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Assessing certainty and uncertainty in riparian habitat suitability models by identifying parameters with extreme outputs

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ABSTRACT

The aim of this paper is to introduce a computationally efficient uncertainty assessment approach using an index-based habitat suitability model. The approach focuses on uncertainty in ecological knowledge regarding parameters of index curves and weights. A case study determines which of two 15-year periods has more suitable surface water and groundwater regimes for riparian vegetation. The uncertainty assessment consists of defining constraints on index curves and weights. Linear programming is used to identify parameters that yield two extreme outputs: maximising and minimising differences between the two periods. Because they are extremes, if both outputs agree on which period is better (e.g. maximum and minimum differences are both positive), then all other models will also agree. Identifying models with extreme outputs prompts learning about the boundaries of our knowledge and identifies patterns about what is considered certain. It helps build an understanding of what is already known despite the high uncertainty.

1. Introduction

Riparian vegetation is increasingly under threat from human activities and climate change. Damming, surface water extraction, groundwater pumping and other human interventions have caused serious changes in the functioning of riparian ecosystems, resulting in widespread decline in the extent and health of riparian vegetation (Allan and Castillo, 2007; Ward and Stanford, 1995). This is especially so for riparian systems in arid and semi-arid regions where water can be more scarce, or at least more temporally variable, yet in high demand for human use, resulting in greater extraction of surface water and groundwater resources (Stromberg et al., 1996).

Maintaining the integrity of riparian ecosystems that provide valuable services whilst continuing to reserve and extract water for other purposes necessitates a greater understanding of relationships between riparian vegetation health and water regimes. Ecological models can be useful tools to investigate these relationships and assess the potential impact of water stress on riparian vegetation (Robson, in press). For example, empirical relationships between surface water hydrological variables and riparian vegetation cover (Auble et al., 1994), structure (Stromberg et al., 2010) and distribution (Camporeale and Ridolfi, 2006) have been developed based on monitoring data. These models have been used to quantify in-stream flow requirements of riparian vegetation or predict vegetation change resulting from a proposed upstream dam or diversion. Loheide and Gorelick (2007) developed empirical relationships between riparian vegetation type and depth to the water table to examine the impact of streambed incision on the composition of riparian vegetation communities. In the absence of sufficient monitoring data, however, an index-based approach can be a very useful way to evaluate habitat suitability based on literature and/or expert opinions (Yamada et al., 2003).

One of the major challenges in ecological modelling for understanding and managing riparian ecosystems is assessment of their uncertainties. These uncertainties can be high especially at large scales and when there is limited knowledge and informative data to quantify relationships between variables. High levels of uncertainty limit the use of models for assisting management and decision making. Traditionally, uncertainty analysis for ecological models has been used as an additional stage in evaluating model outputs using various approaches such as fuzzy bounds (Burgman et al., 2001), Monte Carlo simulations (Dietzel and Reichert, 2012; Straatsma et al., 2013; Van der Lee et al., 2006) and ensemble models (Estes et al., 2013). Those approaches can be limited by their computational cost, particularly where sampling methods such as

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Monte Carlo are used. Their application depends on the availability of sufficient data, models, expert knowledge and assumptions to define parameters such as probability distributions or possibility levels. Using ensemble models only considers a small set of models, which can limit exploration of uncertainty. These uncertainty analysis processes are typically not interactive, emphasising the creation of a final product rather than evolution over time. Their focus is typically on communicating uncertainty, leaving the end-user to understand and make use of that information.

The aim of this paper is to propose an additional uncertainty assessment approach, thereby bridging these gaps and inviting the modelling community to further test its usefulness in their own applications. In the paper, we illustrate a computationally efficient approach assessing uncertainty in index-based habitat suitability modelling, specifically addressing the situation where limited data are available and expert opinions differ significantly. The habitat suitability model estimates the suitability of surface water and groundwater for three riparian vegetation species. The focus of the uncertainty assessment is on what can be presumed certain in predicted model outputs given current agreed knowledge, thereby evaluating the state of knowledge, identifying knowledge gaps and reflecting on the impact of adding assumptions.

2. Study area

The Namoi River Catchment forms part of the Murray–Darling Basin and drains an area of approximately 42,000 km^2 in northern New South Wales (Fig. 1). Rainfall generally decreases from east to west across the catchment, with annual averages of 945 mm at Niangala near the headwaters, 620 mm at Gunnedah in the midsection of the catchment and 480 mm at Walgett in the low lying plains of the west. This study focusses on the mid to lower sections of the Namoi catchment, downstream of Gunnedah. The lower Namoi River is categorised as an anabranch and distributary river zone where the condition of the floodplain is important to river function (Lampert and Short, 2004).

The Namoi River has a long history of river regulation with the first dam having been constructed in 1960. The major impacts of river regulation in the Namoi include altered seasonal flow and reduced flood frequency and flows, most pronounced on the small to medium flood events (Sheldon et al., 2000). It also has the highest groundwater use in the Murray–Darling Basin. In 2004/05, groundwater extraction in the Namoi was estimated to be 255 GL, accounting for 15.2% of the total groundwater use in the Murray–Darling Basin. Some 35% of the groundwater extractions in the Namoi Catchment was from the Lower Namoi Alluvium Groundwater (CSIRO, 2007).

The major streams and rivers of the catchment are dominated by river oak (*Casuarina cunninghamiana*) and river red gum (*Eucalyptus camaldulensis*). Large areas of riverine land in the Namoi catchment have been converted to cropping and pastoral uses, effectively meaning that, except for habitat corridors and patches of riparian vegetation, most of the native vegetation has been cleared (Eco Logical, 2009). The lower Namoi does not have large wetlands, but contains many small lagoons, wetlands, anabranches and flood runners (Green et al., 2011). Although large in number (1829 natural and 937 artificial wetlands), most of the wetlands are small in size and scattered across the floodplain and major tributaries (Eco Logical, 2008).

3. Methods

This section defines terms that will be used, describes the habitat suitability model and introduces the uncertainty assessment approach.

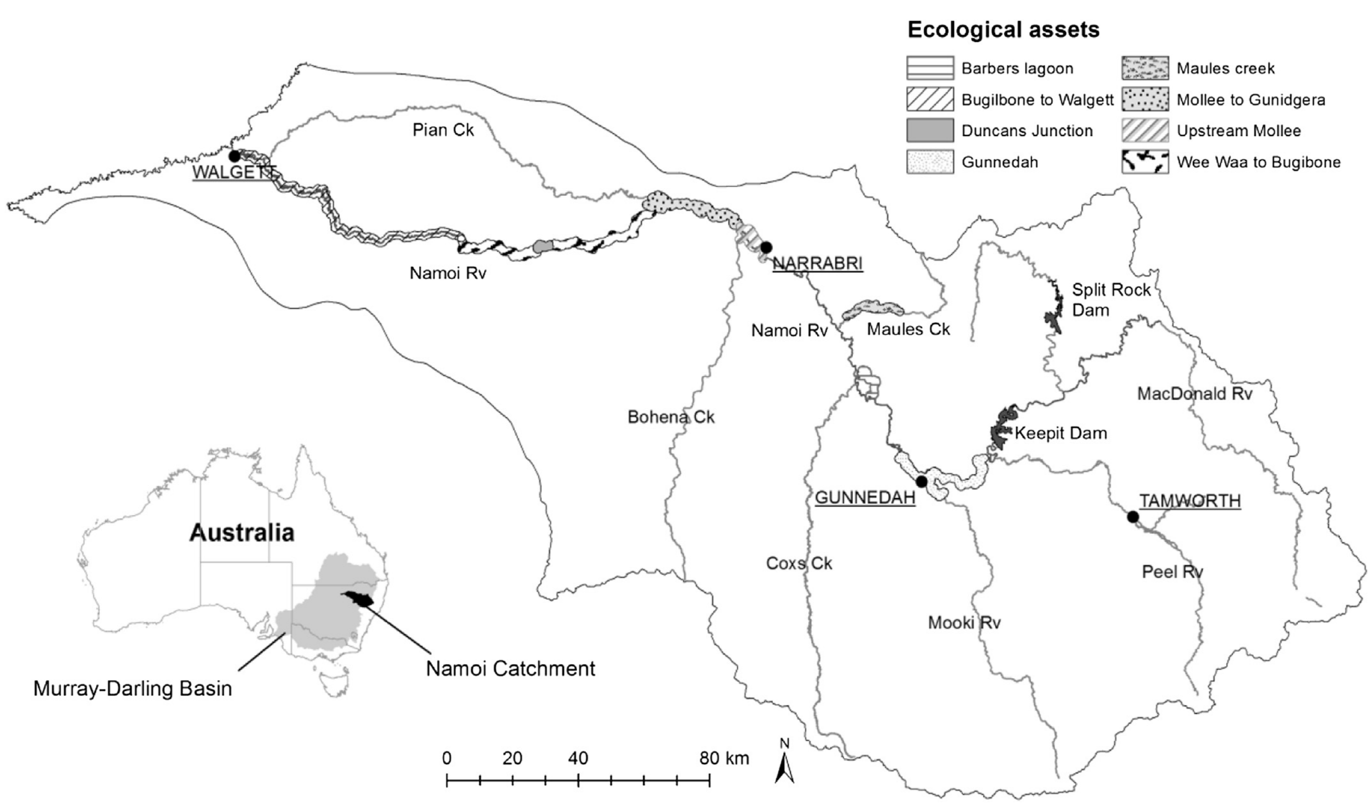

Fig. 1. Namoi River catchment, showing asset sections along the river.