a small overall drying, flood inflows to Lake Wyara are predicted to increase as a result of more frequent but smaller flood events driven by an increase in rainfall intensity (CSIRO 2007). These predicted changes are however, currently highly uncertain.

The Sustainable Yields project also assessed the extent to which rainfall and runoff over the 1997 to 2006 decade differed from long-term (1895-2006) averages. Over this period rainfall ranged from 8% less than the long-term average (Lachlan) up to 7% more than the long-term average (Gwydir), with respective changes in runoff from an 18% reduction to a 24% increase (Potter et al., 2008). However, given the high natural hydrologic variability in these regions, none of these differences from the long-term average values are statistically significant at a P=0.05 level.

Participants in the workshop considered that the projected increase in variability in rainfall and river flows in the drylands associated with the expected increase in frequency of extreme events may become a stronger driver of change in water ecosystem processes in this region than the reduction in total or average flows.

## *The current drought*

The drylands region in the Basin is already experiencing a long dry period compared to the base years 1961 to 1990 (McKeon *et al.* 2004). Visual interpolation from their mapped data again gives estimates of the decline and impact on modelled forage production (Table 5.)

**Table 5. Annual averages for climate attributes in the drylands of the MDB, expressed as change in 1991-2007 in relation to 1961 to 1990 (note different base period to the CSIRO projections in the table above). From McKeon *et al.* (2004)**

| Climate attribute | Change |
|---|---|
| Rainfall | -5 to -10% |
| Forage production | -20 to -50% |
| Available soil water | -20 to -30% |
| River flows | -40 to +40% |

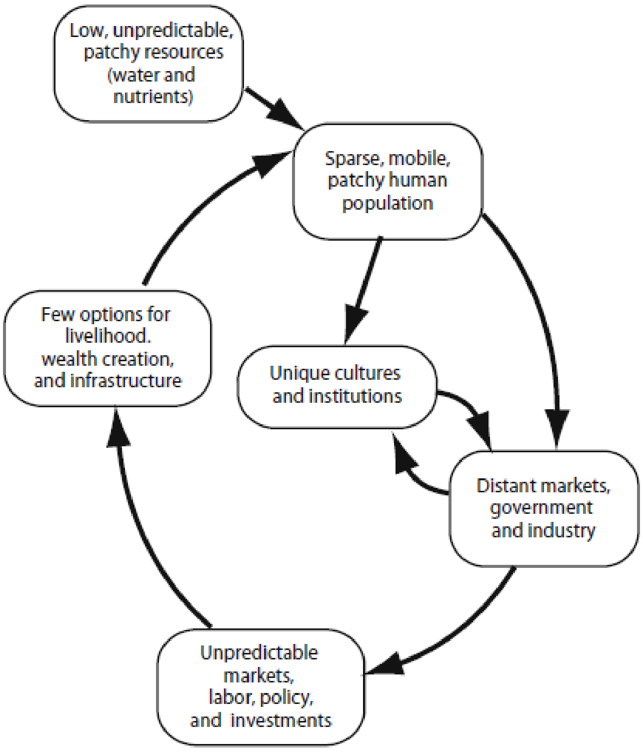
The authors note that in the context of forage production, although an annual decrease in rainfall of 10% looks low, when accumulated over years it has a big impact. "The combination of long-term rainfall decline and continued quasi-decadal variability is likely to episodically place severe stress on rangeland ecosystems, grazing enterprises and rural communities." A similar conclusion could be tested for wetlands, given the importance of water (as flows rather than rainfall) for primary productivity in wetlands.

# Dynamics of Dryland Systems

## *Global understanding*

Drylands of the world exhibit many common characteristics. An international group of dryland scientists has synthesised their understanding of the dynamics of the linked socio-ecological systems of rangelands into a 'drylands syndrome' (Reynolds *et al.* 2007) Unpredictability, resource scarcity, sparse populations, remoteness and 'distant voice' are the key attributes and they interact in the fashion shown in Figure 4. Most of these attributes apply in the drylands of the Murray-Darling Basin, with the possible exception of the human population being mobile.

**Figure 4. Drylands dynamics – a global synthesis. From Reynolds *et al.* (2007)**



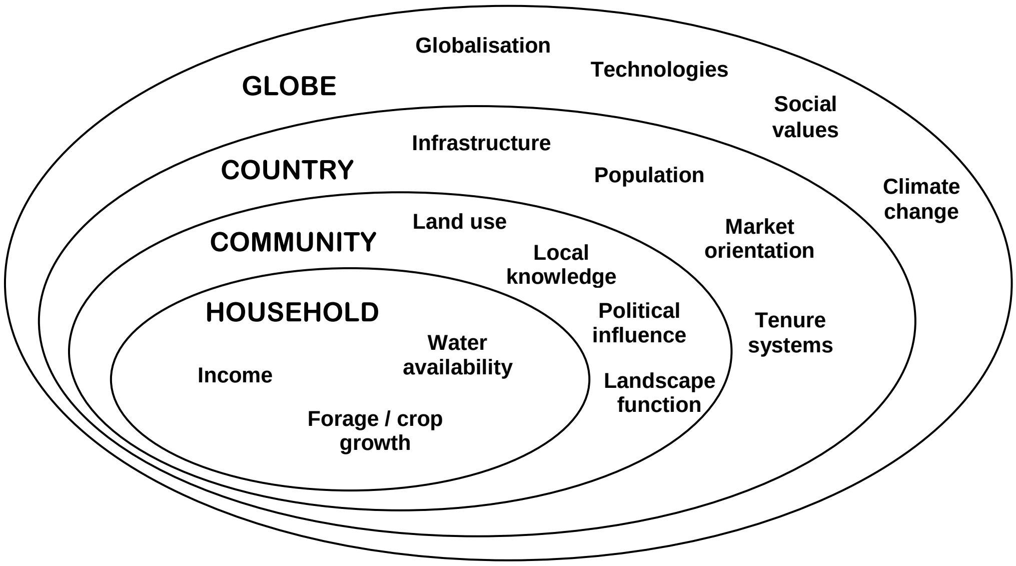

From this international work has also arisen a set of key 'dryland development principles' (DPPs). They are recognisable as being based on the same concepts outlined in the earlier section on resilience thinking but applied more specifically to drylands. They are summarised in Table 6.

Sorting out the focal scale is important in developing a better understanding of system dynamics. Figure 5 from Stafford Smith *et al.* (In press) depicts how outcomes at four scales relevant to the drylands are controlled by variables at the same scale and across scales.

## *Australian understanding*

Concerted effort at synthesising the social-ecological rangeland history in Australia has occurred in recent years. McKeon *et al.* (2004) documented and analysed eight historical degradation events in detail, three of which were in the drylands of the MDB. Their book is titled "Learning from History", but they acknowledge that each drought and degradation event is different. To elicit the learnings, they draw on repetition of common factors to suggest ways to reduce future impacts.

**Figure 5. The relationship between scales in dryland social-ecological systems (from Stafford Smith *et al.* In press). Factors inside an ellipse are relatively fast variables representing controlling variables or immediate goods or services. Factors outside an ellipse are generally slower (but not necessarily controlling) variables.**




Building on this documentation of major events, Stafford Smith *et al.* (2007) analysed them in terms of the Dryland Development Principles of Reynolds *et al.* (2007) (Table 6). All conclusions have apparent applicability to management of the wetlands of the drylands and constitute potential "lessons" from the rangelands.

In particular the conclusions at P2 and P3 could be tested with water analogies: "In early episodes, pastoralists and institutions alike were only monitoring and responding to fast variables" (a wetland analogy might be monitoring the impact of one environmental flow, or building an ecosystem-response model based on data gathered in a limited sample of short term climate) or from P3 "There were critical thresholds observable in both human and environment subsystems … The eventual impacts of high stock numbers, while triggered by drought, were generally a result of slow declines in the resilience of vegetation, coupled in some cases with threshold declines in soil fertility and water holding capacity". A wetland analogy might be the death of redgums triggered by a drought but where there has been a slow decline in resilience of the trees due to other pressures like grazing, timber harvesting, permanent inundation or salt intrusion.)

The authors also point out that human desires to control variability in grazed rangelands has contributed to their loss of resilience. The natural patchiness in these landscapes, which results from self-organisation of the scarce resources into usable amounts, becomes homogenised when managers maintain high stock numbers in drought, resulting in loss of landscape function and decline in resilience.

**Table 6. Conclusions of an analysis of eight drought episodes in Australian rangelands against five global principles for understanding change in drylands (from Stafford Smith *et al.* 2007). LEK is local environmental knowledge.**

| Dryland development principles and key implications | Conclusions from analysis of eight Australian drought episodes |
|---|---|
| **P1** Human–environmental systems are coupled, dynamic, and coadapting, so that their structure, function and interrelationships change over time. Understanding dryland desertification and development issues always requires the simultaneous consideration of both human and environmental drivers, recognizing that there is no static equilibrium to aim for. | The episodes cannot be understood without analyzing the links between the human and environmental subsystems. The two subsystems have shown some coevolution in the way that human learning has caused and responded to change, although there remain dysfunctional aspects to these changes. |
| **P2** A limited suite of slow variables are critical determinants of human–environmental system dynamics. A limited suite of critical processes and variables at any scale makes a complex problem tractable. | In early episodes, pastoralists and institutions alike were only monitoring and responding to fast variables (rainfall and pasture production, not long-term climatic cycles and pasture condition; market prices, not long-term trends and variability), and have only gradually come to focus on the underlying controlling variables. |
| **P3** Thresholds in key slow variables define different states of human–environmental systems, often with different controlling processes; thresholds may change over time. The costs of intervention rise nonlinearly with increasing land degradation or the degree of socioeconomic dysfunction; yet high variability means great uncertainty in detecting thresholds, so managers should invoke the precautionary principle. | There were critical thresholds observable in both human and environment subsystems, management that was viable under good climatic and market conditions collapsed when both declined; the thresholds of rainfall or stock numbers at which such collapses happen were made more sensitive by the effects of antecedent management on pasture condition (and debt levels). The eventual impacts of high stock numbers, while triggered by drought, were generally a result of slow declines in the resilience of vegetation, coupled in some cases with threshold declines in soil fertility and water holding capacity. |
| **P4** Coupled human–environmental systems are hierarchical, nested, and networked across multiple scales. Human–environmental systems must be managed at the appropriate scale; cross-scale linkages are important in this, but are often remote and weak in drylands, requiring special institutional attention. | Understanding the interplay between effects at different scales in space, time, and institutional process is crucial to future solutions. Management and learning at the individual pastoralist scale turns out to be too fine-scaled, particularly in time, while tactical responses at the national level are too ponderous (and often counterproductive). Policy needs to focus on creating a context of regional institutions and knowledge support rather than intervening directly. |
| **P5** The maintenance of a body of up-to-date LEK is key to functional coadaptation of human–environmental systems. The development of appropriate hybrid scientific and LEK must be accelerated both for local management and regional policy. | There was no lack of LEK and learning within some individuals' lifetimes, but this was acting against many institutional and economic pressures and mismatched particularly with the time scale of variability. The climatic drivers of importance were those associated with long-term (quasi-decadal) oscillations. This cycle (~19 years) is too short to be regarded as invariant for a manager's lifetime, but too long for one manager to build up repeated experience of changes. The necessary collective learning requires an alliance of industry, science, and public institutions and is now further hindered by climate change. |

## *Applicability of experience elsewhere to the drylands of the MDB*

The characteristics of the drylands of the MDB as outlined earlier appear consistent with the broader understanding of how drylands systems work.

## *Contrasts between MDB drylands and the south of the Basin*

The workshop created a large set of characteristics of the MDB drylands that contrast with the south of the Basin (Box 5).

**Box 5. Features of the drylands (northwest) of the Basin that distinguish them from the wetter south. Points from workshop.**

- Variability in rainfall and runoff is greater
- Rivers are less regulated, and will never be regulated to the same extent (less potential for dams, more variable rainfall)
- Due to less regulation, connectivity and natural timings of flow have been better maintained in the north (although still not a "natural" system)
- A different history of irrigation development (later, with less government investment, more private control via on-farm water storage)
- Irrigation development occurred post 1950s, in a wet period, when market prices were high. This historical context shaped expectations about the permanence of water availability and the stability of markets. Community resilience was not developed and the transformation needed in the face of declining water availability and instability of markets is difficult.
- Abstractions (as a proportion of flows) have never reached the levels of the south
- Due to greater rainfall variability, and less regulation, there is less reliance on irrigation. Governments have not well recognised that irrigators have structured their businesses and their irrigation activities to deal with the variability
- Environmental allocations more challenging to manage when they don't sit in an account in a dam
- The climate change signal in the north of the Basin is different and less strong than in the south. In the north more variability and more extreme events are projected; in the south a reduction in rainfall will be the major impact.
- Extensive methods of managing wetlands are required, given their extent and low resources available (human and financial). This matches the extensive management style of pastoral lands and contrasts to a more intensive agriculture system and wetland management approach in the south
- Terms like yield and efficiency have less meaning in the north; economic instruments like water trading less appropriate in a less regulated system
- Sparser population, more remote communities
- Different crops are irrigated
- These differences suggest that the same approaches used in the south might not be the best to duplicate in the north. One-size-fits-all policy solutions (especially for regions away from the centre) need to be carefully tested against the distinctive character of the region.

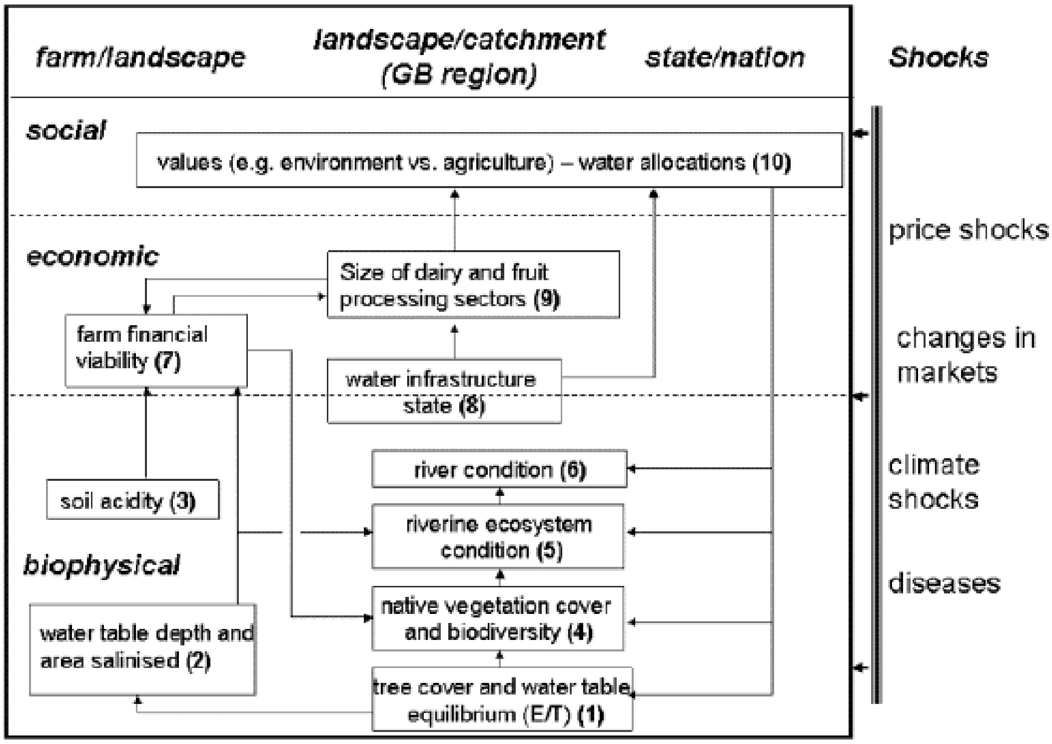
**BUT**

- The Darling and the Murray system are connected, and from time to time, when the south is very dry, good rainfalls in the north can be instrumental in delivering flows to South Australia
- A southern Basin losing opportunities for irrigation through climate change may see more pressure on irrigation development in the north
- A comparison with an arid region water system eg Lake Eyre would provide a contrast from the other direction (drier, and without regulation)

## *System dynamics in the south of the Basin*

In an example outside the drylands but within the Murray-Darling Basin, Walker *et al.* (2009) used a resilience-based approach to assess the sustainability trajectory of the Goulburn-Broken Catchment. Figure 6 illustrates the relationships between the key slow controlling variables that they identified. Thresholds for each variable are explored and quantified.

**Figure 6. Identification of ten slow variables with identified thresholds for the Goulburn-Broken Region. The arrows between boxes indicate possible cascading threshold effects. From Walker *et al.* (2009).**




Examining this analysis from the south of the Basin in the light of the characteristics of the Basin already outlined, and the workshop output about how the drylands of the Basin are distinguished from the south (Box 5), suggests that the same analysis for the drylands would result in a distinctively different picture. For example, the controlling variables 1, 2, 3 and 9 are likely to be absent, and 8 of reduced importance. Variables 4, 5, 6, 7 and 10 might remain, but variables that relate to spatial and temporal heterogeneity of rainfall and other resources might be added. This would have significant implications for policy decisions that might otherwise apply a one-size-fits-all prescription across the Basin.

A conclusion from the Goulburn Broken study was that the Goulburn Broken CMA has little capacity to manage the slow variables within the region and thereby enhance its resilience because many of the investment decisions are made at a larger scale. An adaptive governance approach would suggest better outcomes would be achieved by a better matching of the scale of governance to the scale of ecological and social processes (eg Marshall 2008).

# Ecosystem Services

## *Definition and wetland examples*

Earlier in the report it was noted that an objective of the Water Act 2007 was the protection, restoration and provision of ecosystem services (within the context of optimising economic, social and environmental outcomes).

Ecosystem services was the framework used by the Millenium Ecosystem Assessment to make explicit links (even if not always quantifiable) between ecosystems and human well-being. The Assessment analysed the current condition and trajectories of these ecosystem services globally, then assessed their likely outcomes under different scenarios of global interventions. The synthesis report on water and wetlands (Millennium Ecosystem Assessment 2005) provides a good worked and relevant example of the approach that is needed for assessing whether the ecosystem services objective of the new Act is being achieved.

Two excerpts from the Millenium Assessment report are reproduced in Boxes 6 and 7 to support the material produced in the workshop and documented here.

**Box 6. Ecosystem services provided by or derived from wetlands. (From Millennium Ecosystem Assessment 2005).**

| Services | Comments and Examples |
|---|---|
| **Provisioning** | |
| Food | Production of fish, wild game, fruits, and grains |
| Fresh water | Storage and retention of water for domestic, industrial, and agricultural use |
| Fiber and fuel | Production of logs, fuelwood, peat, fodder |
| Biochemical | Extraction of medicines and other materials from biota |
| Genetic materials | Genes for resistance to plant pathogens, ornamental species, and so on |
| **Regulating** | |
| Climate regulation | Source of and sink for greenhouse gases; influence local and regional temperature, precipitation |
| Water regulation (hydrological flows) | Groundwater recharge/discharge |
| Water purification and waste treatment | Retention, recovery, and removal of excess nutrients and other pollutants |
| Erosion regulation | Retention of soils and sediments |
| Natural hazard regulation | Flood control, storm protection |
| Pollination | Habitat for pollinators |
| **Cultural** | |
| Spiritual and inspirational | Source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems |
| Recreational | Opportunities for recreational activities |
| Aesthetic | Many people find beauty or aesthetic value in aspects of wetland ecosystems |
| Educational | Opportunities for formal and informal education and training |
| **Supporting** | |
| Soil formation | Sediment retention and formation of organic matter |
| Nutrient cycling | Storage, recycling, processing, and acquisition of nutrients |

**Box 7. Excerpt about trade-offs from the Millenium Ecosystem Assessment on Wetlands and Water.**

### Trade-offs among Wetland Ecosystem Services

In all four MA scenarios, actions taken to increase the supply of provisioning ecosystem services such as food and water result in reductions in the supply of supporting, regulating, and cultural services (S12). Such trade-offs have far-reaching consequences for maintaining ecosystem functioning in the long term. Scenarios in which long-term consequences of trade-offs are not considered exhibit the largest risk of declines in supporting and regulating services (such as climate change and biodiversity loss). Those in which a proactive approach to ecosystem management is taken via flexible ecosystem governance mechanisms and learning or technological innovations are more likely to sustain ecosystem services in the future.

## *Towards resilience - a workshopped case study*

The drylands of the Basin are shaped both by their ecological and social characteristics (Box 5) *and* by what the nation wants from them. Some critical points about the objectives for the region were raised (Box 8).

In the workshop, Brian Walker proposed that the group work through a case study of defining ecosystem services and their relationships. The approach was to:

1. Define what is valued. These are the important ecosystem services in the region.
2. Understand the ecosystem services. What are the controlling variables?
3. Examine each ecosystem service and how maintaining one particular ecosystem service will affect another ecosystem service. What are the connections between them? Are there tradeoffs?

**Box 8. Importance of goals. Points from workshop.**

- Is there some vision that has been articulated for the north of the basin?
- Do we want to maximise agricultural production or look for other outcomes?
- How would the drylands be affected by different future scenarios that might be chosen nationally?
- We say sustainability but what does that mean?
- Do we know what we're prepared to give up to get what we're trying to get?
- With regards to resilience, do we need adaptation or transformation?

The outputs from this exercise are in Box 9 (step 1 above), Box 10 (step 2) and Figure 7 (step 3).

**Box 9 List of ecosystem services from a case study river, wetland and floodplain (Macquarie Marshes) in the drylands of the Basin. Points from workshop.**

**Provisioning**

- crop (food) production
- livestock production
- biodiversity (existence value)
- water (to downstream uses)
- cultural values
- fish

**Sustaining**

- vegetation
- soil fertility
- bird breeding
- fish breeding

**Regulating**

- water (via temporary storage)
- floods
- water quality
- sediments

**Box 10. The factors influencing the provisioning ecosystem services defined in previous box for the Macquarie Marshes. Points from workshop.**

**Production**

- inflow of available water (itself a product of rainfall, runoff and the water sharing plan)
- spatial heterogeneity*
- kind of ground cover (affected by land use, grazing and soil type)
- livestock trampling
- pests and weeds
- sediments and nutrients
- groundwater (flow and quality)
- extent of woody vegetation (relates to cropped areas)
- technology

- * three aspects to spatial heterogeneity
- - dynamic renewal (ecological-geomorphic)
- - diversity (biodiversity)
- - flexibility/variability

**Biodiversity existence**

- variability of flow and flow regime
- kind of ground cover
- diversity of habitats
- refuges
- vegetation cover (affects water distribution)

**Recreational fishing**

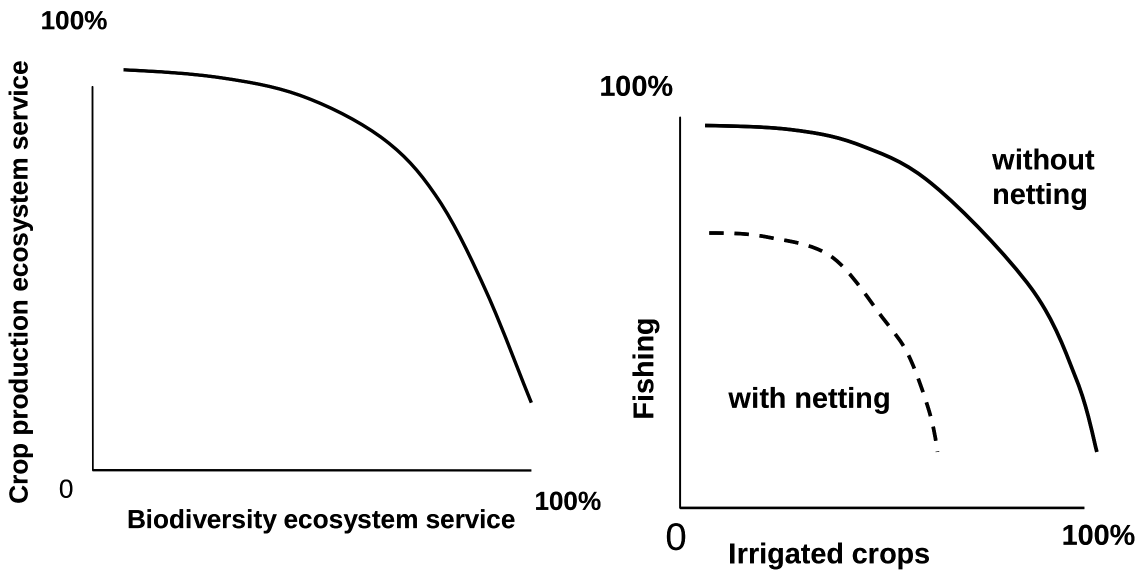
- fish barriers/connectivity
- flow regime
- open water
- temperature (affects water quality)
- pesticides (affect water quality)
- offtake
- birds

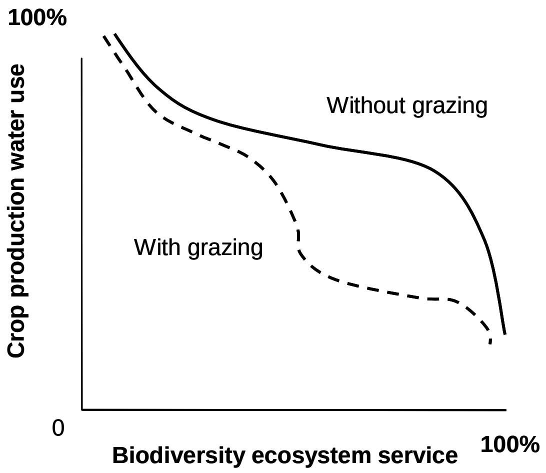
**Cultural values**
**(we focussed on the local and regional scales)**

- access to fishing
- jobs/livelihoods
- sense of pride in being custodians of this place
- self reliance
- water sports (on storages)
- continuity of knowledge and traditions about sites
- mobility/access to transport
- access to sites
- protection of sites
- bird watching
- amount and diversity of biodiversity

We acknowledged that Indigenous people might have a different set and certainly different priorities about cultural values. Values at State and national levels (different scales) may also be different.

**Figure 7. Sample explorations of tradeoffs between different bundles of ecosystem services in the workshop case study.**




These relationships also need to be established for wet and dry periods separately.

They would also be repeated with different institutional interventions.

## *Towards resilience – a framework for further work*

Workshop participants were interested in how this approach could be used in practice and raised the following issues and some points that are noted in Box 11.

- How do we go about identifying which ecosystem services are provided and which are important?
  - Whose voices?
  - Who is involved?
  - Who is the community?
    - Is there a vision for the community?
    - What do people value? Both now and in the past? Evidence of past values may be present in past policies, language (e.g. swamp vs. wetland) and in intellectual ideas.
    - Over what spatial and temporal scales?
    - How do we consider/value both provisioning and non-provisioning services?

- What policy instruments can be used to achieve change?
  - Regulations and sanctions vs. incentives
  - What about building trust and social networks?
  - What governance structure is required?
  - How can adaptive management and certainty be incorporated?
  - How can data gaps/mismatching scales be addressed?
  - Land-based issues are associated with States and water-based issues are tied to the MDBA and the federal government.

- What scope does this approach have to bring change in current policies?
  - For example, considering the Water Act and Basin Plan
  - An opportunity exists with the re-evaluation of the exceptional circumstances funding

- Across all of these areas, how do we take into consideration the likely impacts of climate?

The Resilience Alliance website (http://www.resalliance.org) is a good source of information and examples about resilience concepts and case studies.

**Box 11. Resilience and change. Points from workshop.**

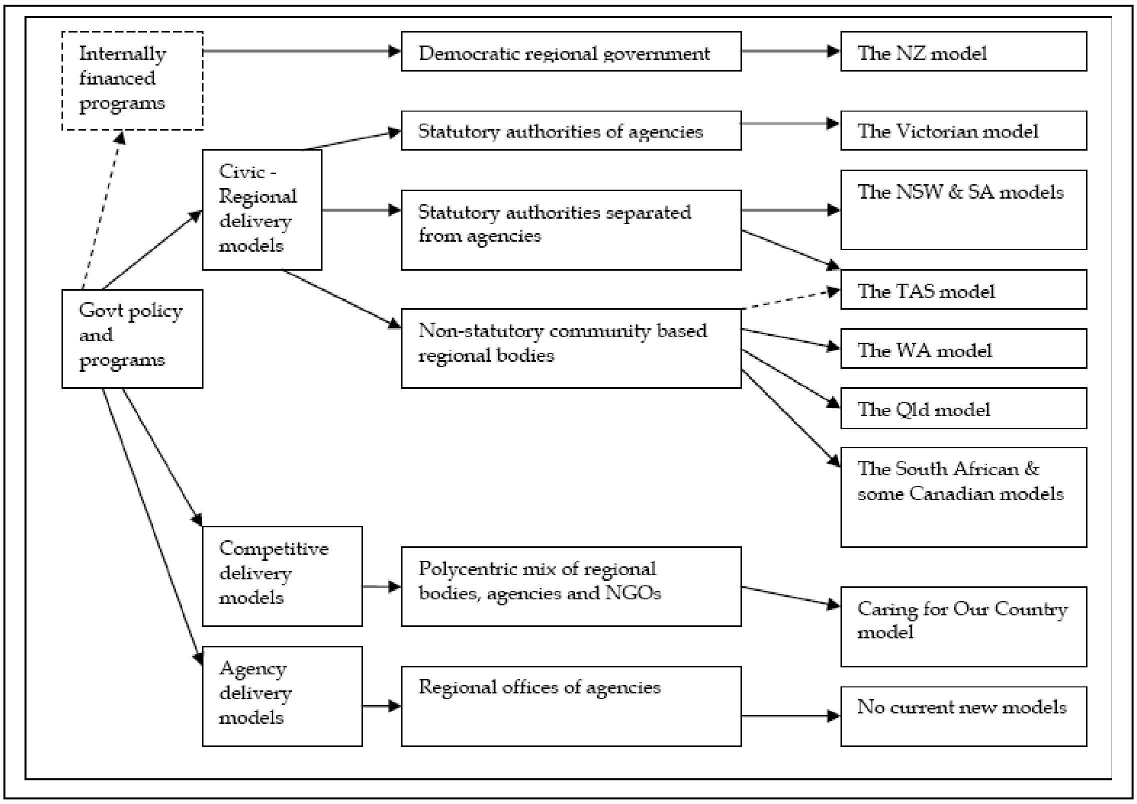
- A resilient community is a patchwork or network of resilient livelihoods in a place.
- Communities set up in 'good times' (eg the wet period when irrigation was developed in the north (1950-1970) will not be resilient in difficult times.
- Attempting to become more resilient by *adaptation* may only make the problem worse.
- Resilience may demand *transformative* change over more than one scale.
- In the rangelands an example of transformative change would be enterprise-based conservation (properties managed predominantly for conservation).
- Local knowledge is important – but needs to be linked with other knowledge at local and larger scales in the system.

# Governance

Improving the long term health of rivers and wetlands in the drylands depends on an integrated NRM approach that is only partly about environmental flows. This is well illustrated in an ecological history of Macquarie Marshes (Hogendyk 2007) which describes the long term trends in rainfall and vegetation responses and the interaction with grazing and land use around the Marshes since first settlement. While the current focus for this and similar wetlands in the Basin is the return of environmental flows, this ecological history shows that a multitude of other factors have led to the current poor condition of the Marshes. Amongst these are changes in the pattern of water distribution as landholders have constructed earthworks to channel floods into particular places, the trampling of stock, pest incursions and movements of saline groundwater. In this and many other wetlands in the drylands,

The NRM delivery system in Australia has very much grown up through an accumulation of programs and policies over time. The legislative basis of models varies from state to state, but the Australian Government has considerable influence as a major investor with national objectives to achieve. The Landcare program initiated in the 1980s, the National Heritage Trust and the National Action Plan for Water Quality and Salinity in the 1990s (which contributed to the formation of the regional bodies) and the new Caring for our Country program have had particular influence. A typology of NRM models in use in Australia today has been developed by Griffith (2009), see Figure 8.

**Figure 8. A typology of some NRM models in Australia and overseas. From Griffith (2009).**



While the mix of models (and mix of bodies delivering services in the competitive delivery models) has some characteristics of a resilient system - due to the different models acting as different "experiments" and their being redundancy between delivery agents - it is a more monocentric than polycentric system as a whole. The power driving the system resides predominantly with the Commonwealth Government.

A wider viewpoint might recognise the voluntary contributions of people acting outside this framework, individually or in groups. As expectations about land and biodiversity condition on privately managed lands grow, landholders are slowly mainstreaming improvements in natural resource management into their practices (eg see data in ABS Rural Atlas). In some place Indigenous people are gaining rights to manage land in traditional ways.

Theoretical contributions from ideas about Integrated Catchment Management in the 1980s can be seen in the regional body component of the existing system, but there has been no review of the complete system in the light of new ways of thinking about the best ways to combine the desires and resources of government, businesses and civic society to achieve desired improvements in NRM.

Theory developed by Elinor Ostrom and others could provide some insights here. This body of theory was developed from the analysis of communities which had successfully managed common pool resources over multiple generations (Marshall 2009). One of the design principles that emerged from this work was that of polycentricity: that the governance system is more effective when it consists of multiple decision-making centres that retain considerable autonomy from one another. A list of the advantages of polycentric governance for addressing complex NRM issues, taken from Marshall (2009) is in Table 7. Polycentric decision making contrasts with monocentric or very centralised, top-down (eg government) decision making.

**Table 7. Summary of benefits from polycentric governance (from (Marshall 2009)**

| | |
|---|---|
| 1 | The growth of reciprocity and trust from which voluntary cooperation evolves |
| 2 | Improved access to local knowledge |
| 3 | Enhanced ability to capture feedback on the performance of decisions in a disaggregated way |
| 4 | Closer matching of policy decisions to the circumstances of each local setting |
| 5 | 'multiple units … experimenting with rules simultaneously, thereby reducing the probability of failure for an entire region' |
| 6 | Increased redundancy in governance arrangements, so that 'when small systems fail, there are larger systems to call upon — and vice versa' |
| 7 | Increased overlapping of management units, enabling lessons from policies that succeeded or failed for one unit to be communicated more easily to other units |
| 8 | Enhanced capacity for adaptive management |

Drawing on these ideas has high potential value for designing systems for the management of water ecosystems in the drylands of the Basin because of the sparse population, local knowledge, remoteness of government (attributes of drylands elsewhere) and because many the ephemeral wetlands are under private landholder management. Elsewhere in Australia Marshall (2009) found that voluntary cooperation from farmers was enhanced under the regional NRM delivery model compared to free-riding behaviour encouraged under earlier paternalistic approaches to agri-conservation. Marshall (2008) explores another of Ostrom's principles – that of nested governance – in relation to environmental governance in Australia.

Discussion in the workshop about governance followed the session on determining tradeoffs between the bundles of ecosystem services. The following points were raised:

- The beginning point is that resolving any trade-off using curves like that is that it affects people's interests. It requires delivering on those trade-offs either by regulation or markets.
- There is a risk that the best guess at the trade-off today may not turn out to be a best guess when evaluated later.
- The ability to adapt and be flexible to incoming information therefore needs to be build into the process.
- There is a trade-off here. Too much changing course may reduce trust and might require bigger financial incentives or regulations to get people to respond.
- Polycentric governance offers opportunities for simultaneous multiple experiments and learning, instead of single "one size fits all" experiments which are very costly if the single decision maker gets it wrong.
- Polycentricity means the whole system is not going to collapse at once. It has more resilience.
- The smaller the building blocks and the more autonomous they are the more you can reconfigure them to match the problem.

Finally, the issue of the role of regulations and incentives arose several times during the workshop (see Box 12 for some examples). There was a strong feeling that this is an important issue for governance in the rangelands, given the sparsity of people and importance of private landholders in influencing large scale environmental outcomes.

**Box 12. Some comments from throughout workshop on the role of regulations vs incentives**

- Regulations are not learned responses by individuals.
- Regulating people to the nth degree hasn't achieved broader societal outcomes in the rangelands when those outcomes are not identical with individuals' aspirations.
- The economic incentives for ephemeral wetlands on private land work to oppose the ecosystem services they deliver. The variability of the wetting drying cycle means there is an imperative to make the most of the wet cycle, because you don't know when it will happen again. Without some way of interrupting that, you're going to see progressive decline of ephemeral wetlands.

# Suggestions for Building on this Project

Some suggestions for further work that arose in the workshop or in subsequent consideration of the report, include the following.

1. To support further explorations of system dynamics for wetlands at multiple scales there is a need for a synthesis and analysis comparable to that done for the rangelands (recognising that the database is probably much leaner). It may be necessary to draw on a wide range of written records from the past.

2. A richer exploration of how pastoralists manage with variability. How are the long and short term decisions made? How does the learning from the past get captured in plans for the future? What lessons might there be for the long and short term plans being made for managing rivers and wetlands in the drylands?

3. A compilation of some applied resilience analysis case studies that demonstrate how a complex systems approach adds value and enables a systems based synthesis of scientific and local knowledge.

4. A ‘wetlands in drylands’ regional companion study to the resilience analysis of the Goulburn-Broken catchment of Walker *et al.* (2009) – both to identify the key controlling slow variables and their thresholds for a better understanding of the consequences of change in the drylands, and as a comparison to assist in deciding how much a one-size-fits-all approach to the Basin will be effective. Early involvement of wetland specialists to identify possible biophysical thresholds and key slow variables would be critical.

5. To complement 4, a resilience analysis at the scale above and below the regional/catchment scale. “Once you try to do this across a range of places, they inform each other very strongly” (from workshop).

6. 4 and 5 together would make a very strong basis for considering options for new governance mechanisms that better match decision-making to the scale of the controlling variables of the mix of ecosystem services desired – with improved resilience an outcome. The framework for governance must be more than a ‘hydrological one’. The governance has to consider all natural resources in an integrated fashion, not water in isolation.

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