Hydrol. Earth Syst. Sci. Discuss., 10, C6090–C6094, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C6090/2013/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Socio-hydrologic drivers of the Pendulum Swing between agriculture development and environmental health: a case study from Murrumbidgee River Basin, Australia" *by* J. Kandasamy et al.

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Received and published: 4 November 2013

We thank the reviewer for the comments provided. We address the comments raised.

MINOR COMMENTS Reviewer comment: I think that numerous downstream regions of European and North American countries have had similar experiences. To go beyond site-specific conclusions, I think that the paper can benefit from a wider discussion of the dynamics of Murrumbidgee river basin that can generalized and the ones that are specific for this case study. For instance, in a review paper on HESS, Di Baldassarre

et al. (2013) discuss the so-called "levee effect" and the fact that in many areas of the world the continuous heightening of flood protection structures, i.e. "fighting floods", has been partly replaced with different policies of "living with floods", e.g. "floodplain reconnection", in the USA; "room for the river" in the Netherlands, making space for water", in the UK. I think that there is a strong analogy between these policy shifts and the pendulum swing described by Kandasamy et al. also in view of their relationships with the environmental concerns underpinning both of them.

Author response: Thank you for this suggestion. Like the reviewer, the authors acknowledge that many catchments around the world appear to have had similar experiences, eg Sacramento River Watershed in California, USA. Further, this pendulum swing trajectory is only explained if one considers the changing norms governing the relative value placed on water use in agriculture, versus in-stream water and its availability to the environment. The existence of common trajectories across many regions suggests that predictive insights may be gleaned by observing the co-evolutionary trajectories of comparable coupled human-water systems. The reviewer's suggestion is a valuable one and in line with the paper objectives in advancing the case for socio-hydrology. This will be incorporated into the revised paper.

Reviewer comment: The paper states that the "Lowbidgee Flood Control and Irrigation District" was established in 1945. In Australia, as in many parts of the world, flood risk and irrigation are two main (interrelated) topics in the management of downstream river reaches. I appreciate that this paper gives emphasis to the irrigation issues, but I believe that it would be worth mentioning the link with flood risk. Besides the aforementioned relationship with the "levee effect", it would be important to understand how flood control is framed in this region and whether the occurrence of extreme events may (or not) have changed the policy discourse. For instance, it is mentioned in the paper that the "reduction of flows significantly reduced the frequency and duration of inundation" that negatively impacted the environment, including fauna and flora. In addition to that, it would be interesting to know if such a reduced frequency and duration of inundation

was actually meant to reduce potential flood damage to people and infrastructures.

Author response: The Lowbidgee is situated on the Murrumbidgee River floodplain between Maude and Balranald (Figure 1). The Lowbidgee Floodplain is the largest area of floodplain wetland in the Murrumbidgee Valley, and includes the second largest river red gum forest in Australia, as well as significant black box, lignum and reed-bed communities. The Lowbidgee has been identified as a nationally important wetland, in part because it covers a large area (217 000 ha) and is strategically placed for the provision of ecosystem services to the Murray-Darling river system, but also because it is regionally significant for waterbirds, both as a drought refuge and as breeding habitat.

Under natural conditions the Lowbidgee wetlands experienced regular inundation by floodwaters from the Murrumbidgee River, driven by reliable winter and spring rainfall and snow melt (Kingsford and Thomas 2004). Channel capacity within the Lowbidgee floodplain was low and comprised a complex system of interconnected creeks flowing east to west (Kingsford and Thomas 2004). Flooding occurred on average every two to three years, although there were years where the river achieved bankfull conditions without overflowing onto the floodplain. Flood events were also known to 'cluster', whereby the system would experience two or three floods in quick succession followed by a drier period. Under natural conditions the entire Lowbidgee system was ephemeral, with the channel, riparian zone and floodplain each linked in a wetting and drying regime that supported a diverse 'boom and bust' ecology typical of inland river systems in Australia. Accordingly, under natural conditions water levels in the Lowbidgee would have been highly variable. Inland Australian wetlands are most productive when flooding follows a period of complete drying.

The Lowbidgee is also a significant wetland habitat for water birds in eastern Australia. Sixty species of waterbirds have been recorded on the Lowbidgee floodplain and 41 of these are known to breed in the Lowbidgee wetland (Kingsford and Thomas 2001). The wetlands additionally provide important habitat for fish, frogs (including the endangered

southern bell frog) and macro-invertebrates.

The Lowbidgee Flood Control and Irrigation District was constituted on 24 January 1945. River flow regulation significantly reduced flooding and inundation of wetlands along the river. The construction of Burrinjuck dam in the headwaters of the Murrumbidgee in 1910, curtailed natural flooding. To compensate for this loss, two weirs; Maude and Redbank, were constructed on the Murrumbidgee River in 1939 to artificially flood the Lowbidgee wetlands.

The extent of the Lowbidgee wetlands has significantly decreased in recent decades due to flow regime changes in the regulated Murrumbidgee River, the construction of levee banks to control floodwaters and the conversion of wetland floodplain into irrigated cropland. Conversion of wetland into cropland in the wider Lowbidgee floodplain has seen construction of extensive channels and embankments throughout the wetlands, and of large supplementary licenced water storage bays. Further, river regulation and the construction of levee banks to control floodwaters have reduced wetland availability by 60% (1975-1988) .The Lowbidgee wetland area in 1902 was estimated at 303,781 ha. Between 1902 and 1998, 232,276 ha were estimated to have been lost or degraded. During this period, 2,145 km of levee and 394 km of channels were constructed for irrigation and agriculture purposes.

Surveys of the wetlands between 1983–2001 into numbers of species, abundance, and different waterbird groups in the valley show a significant decrease over time. The total numbers of waterbirds is expected to decline by 80% (1983-2000), implying the degradation of the associated wetlands in the Murrumbidgee, Kingsford and Thomas (2004). This threatens the health of the remaining wetlands which are adversely affected by the change in the distribution of flows and reduced flood volumes. The current extended drought has exacerbated the effects of river regulation placing greater environmental stress on water dependent ecosystems.

In relation to the authors comment, the reduction in frequency and duration of inunda-

tion was not actually meant to reduce potential flood damage to people and infrastructures but to provide more land for agriculture and in doing so caused the significant reduction in what was an extensive wetland in inland Australia.

The issue of flooding and the health of the wetlands and the wider ecology issues are intimately inter-connected and this will be incorporated into the revised paper.

TECHNICAL COMMENTS Reviewer comment: Would be possible to express the figures in page 7202, lines 11-17, in relation to Australian GDP? Author response: As an indication, the GDP in the years 2006–07, 2007–08, 2008–09, 2009–10, 2010–11 were 1202 billion (B), 1247B, 1264B, 1293B and 1320B respectively. Agricultural production within the Murrumbidgee which is valued at over $ 1.9 billion annually is about 0.2% of the Australia's GDP. During the first half of the 20th century, agriculture accounted for up to 35% of the Australian economy and 70–80% of Australia's exports. Agricultural share of the Australian economy started to decline from the 1950's to its present value of just 4% and Australia's reliance on agricultural exports declined to about 20% (Fig. 4g).

This paper will be amended to also express these figures in relation to Australian GDP.

Reviewer comment: The paper would benefit from a double check of the text. I found a few minor typos (e.g. "This emergent dynamics"; Sentence in page 7206, lines 5-7, check the use of "here" after "in this paper"). Author response: This will be amended in the revised paper along with relevant text.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 7197, 2013.