BIO-CLIMATIC MODELING OF THE POTENTIAL DISTRIBUTION OF COASTAL WETLANDS IN RESPONSE TO CLIMATE CHANGE, NORTH-EASTERN NSW AUSTRALIA

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Abstract - Climate change will have a profound impact on coastal ecosystems, particularly, wetland cover types. It is therefore important that such changes are predicted so that appropriate adaptations can be suggested. This study investigated the changes of spatial distribution of four coastal wetland plant species in response to potential climate change in north-eastern NSW, Australia. The study used BIOCLIM, a bioclimatic analysis and prediction system modeling package to generate the climate profiles of the species. Multispectral Landsat TM images were used to delineate wetland classes and to extract the wetland species. Bioclim climate parameters generated using Digital Elevation Model (DEM) and species climate profile were then used in BIOMAP to generate the predicted locations of the wetland species in response to mean annual temperature increase. Predicted locations were imported into GIS for mapping the potential spatial distribution of the wetland species. The study found that an increasing mean annual temperature would likely redistribute some of the wetland species such as *Avicennia marina* and *Melaleuca quinquenervia* southwards, in north-eastern NSW. This information could be used to enhance wetland conservation.

Keywords: Bioclim, Climate, Coast, GIS, Landsat, Wetlands

1. INTRODUCTION

According to the IPCC Fourth Assessment Report, there will be a significant increase (appx 6.4°C) in global average surface temperature by the end of the century (IPCC, 2007). Consistent with global trends, CSIRO projections for future climatic changes in Australia indicate increases in annual average temperatures of 1.0 – 5.0 by 2070 (CSIRO 2007). The temperature increase is predicted to cause shift in species distribution (Gedan and Bertness 2009). The main challenge facing ecologists is the understanding of how ecosystems will respond to modified environmental conditions in the future. It is therefore important to predict such changes so that appropriate adaptation strategies can be suggested.

There have been several studies examining the impact of climate change on forest vegetation at various geographic regions. Tang and Beckage (2010) report that temperature increase will reduce the suitable climate space for boreal forest in New England of about 75% by the end of the century while, in another study, climate change may lead to changes in species composition and distribution among seven major vegetation species (Koca et al., 2006). Hughes (2003) reports that future changes in temperature and rainfall are predicted to have significant impacts on most vegetation types in Australia. These could lead to an increase in the encroachment of woody shrubs into arid and semiarid rangelands and a continuous incursion of mangrove communities into freshwater wetlands. In Australia, various studies have investigated the impact of climate change on wetlands and the potential distribution of some selected plant and animal species including Akumu et al. (2010a), Akumu et al. (2010b), Williams (2007) and Kriticos et al. (2003). Akumu et al. (2010a) used time series Landsat and ASTER data to map coastal wetland communities in the north eastern NSW. They found significant changes in coastal wetland communities in terms of quality as well as geographic extent between 1989 and 2003. According to their findings, spatial extents of mangroves, salt marshes and coastal upland water bodies increased while forested wetlands decreased primarily due to urbanization. Williams (2007) predicted the likely ecological impacts of climate change on the wet tropics heritage area in Queensland. He found a decrease in the geographic pattern of species richness of regionally endemic rainforest vertebrates with an increase in temperature. Despite the fact that a change in climatic variables such as temperature would affect the survival and distribution of most species, there is still no known research on modeling the potential spatial distribution of most wetlands species especially in north-eastern region of NSW Australia. This study has selected the following wetland species i.e. *Avicennia marina, Melaleuca quinquenervia*, *Leptospermum liversidgei and Banksia integrifolia* from mangroves and saltmarshes, forested wetlands, coastal swamps and dunal wetlands respectively to predict their potential spatial distribution with climate change (mean annual temperature increase). These species were selected as representatives of the wetland classes because they were either dominant species or are indicator species of the wetland types.

2 MATERIAL AND METHODS

The study area is located on the north-eastern coastal area of New South Wales. It is a subtropical coastal region which extends from Tweed Heads to Evans Heads within 20 m elevation from the coastline of north-eastern NSW, Australia (Figure 1). The region consists of several plant and animal communities and is the fastest growing region in the state of NSW, with rapid residential and agricultural developments (Morand 2001). Major urban centres within the study area are Kingscliff, Murwillumbah, Pottsville, Ballina, Broadwater, Woodburn and Byron Bay. The region is subtropical with a pronounced summer and autumn ‘wet’ season and drier winters and springs. It is also one of the wettest areas in the state of NSW with intense rainfall and mildest winters (Morand 2001). Some of the vegetation types in the region include: rainforests, woodlands, closed-grassland and heaths. The main datasets used in this research include a subset of Digital Elevation Model (DEM) of the study area and the wetland classes data layers extracted from Landsat TM (Akumu et al. 2010a).

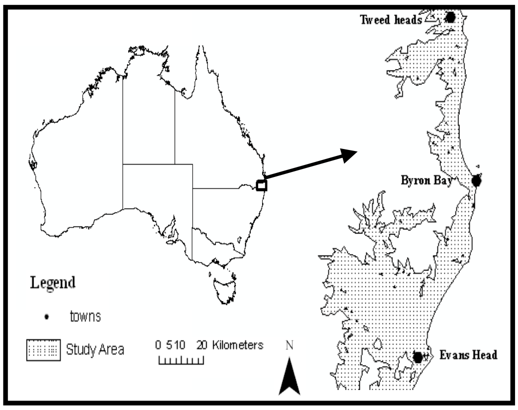

Figure1: Study Area

Bioclimatic models are widely used tools for assessing potential responses of species to climate change. BIOCLIM, which is a bioclimatic analysis and predictive system initially developed by Nix (1986), assesses the climatic suitability of habitat under current and future climate scenarios. It summarises 35 climatic parameters for any given location and suggests that a species can tolerate locations where values of all climatic variables fit within the extreme values determined by the set of known locations (Carpenter et al. 1993). The distribution of species is determined by interpolating the climate within each grid cell of a Digital Elevation Model (DEM) and comparing it to the climatic profile of the species. The output of BIOCLIM is typically a single map and an accompanying bioclimatic profile represented by a set of climatic indices (Jackson & Claridge 1999; Lindenmayer, et al. 1996).

Four wetland species: *Avicennia marina, Melaleuca quinquenervia* and *Leptospermum liversidgei* were identified using field techniques. Their geographic positions and elevations were recorded using a global positioning system (GPS). These data constituted the site file of the species and were imported into BIOCLIM to generate the climate profile of the species. Digital Elevation Model (DEM) of was used to generate the climate parameters of the study area using the climate surface of Australia. Both the climate profile of the species file (.pro file) and the climate parameters of the study area file (.bcp file) were used in BIOMAP to generate the predicted locations of the wetland species with temperature increase. The predicted locations were exported to GIS for mapping.

3 RESULTS AND DISCUSSION

The coastal swamp wetland species *Leptospermum liversidgei* (Swamp May) occurs in tropical environments and would likely adapt to an increasing mean annual temperature as a result of climate change. According to the model, the species would most likely redistribute southwards and westward from the coastline with an increasing mean annual temperature in north-eastern NSW, Australia (Figure 2).

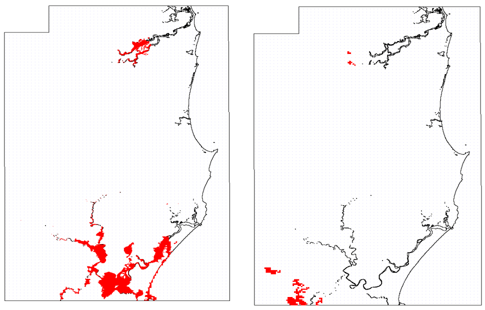

Figure 2: Current and predicted distribution of *Leptospermum liversidgei* at 7°C temperature increase

The forested wetland species i.e. *Melaleuca quinquenervia* (broad-leaved paperbark) occurs in both subtropical and tropical climates and can therefore tolerate dry conditions. The species would also likely to redistribute southward and inland with an increasing mean annual temperature due to the more availability of suitable climate space (Figure 3).

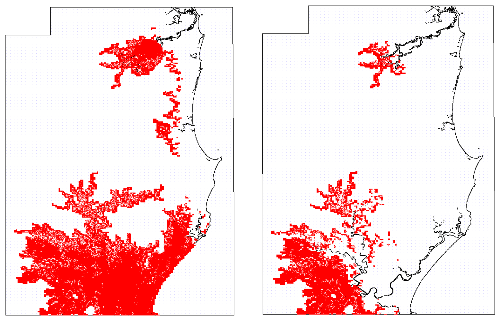

Figure 3. Current and predicted distribution of *Melaleuca quinquenervia* at 7°C temperature increase

The study found that *Avicennia marina* (Grey Mangrove) will be limited to the tidal range that would provide suitable habitats (Figure 4). According to the model, the species would adapt to higher temperatures in north-eastern NSW. Furthermore, *Avicennia marina* would likely to redistribute southwards in north-eastern NSW, Australia with an increasing temperature. This is probably because of the currently existing tropical conditions northward in Queensland and a rise in temperature would likely produce unsuitable climatic conditions for *Avicennia marina* northwards.

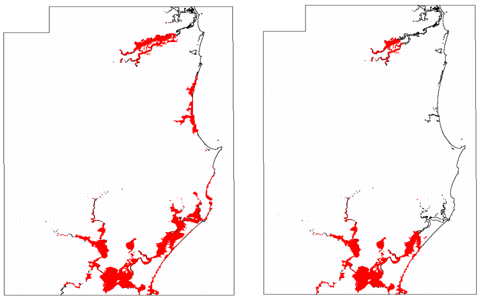

Figure 4. Current and predicted distribution of *Avicennia marina* at 7°C temperature increase

The dunal wetland plant species *Banksia integrifolia* (Coastal Banksia) would likely redistribute to suitable climate space covered by sand dunes (Figure 5). They commonly grow on sandy coastal areas (Leiper et al. 2009). They are also found in regions with tropical conditions and are moderately drought and frost tolerant which suggests their high adaptability potential to climate change.

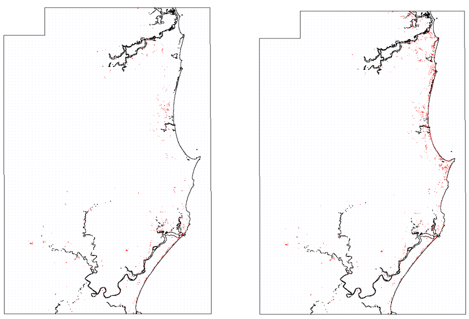

Figure 5. Current and predicted distribution of *Banksia integrifolia* at 7°C temperature increase

As these species would occur in environments with tropical conditions, suitable habitats may still be available by the end of the century in north-eastern NSW with the predicted 6.4°C rise in mean annual temperature. However, a rise in mean annual temperature beyond 7^{o}C would likely results to a complete loss of suitable habitats for these species in north-eastern NSW.

4 CONCLUSION

As with many other land cover types, climate change, particularly changes in temperature would have profound impact on the distribution of wetland species. This study used BIOCLIM climate modeling program to predict the potential changes of spatial distribution of four wetland species in the north-eastern NSW, Australia. The climate model evaluates the climatic suitability of habitats under current and future climate change scenarios. The results show that temperature increase from the current level to the extremes estimated by the end of the century would likely redistribute some of the wetland species such as *Avicennia marina* and *Melaleuca quinquenervia* southwards in north eastern NSW. The results further suggest that suitable environments for some wetland species would still be available by the end of the century at the predicted temperature ranges. It is important to note that even though the model shows the potential areas of spatial change of wetland species, the availability of the areas would depend on the anthropogenic factors and other unpredictable natural phenomena.

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