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Local and landscape effects on spatial patterns of mangrove forest during wetter and drier periods: Moreton Bay, Southeast Queensland, Australia

L. Eslami-Andargoli[a,*], PER Dale[a,b], N. Sipe[a,c], J. Chaseling[a]

[a] Griffith School of Environment, Griffith University, Nathan Campus, Nathan Queensland 4111, Australia
[b] Environmental Futures Centre, Australia
[c] Urban Research Program, Australia

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ABSTRACT

Land use/cover and mangrove spatial changes were assessed for ten sites and their sub-catchments in Southeast Queensland, Australia. Two time periods were involved: 1972–1990, a period of relatively high rainfall, and 1990–2004, which was significantly drier. Aerial photographs and Landsat satellite imagery were used to map the inter-tidal wetlands and classify the land use/cover in the sub-catchments. A Maximum Likelihood Classification was used to map three types of land cover: agriculture, built-up and plantation forest. Mangroves (mainly *Avicennia marina*) were the focus as they have been recorded over recent decades encroaching into salt marsh. The Mangrove-Salt marsh Interface (MSI) Index was developed to quantify the relative opportunity for mangroves to expand into salt marshes, based on the shared boundary between them. The index showed a consistent relationship with mangrove *expansion* and *change*. To address problems of high dimensionality and multi-collinearity of predictor variables, a Partial Least Squares Regression (PLSR) model was used. A key finding of this research was that the contribution of environmental variables to spatial changes in the mangroves was altered following a reduction in rainfall. For example, agriculture had more influence on mangrove *expansion* and *change* during the wet period than during the dry period.

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1. Introduction

As a key component of the tropical and subtropical inter-tidal landscapes worldwide, mangrove forests are likely to be influenced by factors associated with climate change (Gilman et al., 2008). Changes in sea-level have strongly affected mangrove distributions over the long-term (Field, 1995; Gilman, 2004), whereas changes in regional rainfall and catchment runoff may be more significant in the short-term (Snedaker, 1995; Eslami-Andargoli et al., 2009). The effects of climate change on mangrove ecosystems can be exacerbated by anthropogenic modifications of landscapes which affect wetland hydrology, sedimentation and nutrient regimes. For example, where mangroves that are exposed to high nutrient loads will show increased growth rates, this will be offset during drought by greater mangrove mortality (Lovelock et al., 2009). This effect during drought will be exacerbated by increased groundwater extraction for residential and agricultural uses resulting in a tendency to increase mangrove vulnerability to changed climate conditions (Gilman et al., 2008).

In south-eastern Australia, there is evidence of recent (over the past six decades) landward encroachment of mangroves into salt marshes. This has been attributed to a combination of factors operating at both global and regional/local scales (McTainsh et al., 1986; Morton, 1993; Saintilan and Williams, 1999; Saintilan and Wilton, 2001; Jones et al., 2004; Eslami-Andargoli et al., 2009; Saintilan et al., 2009). At the global scale there are climate-related effects, such as sea-level rise and changes in precipitation (McTainsh et al., 1986; Wilton, 2002; Rogers et al., 2005a; Ellison, 2008). At the regional/local scale are catchment modifications that lead to changes in hydrological regimes, sediment regimes, nutrient flux and chemical pollutant inputs (Morton, 1993; Saintilan and Williams, 1999; Nicholls and Ellis, 2002; Williams and Meehan, 2004). Wilton (2002) has suggested that regional factors are important for mangrove expansion generally, but that local factors determine habitat extent.

This paper focuses on sub-catchment characteristics and local environmental conditions that affect mangrove distributions. It addresses the contributions of land cover/use in sub-catchments and wetland landscape structure to changes in the distribution of mangrove forests. The research covers multiple sites within one region, the northern part of Moreton Bay, Queensland, Australia, over a 32-year period from 1972 to 2004. Previous research for

* Corresponding author.
E-mail address: l.eslamiendargoli@griffith.edu.au (L. Eslami-Andargoli).

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the same area has demonstrated that rainfall influenced the net rate of mangrove increase, especially encroachment into salt marshes (Eslami-Andargoli et al., 2009). That study showed that 1990 was the most significant point of change (change-point) in the rainfall pattern. The earlier period from 1972 to 1990 was significantly wetter than the 1990–2004 period. This was reflected in significant differences in the net rates of mangrove increase between the two periods. The present work builds on our previous study and aims to;

- Identify the spatial distribution of mangroves and calculate the rates of *expansion* (gross increase) and *change* (net increase) in periods of higher and lower rainfall;
- Identify the landscape structure of each wetland, using spatial metrics to calculate the shared edge between mangrove and salt marsh and its impacts on changes in the distribution of mangroves;
- Identify the levels of modification in the mangrove sub-catchments using the proportion of different types of land use/cover, as well as population density; and
- Identify the interrelationship between mangrove distribution (*expansion* and *change*) and localized conditions (rainfall, wetland landscape structure, and sub-catchment land use/cover) during the periods of higher and lower precipitation.

2. Methods

2.1. Study area

The study area contains ten inter-tidal sites and their sub-catchments within middle estuaries (Environmental Protection Agency, 2007) of northern Moreton Bay, Southeast Queensland (27°20′ S, 153° 10′ E) and north of the state capital, Brisbane (Fig. 1). The seaward part of each site is dominated by the grey mangrove (*Avicennia marina*), with salt marsh and mudflats at higher elevations in the inter-tidal zone. The climate is subtropical with the El Niño-Southern Oscillation (ENSO) affecting both rainfall and stream flow patterns. Eastern Australia experiences higher rainfall and stream flows during the cool La Niño phase of ENSO whereas drier, hotter conditions prevail during El Niño (Verdon et al., 2004). The coastal sub-catchments include a variety of land covers, with exotic pine plantations dominating in the northern sub-catchments and built-up as the main land cover in the southern sub-catchments. These sub-catchments have been subject to large population increases along with associated urbanisation (Abal et al., 2005). To identify the interrelationship between localized conditions (rainfall, wetland landscape structure, and sub-catchment land cover) and mangrove distribution, study sites were selected in areas not directly impacted by human development and where there had been no mangrove clearing.

2.2. Mangrove spatial patterns

To map mangrove spatial patterns, aerial photos were selected for 1972, 1990 (the most significant year that change in rainfall pattern occurred (Eslami-Andargoli et al., 2009)) and 2004. The photos were scanned and imported into ArcGIS (ESRI Inc. version 9.3) as digital images. All digital images were registered to GDA 94, MGA 56 map system, and had a RMS error of less than 0.5 pixels (Eslami-Andargoli et al., 2009). The inter-tidal land cover (mangroves, salt marsh/saltpan) was mapped through on-screen digitising and validated using field data and information from Dowling and Stephens (2001). The ArcGIS intersect function was used to estimate rates of both *change* and *expansion* of mangroves between 1972 and 2004 and pre- and post-1990. Rate of *expansion*, estimated as the percentage of annual gross increase, indicates the mangroves' ability to occupy new habitats, whereas rate of *change*, the percentage of annual net increase, takes into account any dieback of mangrove (i.e., gaps occurring or the death of individual trees). The mean rates of mangrove *expansion* and *change* for the two series (pre- and post-1990) were compared using a *t*-test.

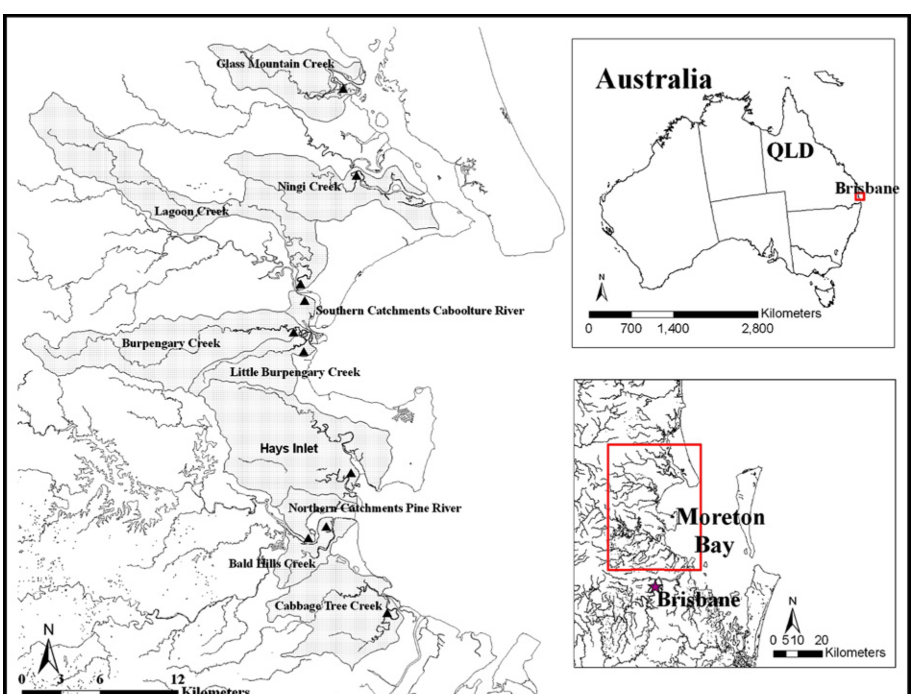

Fig. 1. Locality map of study sites, northern Moreton Bay, Queensland, Australia. The sub-catchments of each of ten sites are indicated in grey.

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