Socio-ecological value of wetlands: the dilemma of balancing human and ecological water needs

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Humans' need for water has changed flow regimes, degraded ecosystems and depleted water resources. In the Wimmera Mallee in Victoria, the dilemma between human and ecological water requirements began in the colonial era when a channel and dam system was built to transport water. Prolonged drought prompted government to replace this with the Wimmera Mallee Pipeline. This pipeline produced a closed system, reducing water available for the environment, including on-farm wetlands. This study identifies the socio-ecological values of on-farm wetlands and the impact the changed water regime had on these. An interpretative landscape approach was used to integrate geophysical, ecological and social information on nine on-farm wetlands. This identified a range of socio-ecological values on-farm wetlands provide, including aesthetic, amenity, production and biodiversity, that are impacted by the pipeline system. A range of implications for on-farm wetland management were also identified in this study.

Keywords: Floodplain wetlands; on-farm wetland management; changing water regime; interpretative landscape approach

Introduction

In Australia, from the first European settlement, the need for water has led to the engineering of waterways. Over time, this has changed the landscape and degraded natural waterways, particularly in floodplains. Most Australian inland wetlands are located on floodplains in arid or semi-arid areas subject to intermittent rainfall punctuated by episodic flood events. Accordingly, these wetlands are unique in that their biota and ecological processes rely on the 'boom and bust' regime of alternating flood and drought (Jenkins et al. 2005). The life-cycles of arid-zone wetland biota are linked to flood pulses with the breeding of fish, waterbirds, frogs and other species, as well as seed production of fringing vegetation triggered by flood inundation (Junk et al. 1998; Reid & Brooks 2000). However, the majority of these ephemeral floodplain wetlands have been impacted by modified water regimes through river regulation, extraction for irrigation and domestic supply that have altered the flood-drought cycle (Bunn et al. 1996; Kingsford 2000; Jenkins et al. 2005). Furthermore, they have been heavily impacted by agriculture, though cropping, grazing, draining or filling and through pollution from catchment runoff (Jenkins et al. 2005).

Serious concerns for the loss and degradation of wetlands worldwide are well-documented, as this has resulted in a range of impacts on ecosystem health and functioning (Finlayson & Rea 1999; Bren & Sandall 2004; Swanepoel & Barnard 2007). Yet wetlands play important roles in ecological and social systems, providing a range of ecosystem functions (such as habitat for migratory birds and frogs, seed banks, watering holes for fauna and nutrient cycling) and social and recreational opportunities (including swimming, fishing, a place for contemplation and bird watching) (Finlayson et al. 2005). The value of wetlands, i.e. the range of range of functions and benefits they provide for both ecosystem and human wellbeing (Daily et al. 1997) has not been well-documented. This applies particularly to floodplain wetlands which are vulnerable to changes in flow regimes (Bunn & Arthington 2002). Decision makers have not taken into account the impact of changes in flow regimes on wetlands (De Groot et al. 2006). This paper aims to answer the questions: 1) What are the social and ecological values of on-farm floodplain wetlands? And 2) How do these values change with a change in flow regime? The Wimmera Mallee, in western Victoria, was chosen as a case study to answer these questions, as this region was undergoing a major change in water regimes.

In the Wimmera Mallee, the dilemma of balancing human and ecological water requirements began in the colonial era with the development of the Wimmera Mallee Stock and Domestic Supply System (WMSDSS), a regulated channel and dam water delivery system (called "channel system" here) to supply farms and towns from headwater storages. For over a century, this network of channels and dams was an integrated feature of the Wimmera Mallee landscape. Although this changed the natural landscape, this system provided a water source for people, flora and fauna.

Prolonged drought prompted the government to build the Wimmera Mallee Pipeline (WMP) between 2006-2010 to replace the channel system, minimising the loss of water from seepage and evaporation which occurred with the WMSDSS. As the pipeline is a closed system, it significantly reduced water in the environment, including for on-farm wetlands. Yet, on-farm wetlands play a vital role in the lives of farmers, their families and communities, providing a space for recreational and social activity i.e. family gathering, boating, barbeques, fishing and yabbying (McManemey 2009), as well as, birds, frogs and flora (Reid & Brooks 2000; Jenkins et al. 2005).The piped water delivery system is therefore likely to have many impacts on the social and ecological condition of the region. Thus, this article aims to identify the social and ecological values of on-farms wetlands in the Wimmera Mallee and how these values are affected by a changed water regime to understand the impact that changing water regimes has on social and ecological values of on-farm floodplain wetlands.

Water reform in the Wimmera Mallee

In Australia, the National Water Initiative (NWI) instigated major water reforms that are driving significant surface water distribution changes across the landscape (National Water Commission 2007). Victorian water policy advocates integrated water management strategies and water regime developments, like the WMP, as innovative water saving measures to secure future water supplies for people and the environment (DSE 2004a). Based on the water savings produced by the pipeline (estimated to be 103 000 ML (SKM 2001; DSE 2004a)), the Victorian government established a bulk water entitlement specifically to provide healthy aquatic ecosystems. In the Wimmera region this water entitlement specifies that the Wimmera and Glenelg Rivers receive an Environmental Water Allocation (EWA) from the proposed pipeline savings, to be managed by local Catchment Management Authorities (CMA).

The amount of water available for EWA is determined by GWMWater (the local water corporation). However, in Victoria the waterways which receive an EWA are prioritised based on the size and location of waterways, with major rivers receiving an EWA over minor waterways and large public wetlands before small on-farm floodplain wetlands. Further, wetlands listed as significant by Ramsar or similar lists also have priority access to EWAs. Thus, small rivers, floodplains and wetlands are not provided with an allocation. This is likely to reduce biodiversity within natural floodplain areas (Bunn & Arthington 2002) once a channel system is decommissioned, with potential consequences for the socio-ecological values of waterways such as on-farm floodplain wetlands.

Further, water harvesting practices in the higher rainfall regions of the Pyrenees, Grampians and Black Ranges reduces rainfall runoff into the Wimmera region that previously replenished ephemeral wetlands in this lower rainfall area, particularly during episodic flood events. Thus, although the WMP system will ensure water security for people living in the Wimmera Mallee, it will continue to reduce water availability for floodplain wetlands in the region.

Changing water regimes in the Wimmera

The WMP and channel system represent large-scale landscape hydrologic changes. Prior to the construction of the WMSDSS at the turn of the century, the ephemeral floodplain wetlands consisted of small freshwater lakes, meadows, swamps, gilgais (small ephemeral lakes formed in depressions), sinks and water holes situated in natural drainage lines and depression areas that captured runoff during episodic rainfall events.

The WMSDSS was the first regional hydrologic change in the Wimmera. The WMSDSS consisted of an extensive network of headwater storages, gravity-fed channels and dams that distributed water across the floodplain. Consequently, the WMSDSS altered natural floodplain hydrology, reducing floodplain runoff and altered timing and volume of flow events through the ecosystem.

The Yarriambiack Creek floodplain wetlands, the case study area for this article, are located in the low-lying or depression areas where runoff collects, making them ideal locations for on-farm dams. Surface water in these wetlands increased by the filling and sometimes the overflowing of the channels or farm dams. Seepage derived from the channels and dams also contributed to soil moisture. For over a century, associated wetland floristic communities, fauna and seasonal migratory waterbirds have adapted to the channel system surface water sources and high seepage rates in this highly modified regional water regime.

With the introduction of a reticulated piped water delivery system, headwater harvesting and the regulation of the natural watercourses will continue. The decommissioning of the channels means the end of regular annual floodplain seepage and surface water sources that came with annual channel runs. During the public consultation phase for the WMP, farmers expressed concern regarding future water sources for flora and fauna and for recreation. Whilst most agreed that the evaporation and seepage loss of water from the system was unsustainable, the loss of free water for floodplain ecosystems and recreation when the channels and dams are decommissioned was recognised as an issue for the socio-ecological landscape of the region. The main issues raised were about the loss of biodiversity and habitat, and the loss of dams on farm for recreation and amenity (Letts 2003; Barber 2004; Arthur 2004). Understanding the impact of this changed water regime is therefore vital for developing management strategies to reduce the socio-ecological impacts on floodplain wetlands and their associated communities.

This story is one that continues to be replicated in many arid to semi-arid areas in Australia, where water scarcity is driving similar water reforms to ensure water for communities. Therefore, this case study will provide some insight into the impact water reforms can have on the values of on-farm wetlands to help decision makers consider the full impact of water reform decisions and water management policies.

Thus, the aim of this study was to identify the social and ecological values of on-farm wetlands and investigate the impact the changed water regime had on these values for the Yarriambiack Creek floodplain in the Wimmera Mallee. To do this, an interpretative landscape approach was used which synthesises, integrates and spatially analyses geophysical, ecological and social information from maps, farmer interviews, field observations and secondary data.

The study area

The study area is located on the Yarriambiack Creek floodplain (Figure 1) in the Wimmera River Basin in Victoria. The Yarriambiack Creek floodplain wetland system is within the management jurisdiction of both the Wimmera CMA (WCMA) and GWMWater. The floodplain is a sparsely populated broadacre agrarian landscape, characterised by small wetland areas with remnant *Eucalyptus largiflorens* (Black Box) woodlands. These wetlands have varying degrees of connectivity to the channel system.

Within the study area, nine wetland areas on freehold agricultural land were selected as cases for this study. These wetlands are examples of the smallest landscape scale within an ecosystem (Kratochwil 1999). In this article, a wetland is considered as a small fragmented topographic low-lying, or depression floodplain area, subject to inundation.

The method used for this study was holistic, examining the geophysical, social and ecological operations within, and interactions between, the landscape scales within a regional system. The wetland, farm, floodplain and region scales were selected, as each of these scales have geophysical, social and ecological degrees of conformity within the regional water management context.

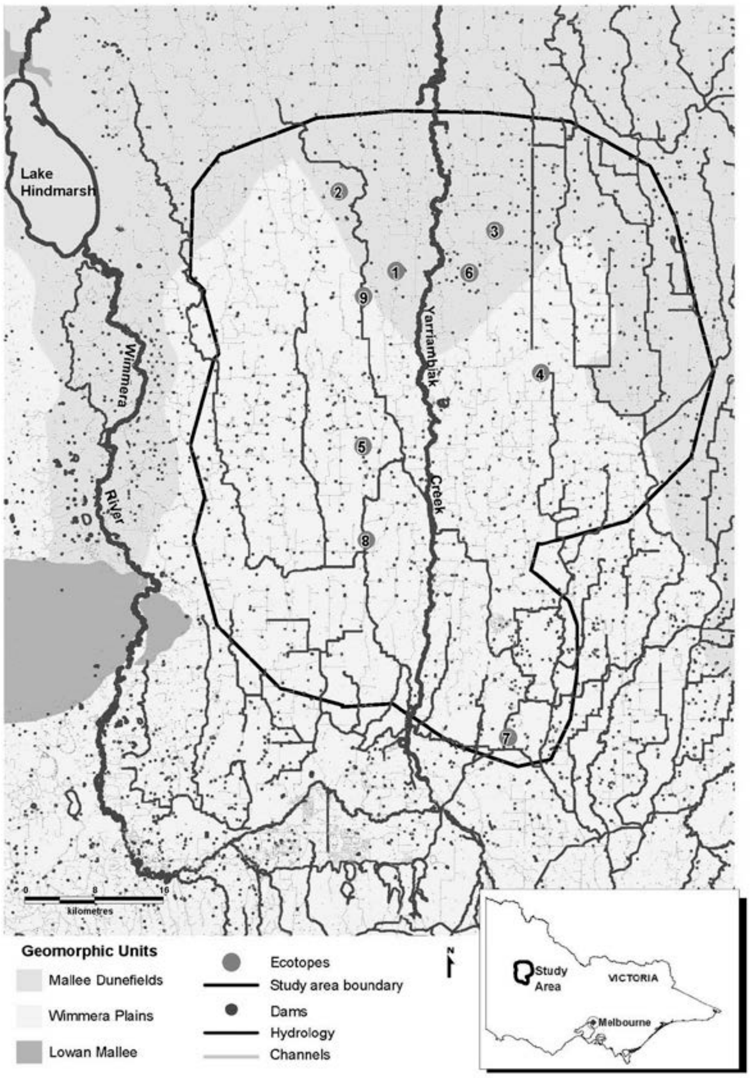

Figure 1. The study area and case locations within Yarriambiack Creek floodplain, Victoria, Australia

Method

Adopting a geophysical, social and ecological regional interpretative landscape approach provides a holistic context for understanding wetland socio-ecological values and water regime influences within a floodplain and regional context. As current knowledge of wetlands is diverse and fragmented, understanding wetlands within a landscape context through a geography lens reintegrates the fragmentation of wetland knowledge.

This article revisits traditional geography precepts that transcend multidisciplinary boundaries (Johnson 1985). This is because the human and physical variables within geography provide a holistic way to understand the interactive relationships and interconnectedness of the values that define a regional landscape (Johnson 1985). This study brings together geophysical, social and ecological data about the wetlands in relation to the channel system and pipeline water regimes within a farm, floodplain and regional landscape context (Figure 2). Thus, a mixed methods case study design was used where primary and secondary geophysical, ecological and social data were integrated to identify the socio-ecological values of on-farm wetlands using five stages:

1. Identification of wetland cases
2. A desktop study of the Yarriambiack Creek floodplain based on secondary data sources
3. An ecological assessment of each wetland during autumn and spring
4. Semi-structured interviews with the landholders of each wetland
5. Integration and synthesis of all data sources to determine the social and ecological values of these wetlands.

Wetland selection process

Floodplain or lentic wetlands with *E. largiflorens* woodlands that were not directly connected to the Yarriambiack Creek were targeted. This ensured conformity in the level of modification and pre-settlement floodplain hydrological processes between the wetland cases. However, final selection of each case was determined by the willingness of the landowners to allow the researcher to access the wetland on their property three times during the study and to participate in an interview.

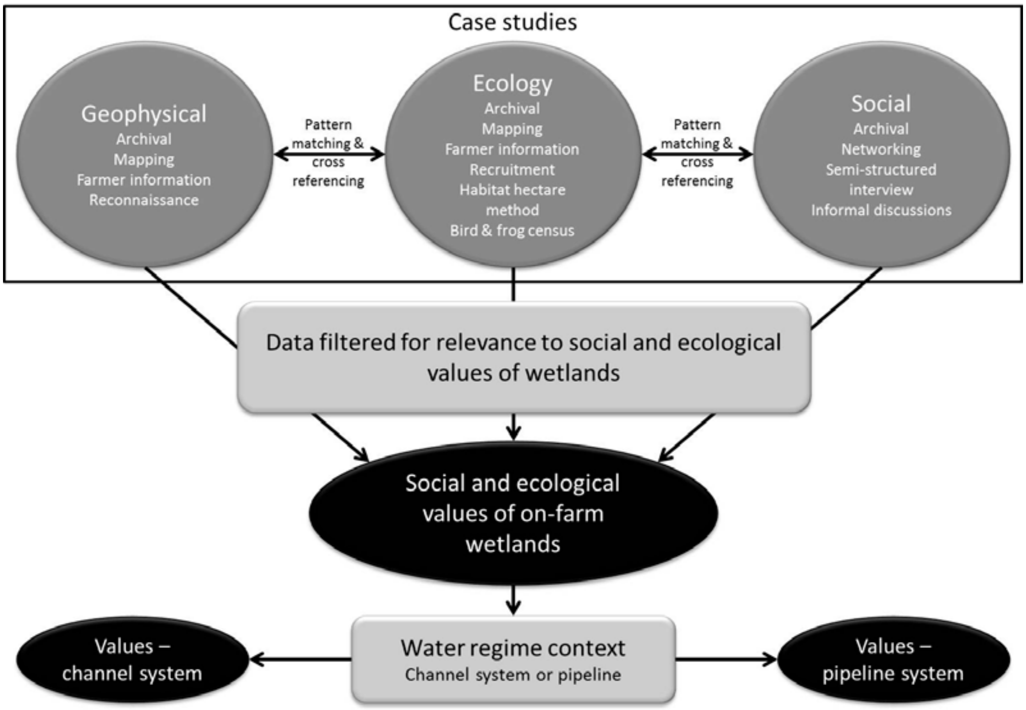

Figure 2. The research design.

An invitation to participate in the study was included in a WCMA mail out to farmers that was informing them of their wetland's EWA eligibility. Three farmers agreed to the study requirements. Using the snowballing sampling technique (Lewin 2005), a further ten farmers were approached and six agreed to participate in the study. During the preliminary assessment phase, one farmer withdrew from the study. Another farmer requested an additional wetland on his farm be included. This wetland was owned by three farmers with adjoining farms, who agreed to participate although one farmer later pulled out of the study. This wetland is treated as a single case.

This process of selecting wetlands could have led to some bias in the types of farmers involved with the study. However, the participants had a range of attitudes towards their wetlands and also used them in a variety of ways with some using them for production and others managing them for conservation purposes.

A total of nine wetland cases were selected (Figure 1 for locations). Each case is an on-farm ephemeral lentic (intermittent off-stream) wetland with an inundation area and associated *E. largiflorens* woodland. Each wetland had a range of locational variations such as distance to home site and connectivity to channel system. Further, each of the farmers manages their wetland in a variety of ways from fencing off areas of remnant vegetation to allowing livestock to graze in them. The following section describes the desktop and primary data collection methods used for this study.

The desktop study

The desktop study was a regional synthesis and integration of secondary data according to the landscape layers, spatial and temporal units and any external factors that may influence the value of on-farm wetlands. The desktop study compiled data as follows:

- A geophysical analysis study focused on the floodplain, farm and wetland scales using topographical maps, digital elevation models and aerial photographs.
- The ecological study synthesised the flora and fauna information sourced from Ecological Vegetation Class, ecological reports and floodplain species lists that relate to species' presence or absence, locational requirements, habitats, distribution and classifications (common, vulnerable or endangered) within the case study area. Introduced weeds and feral animals were also considered.
- The social study focused on community information and management reports relating to wetland and water regime management, conservation organisations and farmer's incentives, issues, values and attitudes.

The desktop study informed the primary data collection methods.

Primary data collection

Primary data collection principally focused on each wetland case based on sequential data collection for the mixed methods design (Creswell & Piano Clarke 2007). This included an onsite reconnaissance (in April 2007), a semi-structured farmer interview, and an autumn (in May 2007) and a spring (in September-October 2007) ecological appraisal. For each of the three fieldwork trips, the researcher spent a full day at each wetland. The data collection methods for each domain are described below.

Geophysical

Geophysical primary data collection relied on observation. The focus was the topography, hydrology and infrastructure spatial relationships and distribution patterns (Thorn 2006) in relation to soil-type, elevation, runoff patterns, flora and human occupation identified through aerial imagery and secondary data. All observations were recorded in a notebook.

The preliminary site investigation familiarised the researcher with the wetland's geophysical characteristics and ensured site suitability. The autumn fieldwork verified information obtained from the desktop study and, where possible, these observations were cross-referenced with farmer information from the interview and questionnaire. The spring fieldwork included natural or human modifications to the drainage patterns, the impacts of drought and the autumn rainfall events on run-off, changes in land-use (cropping and stock movements) and other changes that may have impacted on the wetland. It also provided the opportunity to cross-check the accuracy of the integrated autumn field observations, farmer information and secondary sources.

Ecological

The ecological component was not a scientific biodiversity study. Instead, the ecological appraisal indicated ecological values using methods that could be applied by lay assessors, such as farmers, without formal ecology training. Biodiversity indicators were based on Krebs (2001) and DSE (2004b), which included the presence of flora, bird and frog species, quality of the seed bank, distribution of species, numbers of hollows, canopy and tree health, regeneration and invasive weeds. The researcher randomly walked through each wetland area, stopping at intervals to observe, identify and record flora, bird and frogs. Sightings of other fauna species, weeds and feral animals were also recorded. This has been confirmed as a valid way of obtaining or confirming the biodiversity and health of a particular area (Jansen & Robertson 2001; Watson 2003). For birds, Watson's (2003) bird survey method was used, with three one hour random walks through each wetland at 9am, midday and 3pm. Upon arrival and before leaving the wetland the researcher sat and listened for frog calls. Frog calls were identified using the WCMA CD of Wimmera frog calls. Also, waterpools were checked for frog eggs and tadpoles, with any presence recorded.

Autumn fieldwork recorded observations including flora community, presence of habitats like tree hollows, density of leaf litter and logs, and presence of birds and frogs.

Spring fieldwork focussed on determining wetland ecological values using the Habitat Hectare vegetation quality assessment (DSE 2004b), to provide an indication of ecological condition, and diameter breast height (DBH) measurements (Brower et al. 1997) of *E. largiflorens* were taken to determine recruitment events. Further, the presence or absence of waterbirds, woodland birds and frogs as the indicator species were recorded.

Semi-structured farmer interviews

To understand the social values, and confirm ecological values, of on-farm wetlands and the impact of changing water regimes on these values, in-depth semi-structured interviews were conducted with farmers. These interviews took place at the farmer's residence or at the wetland. Conducting the interview in the 'natural setting' makes people more comfortable and reflective of the issues being discussed (Norris & Walker 2005), and allows the farmer to convey their values through their understanding of the geophysical features, ecology and management practices (Creswell & Piano Clark 2007). The study methods were approved and managed in accordance with the University of Ballarat Human Research Ethics Committee guidelines.

Sample

The nine farmers who managed the wetland cases were interviewed. These farmers had a range of social and demographic variables not dissimilar to that of farmers in the wider Yarriambiack Creek floodplain (Table 1). They also had a range of attitudes towards their wetland from a production to conservation focus.

Interview questions

The interview was designed to determine how farmers use their wetlands and how they feel about them. The interview was divided into three sections: geophysical, ecological and social. The geophysical section asked about the farm-scale and wetland topographic features, soil types, gypsum use, landscape modifications, agricultural land use and hydrological characteristics. The ecological section included floral and faunal knowledge, the channels' and dams' influence on the ecology, and farm and conservation management practices. The social section included farmers' generational information, succession planning and current farm ownership, the use and value of the wetland to the farmer and the farming business. Farmer views on the impact of decommissioning the channel system on the wetland were also sought.

Table 1. Farmer profiles for the nine wetland cases

Farmer	1	2	3	4	5	6	7	8	9a	9b
Age group	>55	>55	46-55	46-55	36-45	>55	36-45	46-55	>55	>55
Employment status	SR	FTF	FTF	FTF	FTF	SR	FTF	FTF	SR	R
Live on/off farm	On	Off	On	On	On	On	Off	On	Off	Off
Owns/leases farm	Owns	Owns	Owns	Owns	Leases	Owns	Owns	Owns	Part-owns	Part-owns
Household size	1	1	2	5	2	2	4	4	1	2
Farm inherited (I) purchased (P) or leased (L)	I	P	P	I	L	I	P	P	P	P
Farm size (ha)	500	2130	1600	1042	1021	550	450	470	350	547
Wetland area (ha)	17.7	26.6	18.3	42	8.2	23.9	73.7	20.7	17.0	10.4

Note: SR=Semi-retired; FTF = Full-time farmer; R = Retired

Data collection and analysis

Data was collected between April and October 2007. This was influenced by autumn rainfall limiting access to some sites and the cropping season limiting access to farmers. The interview took two hours. Notes were taken during the interviews and were used to identify the social and ecological values of on-farm wetlands using a thematic analysis.

Data interpretation

Integration of the geophysical, social and ecological research domains requires the interpretation and synthesis of diverse data using a range of methods including spatial synthesis (Daniels 1985), pattern matching logic (Trochim 1985; Yin 2003) and cross referencing between data sources. Spatial synthesis, which is the synthesis of a range of data connected to a specific location, was used to integrate the secondary and primary data collected for each case study to begin to identify the socio-ecological value of each wetland. Pattern matching logic is a method where themes from one case study or source are compared to other cases to determine if they fit, providing validation for the original themes (Trochim 1985; Yin 2003). This method was used to validate the socio-ecological values identified from each case. Fieldwork observations and secondary data including geophysical, ecological and spatial imagery were then used to cross-reference the values identified to further strengthen the validity of the findings. The socio-ecological values were considered both in the context of the channel system and the pipeline system to resolve whether the value of the on-farm wetlands changed with the water regime change. The aim was to identify the range of socio-ecological values of on-farm wetlands and the change in these values due to the water regime change. Hence no attempt was made to discover whether any groups of farmers had different values attached to their wetland.

Results

The social and ecological values of on-farm wetlands

Within the Yarriambiack floodplain, on-farm wetlands are one of the last remaining natural habitat areas due to wide-scale clearing for agriculture. These wetlands survived as they were low-lying depression areas subject to flooding and drying out, making them unsuitable for cultivation. They have a range of social and ecological values (Table 2), as revealed by the integration of geophysical, social and ecological data collected in this study.

The social values of these wetlands extend beyond the traditional farming production benefits of water and shelter for stock, grazing area or drought proofing the farm. The wetlands also provide a place for relaxation, recreation and social and family gatherings: a place where people can stay connected with nature. Farmers commented:

> *It is important to have trees around as trees give us pleasure and have a deep seated value for humans*

> *Water came down the channel…and so did the kookaburras. We were delighted…they 'laugh' every morning at 5.30am!!*

> *The timber paddock [wetland] was kept for recreation, walks and to study nature such as bids and wildflowers*

On-farm wetlands also provide a sense of place and help enhance farmer and farm family mental health and quality of life, as demonstrated by this farmer's comment:

> *I would love to look out the window once again and see the lake full of water and the quality of life it brings*

The ecological values of on-farm wetlands include regional and local biodiversity, wildlife habitat, refuges and corridors, landscape hydrology, soil maintenance, seed banks for flora, insect and frog recruitment and groundwater recharge. For example, the large to small hollows in *E. largiflorens* provide valuable habitats for many wetland species.

Many of these ecological values provide ecosystem services which also aid farm production, such as pollination, flood mitigation, nutrient cycling, soil moisture retention and erosion control. They also contribute to the aesthetic, cultural and heritage, recreational and other social values described by the farmers, such as bird and wildlife watching, clean water for the farm and household and insect control. Thus, the ecological values of wetlands are intertwined with the social values, as demonstrated by these farmers' comments:

> *Native bees pollinate crops, fruit trees [on-farm] and native plants*

> *Frogs take care of the mosquitos breeding in the stagnant waterpools [on-farm]*

Table 2. The social and ecological values of on-farm wetlands

Social values	Ecological values
Aesthetic	Habitat for birds and other wildlife (aquatic and terrestrial)
Amenity (being close or seeing nature)	Water source for fauna
Bird and wildlife watching	Flood mitigation
Family life	Mosquito control via frogs
Social gatherings	Soil moisture retention
Recreation (i.e. boating, swimming and yabbying)	Nutrient cycle
Farm management	Erosion control
Drought proofing	Groundwater recharge
Grazing area	Provision of clean water
Stock water source	Pollination of crops, fruit trees and native vegetation
Stock shelter	Wildlife refuges
Quality of life	Soil maintenance
Mental health/relaxation	Landscape hydrology (runoff direction/barrier)
Water source for household	Flora recruitment (flora seedbank)
Timber for firewood	Frog recruitment
Cultural and heritage (sense of place and belonging)	Insect recruitment
	Wildlife corridors for migratory fauna

Furthermore, farmers who highly value the ecological benefits they receive from their wetland tend to implement conservation measures to preserve and enhance their wetland's ecological value. As the ecological values of the wetland increase, so do the social benefits the farmer receives from the wetland; hence, ecological values contribute directly to social values of wetlands, demonstrating the reciprocity between people and nature.

Although not the main focus of this article, a number of sequent occupance (Leighly 1967) factors, that is factors related to human occupation, were identified that influence farmer's values, their sense of place and connection to the on-farm wetland. These include the location of the wetland in relation to their residence, type and amount of wetland use, farm management practices, length of time on farm, farmer values (i.e. environmental versus production) and owner versus lessee. Farmers are more likely to identify a wide range of social and ecological values when the wetland is near the house, they have been on the farm for a long time and have a connection to the wetland though history of use for recreation, family and social gatherings, and even farm production. In comparison, farmers who do not own the property, do not live near the wetland, have no historical connection to the wetland or are more production focussed are less likely to identify a wide range of social and ecological wetland values. This difference in values has implications for how the wetlands are managed by the farmer: as already noted, if the farmer places more value on the wetland they are more likely to be using conservation measures.

Changes in social and ecological values due water regime change

The change in water regime in the Wimmera Mallee will reduce the amount of water flowing to many on-farm wetlands in the region as they are not eligible for environmental water allocations as they are not 'wetlands of significance'. This means that many on-farm wetlands, including the majority in this study, will become dry, changing their social and ecological value. Some of these changes provide benefits to farmers, their communities and the ecosystem; others have a negative impact on socio-ecological values (Table 3).

The main positive changes in social values are an increase in water security and quality for farm and domestic use and increased surety of farm production. These were described as '*…the huge advantage of piped water to our farm*' by one farmer. The negative impacts on social values are the loss of wildlife, amenity and aesthetics, loss of recreational opportunities, loss of space for family and social gatherings and associated negative impacts on quality of life and mental health. Some of the negative impacts are summed up by this farmer's comment:

> *The channel and dam system has been the lifeblood of this country and it will be sad to see it go as without water there is no stock, gardens or biodiversity*

Ecological values will be heavily impacted with the '*loss of 'free' water for wildlife'* and vegetation, decline in soil moisture, loss of birds and other wildlife, change in vegetation structure and reduced ecosystem function. The loss of water in the system will cause dieback of large trees from water deprivation, causing a loss of structural flora. This will reduce habitats for birds and other fauna placing further pressure on habitat availability within the floodplain system. Fauna are more closely linked to the channel systems, and therefore, biodiversity is likely to decline with the introduction of the pipeline, in particular frog and waterbird species who have adapted to the annual channel and dam water sources that coincided with their breeding cycles. One positive ecological change identified was a reduction in the spread of pests and weeds transported by the channel system.

Table 3. The change in social and ecological values of on-farm wetlands due to the changed water regime

Impact	Social values	Ecological values
Positive	Water security	Reduced weeds
	Cleaner water for use	Reduced numbers of pest species
	Domestic water supply	
	Ability to have watering system for garden	
	Agriculture production	
	Farm management	
	Access to water for fire fighting	
	Stock water	
Negative	Loss of wildlife	Loss of water for wildlife
	Reduced aesthetic and amenity values	Loss of water for vegetation
	Loss of recreational opportunities	Loss of habitat for fauna
	Loss of a stock watering point	Loss of birds and other wildlife
	Impact on quality of life	Decline in soil moisture
	Impact on mental health	Change in vegetation types
	Loss of space for family and social gatherings	Impacts on recruitment of flora and fauna
	Reduced bird and wildlife watching opportunities	Dieback of vegetation
	Loss of dam water for fire fighting	Ecosystem function reduced

Implications for wetland management under changed water regimes

The socio-ecological values of on-farm wetlands identified in this study highlight the wide range of benefits farmers, their community and the ecosystem receive from wetlands in arid and semi-arid areas. The social values include a place for social gatherings, finding solace in nature, recreation, drought proofing the farm, stock watering and flood mitigation. The ecological values include a water source and provision of habitats for birds, frogs and other fauna, soil moisture and seed banks for flora recruitment. These socio-ecological values are often intertwined, with many of the social values reliant on high ecological values, and the protection of ecological values being related to high social values attached to the wetland by the managing farmer. The range of values identified here is comparable to that of Finlayson et al. (2005) for inland wetlands, indicating that these values are indicative of the socio-ecological values of on-farm floodplain wetlands in arid areas. Thus, this article provides decision makers insight into the value of these wetlands to farmers, farm families and their associated communities for consideration in future water regime decisions.

The dilemma of finding the balance between human and ecological water has become apparent in the Wimmera, with the decommissioning of the channel system and replacement with the pipeline. This change in water regime is likely to ensure human water needs will be met into the future in the region and prevent flooding. However, it reduces the water available for floodplain on-farm wetlands, changing both the social and ecological values of these wetlands. The social values related to farming will increase, reflecting the fact that the Wimmera Mallee Pipeline will help meet human water needs, yet the majority of ecological values and social values related to quality of life, cultural, recreation and amenity will be negatively impacted.

The negative impacts on socio-ecological values of on-farm wetlands were not fully understood or considered during the decision-making process for the pipeline. However, with many on-farm wetlands in the region not listed as significant, they are not eligible for an EWA and will only receive water from localised rainfall or if the farmer pays for water for the wetland, because water flows through the region's rivers are largely restricted to prevent flooding. This study shows that on-farm floodplain wetlands have many socio-ecological values for farmers, their families and communities, and thus, they are 'significant' to these communities. Thus, the impact of this pipeline on ecosystem and community health and wellbeing in this region may be significant with flow-on effects to the local economy. This is not a situation unique to the Wimmera, as similar water supply decisions are being made in many arid and semi-arid regions in Australia. Consequently, this article calls for a revision of the criteria used to determine which wetlands receive EWAs, and how EWAs are determined each year, to reduce the impact that the pipeline has on ecological and community health and wellbeing in the region.

The findings of this study have implications for wetland management on freehold agricultural land subject to a modified water regime in arid and semi-arid climates. To reduce the impact of a change in water regime on on-farm wetlands, natural resource managers need to work closely with farmers to identify and maintain the socio-ecological values of on-farm wetlands, as much of the knowledge about wetland management is held by farmers who currently manage the wetlands. There needs to be greater levels of community collaboration in decisions on water management to ensure that any change in water regime and environmental water allocation decisions consider the impact on the socio-ecological values of on-farm wetlands.

A closer collaboration will also help farmers and natural resource managers to work together to preserve and enhance the socio-ecological value of on-farm wetlands, even in the face of changing water regimes. Without this change to wetland management, we can expect to see many more floodplain wetlands become degraded, which will have far-reaching landscape, biodiversity, community health and wellbeing and economic impacts at the farm, community and regional scales. Thus, it is important for natural resource managers to develop inclusive communication pathways and adaptive management strategies that recognise farmers' wetland conservation management knowledge and practices. This would help current knowledge gaps to be bridged and appropriate conservation management strategies to be developed for on-farm wetlands, and make steps to address the dilemma between human and ecological water needs.

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