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Assessing the net benefits of achieving water quality targets using a bio-economic model

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ABSTRACT

The aim of this study was to develop a bio-economic model to estimate the feasibility and net profit (or net costs) of achieving set water quality targets (sediment, nitrogen, phosphorus and herbicide load reductions) in the Burnett-Mary region within the southern portion of the Great Barrier Reef (GBR), southern Queensland, Australia. Two sets of targets were evaluated, namely (1) Reef Plan Targets (RPTs) representing currently agreed targets, and (2) the more ambitious Ecologically Relevant Targets (ERTs) designed to halt the decline and improve the condition of the GBR. This paper describes the construction of a bio-economic optimisation framework linking field and catchment scale biophysical model results and farm economic analysis to solve for RPTs or ERTs assigned either regionally or within discrete basins. Key outcomes from the study were that RPTs could be achieved whereas ERTs required significant additional investment and were infeasible if individual basins must meet the targets.

1. Introduction

The spatial optimisation of land use and management practices under various objective functions and constraints is a useful approach to evaluate the likely degree of land use and management change required to meet environmental targets. Numerous methods of spatial optimisation have been developed to identify the optimal location and management practice within a watershed to minimise detrimental environmental impacts whilst maximising profitability. Options include dynamic linking with (1) a watershed model, (2) a surrogate model or (3) lookup tables. These three options have varying computational costs, model complexity and applicability in a participatory modelling context. A popular method of spatial optimisation is the dynamic linking of a watershed simulation model with an optimisation algorithm (Arabi et al., 2006; Kalcic et al., 2014; Cibin and Chaubey, 2015). This approach generally requires thousands of simulations to predict the optimal distribution of spatially variable water quality processes. Additionally, the watershed models are typically computationally complex and the optimisation process may take weeks to complete. To overcome these limitations surrogate models based on a simpler representation of the complex physical processes have been applied to limited scenarios (Sreekanth and Datta, 2011). However, these models can induce more uncertainty to the optimisation results (Sreekanth and Datta, 2011; Cibin and Chaubey, 2015) due to the limited level of complexity in the conceptual model. Another approach is the use of a lookup table of effective export coefficients or tabulated calibrated results from a range of biophysical models. This approach does not involve the dynamic linking of a watershed model with the optimisation algorithm which overcomes issues with the size and non-convexity associated with the former approaches (Doole and Pannell, 2008). The major benefits of an optimisation construct built around lookup tables is that it is basic enough to use in a participatory context (Roberts et al., 2012; Beverly et al., 2013; Doole, 2013) whilst being sufficiently flexible to utilise results from complex hydrological watershed models (Doole, 2015). Importantly, the complexity of the model can be readily altered which is a key consideration if the model and results are to be applied in multiple contexts (Doole and Pannell, 2013) and/or communicated to diverse stakeholders. The general form of this type of modelling approach has been extensively applied throughout Australia and New Zealand in numerous agricultural and policy contexts (Doole, 2012; Roberts et al., 2012; Howard et al.,

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2013; Beverly et al., 2013; Doole, 2013; Doole et al., 2013; Holland and Doole, 2014).

This paper describes the design and application of a spatial optimisation model based on the lookup table approach to assess the feasibility and cost of land management change required to meet environmental targets in the Burnett-Mary region in Queensland, Australia. This region includes the southern-most portion of the World Heritage listed Great Barrier Reef (GBR) Marine Park and the Ramsar listed Great Sandy Strait (Fig. 1). The region covers 56,000 square kilometres (5.6 million ha) of land and encompasses five major river basins (Baffle, Burnett, Burrum, Kolan and Mary). The Baffle, Kolan and the Burnett catchments flow to the GBR Reef Marine Park whilst the Burrum and Mary flow to the Great Sandy Strait Marine Park. Arguably, the region hosts biodiversity values that are globally important. The health of the coastal and inshore marine areas is influenced by the quality and quantity of runoff from these five river basins in which the major primary industries are grazing, sugarcane, horticulture, forestry and mining. Increased loads of nitrogen, phosphorus, sediments and pesticides from adjacent catchments as reported by Kroon et al. (2013) have led to detrimental changes in environmental conditions for GBR species and ecosystems (De'ath et al., 2012).

To help protect the values of coastal and marine receiving waters, the Burnett-Mary Regional Group (BMRG) with funding from the Australian Government commissioned the development of a Water Quality Improvement Plan (WQIP). The focus of the WQIP (Anonymous, 2015) was to improve water quality through the implementation of agricultural management practices based on the 'ABCD' water quality risk framework for the sugarcane and grazing industries (Anonymous, 2013a, 2013b). 'A' practice represents cutting edge unproven technologies, 'B' represents current best-management practices, 'C' is common current industry practice and 'D' is below industry practice expectations. A bio-economic model was developed to assist the Burnett-Mary regional group evaluate the feasibility and costs of various management options to achieve two sets of pollutant load reduction targets, namely (1) the Reef Plan Targets (RPTs) representing the currently formally agreed targets, and (2) the more ambitious Ecologically Relevant Targets (ERTs) reported by Brodie and Lewis (2014) which might be needed to better protect the values of the GBR. This paper describes the construct and underpinning data used to develop the bio-economic model that explicitly considers the feasibility and net profits/costs of achieving water quality objectives. The aim of this paper is to demonstrate the utility of a bio-economic model to assess the feasibility and cost of land management change required to meet environmental targets and policies.

This paper is structured as follows: The construct and data sources pertaining to the study area and as used to develop the bio-economic framework, including the biophysical and economic modelling approaches, are outlined in Section 2. Application of the framework to evaluate the land use and cost implications of achieving water quality targets are presented in Section 3. Section 4 presents a discussion of results and the multiple benefits associated with the use of the bio-economic model, and Section 5 outlines conclusions.

2. Methodology

The approach adopted in this study dynamically links outputs derived using a field-scale and a watershed simulation model with an optimisation algorithm. A large component of the work was to disaggregate the watershed simulation model end-of-catchment constituent loads (expressed as a function of Dry Weather Concentration (DWC) and Event Mean Concentration (EMC)) to soil and productivity levels within each catchment as the version of the catchment model used did not have the capability to report these

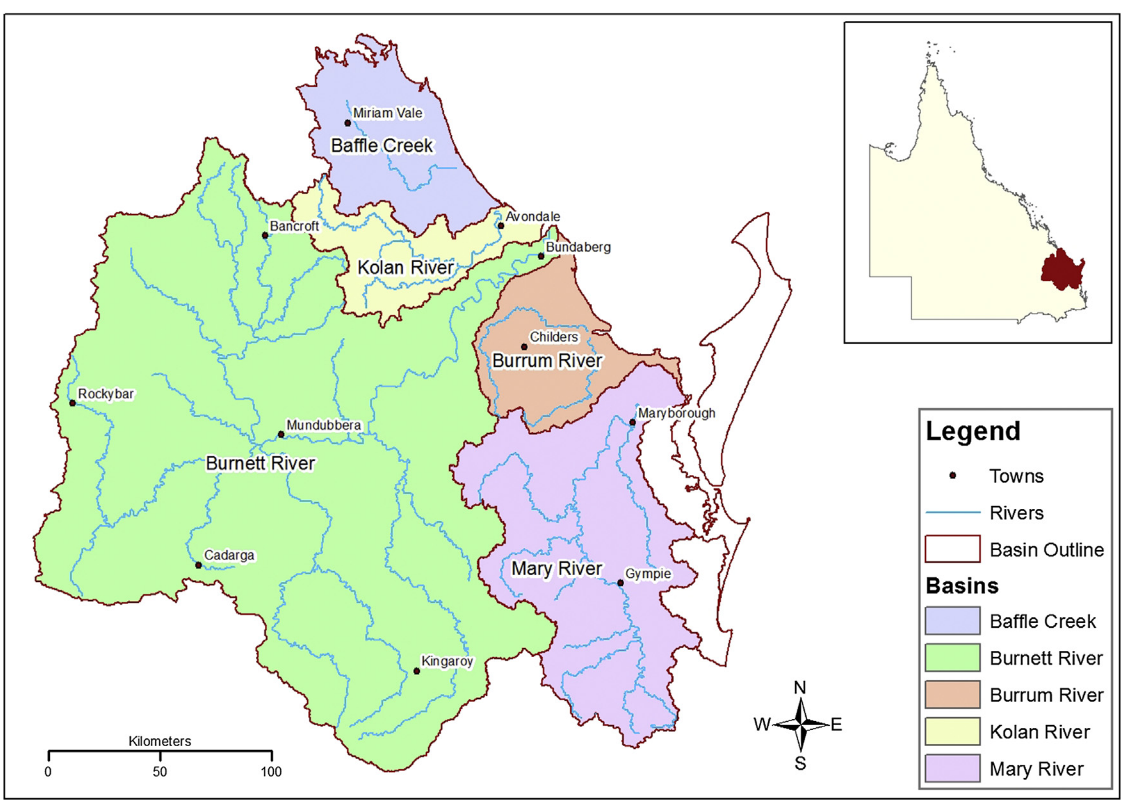

Fig. 1. Location of the Burnett-Mary watershed in Queensland, Australia.