Adapting coasts to climate variability and change: integrating outcomes from "Future Coastlines" and the "South East Queensland Climate Adaptation Research Initiative"

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Published

2011

Conference Title

20th Australasian Coastal and Ocean Engineering Conference 2011 and the 13th Australasian Port and Harbour Conference 2011, COASTS and PORTS 2011

Adapting coasts to climate variability and change: integrating outcomes from "Future Coastlines" and the "South East Queensland Climate Adaptation Research Initiative"

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Abstract

The South East Queensland (SEQ) coast is exposed to coastal hazards that are likely to be exacerbated in the future. Rising sea levels, in combination with extreme meteorological events such as tropical cyclones and east coast lows, will increase the exposure to extreme water levels in open coastlines and transitional environments; at the same time, the region's population growth and development rate have the potential to increase risks in the future. In this paper we explore the recent outcomes of two ongoing research projects, "Future Coastlines" and the "South East Queensland Climate Adaptation Research Initiative" and how these are informing the development of adaptation pathways and options for vulnerable coastal areas within the SEQ region.

Keywords: South East Queensland, extreme events, climate change, vulnerability, adaptation.

1. Introduction

Climate variability and change are major concerns in the context of managing sustainable development in coastal areas. This is particularly relevant for South East Queensland (SEQ), one of the fastest growing regions of Australia. The project "Future Coastlines" is a Queensland State-wide project developing approaches to model extreme storms and provide information for coastal and emergency managers, with a strong focus on SEQ. In parallel, the SEQ-CARI project is a major research programme looking at climate change projections, vulnerability, adaptive capacity and adaptation options for the SEQ region, covering various sectors including coastal and emergency management. In this paper we present a synthesis of the outcomes of these two projects focusing on coastal management including (i) the identification of coastal vulnerability hotspots across the SEQ region; (ii) a detailed assessment of the vulnerability of one of these hotspots (Palm Beach, Gold Coast); (iii) explorations of the determinants of adaptive capacity as a critical element for vulnerability reduction; and (iv) an introduction to the potential adaptation pathways for the region and development of associated adaptation options.

2. Case study area

South East Queensland (SEQ) is one of the most developed and fastest growing coastal regions in Australia. The current population is approximately 2.8 million people and is expected to grow by 60% in the next 20 years, reaching a population of approximately 4 million people in 2030 [1]. The high concentration of human settlements within the low-lying coastal zone of the SEQ region motivated the Intergovernmental Panel on Climate Change (IPCC) to nominate this area as highly vulnerable to the impacts of climate change [2]. In particular, SEQ coastal settlements are extremely vulnerable to sea-level rise (SLR), changing wave climate and extreme sea levels associated with storm tides.

3. Approach

The approach presented here integrates the results of the two research projects grounded on the concept that vulnerability is a combination of exposure, sensitivity and adaptive capacity [2] (Figure 1). This is then used as the basis to inform the development of adaptation options for the coastal communities of the SEQ region.

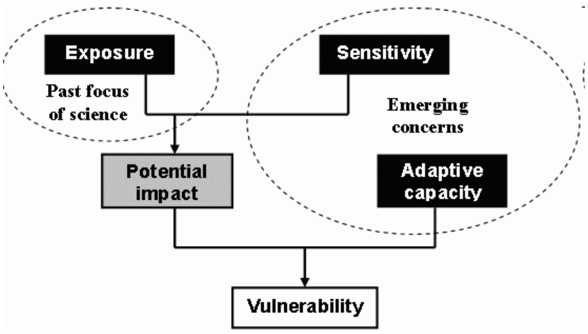

Figure 1. Framework for vulnerability assessment (IPCC 2007)

Using the outcomes of a spatial assessment to determine vulnerability hotspots across the SEQ region, we selected a specific location (Palm Beach, Gold Coast) to perform a more detailed assessment of vulnerability based on models of extreme events under future sea level scenarios.

At the same time the adaptive capacity of coastal communities, the main leverage for vulnerability reduction, was further explored using participatory techniques rooted in systems sciences and probabilistic inference during workshops in three local government areas - Sunshine Coast Regional Council, Moreton Bay Regional Council, Gold Coast City Council.

These outcomes were then used to explore potential adaptation pathways, which are used to inform the development of specific adaptation options to climate variability and change for the coastal region.

3.1 Determination of vulnerability hot spots

As a first step, a spatial assessment was carried out to determine vulnerability hotspots across the SEQ coastal areas. For this purpose we used the IPCC AR4 concept of vulnerability as a combination of exposure, sensitivity and adaptive capacity. Differences in vulnerability were then mapped at the suburb scale. In this approach, exposure refers to the expected changes to climatic stimuli in a given location. Coastal regions are exposed to SLR and other climate change-driven changes in coastal processes while sensitivity is the degree to which a system is directly or indirectly affected by climate variability or change. For example, the sensitivity of low lying and sandy coastal regions to SLR is much higher than for a rocky coastline. Together, exposure and sensitivity produce the potential impacts of climate change, which can be attenuated by the individual or system's adaptive capacity. Adaptive capacity refers to the ability or potential to respond successfully to climate variability/change, including adjustments in behaviour, resources and technologies. The assessment used here was based on a combination of sets of indicators of exposure, sensitivity and adaptive capacity using the suburb as a spatial management unit for data representation (Figure 2) [3].

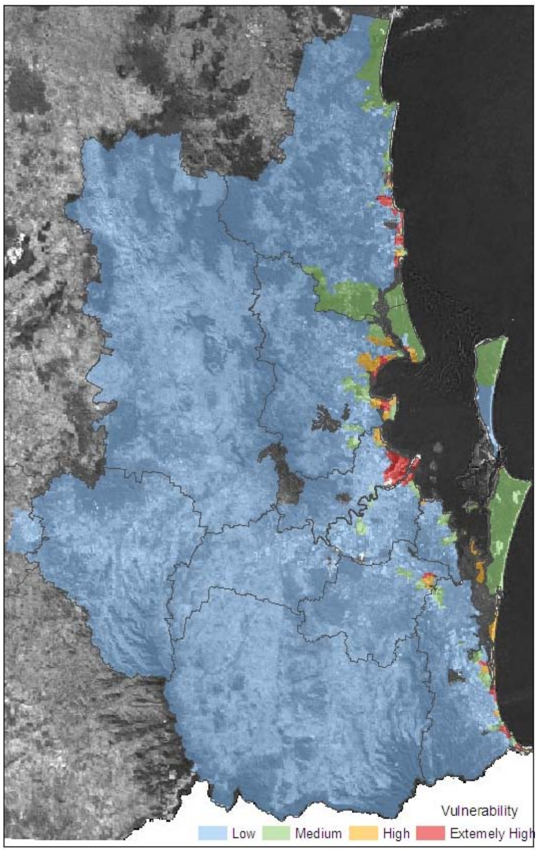

Figure 2. Vulnerability map showing hotspots across the coastal region.

Results show that all coastal councils exhibit some level of exposure to coastal hazards based on their low elevation (Figure 2). The sensitivity assessment, which is based on geomorphologic maps, shows that most suburbs are characterised by extremely sensitive sedimentary environments that can be affected by SLR and hydrodynamic changes. This is further compounded by the high density of the population and presence of major infrastructure located within close proximity to the coastline. Whilst the entire coastline is considered to exhibit extremely high sensitivity to coastal hazards, it is important to note that the five coastal councils have considerable capacity to deal with coastal hazards, with most showing medium to high levels of adaptive capacity. There are, however, areas of lower adaptive capacity present [4]. Overall, the vulnerability map shows that low lying suburbs, especially in the Gold Coast and to a lesser extent in the Sunshine Coast, are the most vulnerable to coastal hazards and coastal impacts of climate change across the region. The vulnerability of Palm Beach, a suburb of the Gold Coast, was subsequently explored in further detail to provide a vulnerability assessment at the local scale.

3.2 Vulnerability assessment at the local scale

The regional vulnerability assessment was particularly useful to identify hotspots of vulnerability at the local scale [5]. Palm Beach, in the Gold Coast, is one of the most vulnerable areas of SEQ and was chosen for a more detailed assessment covering: (i) the exposure to changing sea levels and storms by assessing the impact of sea level rise on already catastrophic extreme events using a hydrodynamic model (Mike21) forced by a specific re-constructed storm of the past (East Coast Low (ECL) of May 2009) combined with future sea level rise scenarios; (ii) the sensitivity of the beach system by assessing the impact of sea level rise on beach erosion during the same extreme event (ECL of May 2009) using XBEACH (a morphodynamic model) combined with future sea level rise scenarios; (iii) the adaptive capacity of the coastal settlement, as a function of the socio-economic profile of the area of study based on a socio-economic disadvantage index [6].

The assessment is based on the current situation and on two scenarios of sea level rise: 0.5 m by 2050 and 1 m by 2100.

The results of the hydrodynamic simulation show that deeper waters associated with sea level rise increase the storm surge level by approximately 5 cm. This value was measured at two points at approximately 20 m depth. In practice, the effect of sea level rise can amplify the impact of storm surges in the future.

Morphodynamic simulations under sea level rise conditions showed limitations considering that sea level rise, erosion and the formation of new equilibrium profiles are all gradual processes. With this in mind, we performed XBEACH simulations under future sea levels showing that a storm such as the ECL of May 2009 eroded back to the boulder wall, the last protection of coastal settlements in the area, which remains exposed to the wave attack (Figure 3).

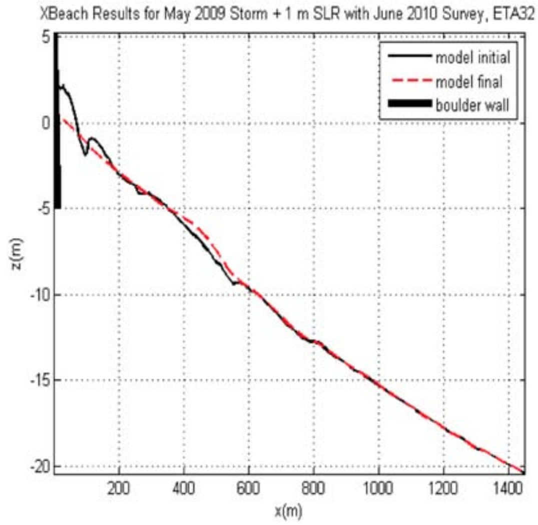

Figure 3. XBEACH results of the ECL 2009 under 1 m SLR, resulting in extreme erosion to the boulder wall.

In terms of adaptive capacity, we found that Palm Beach has the second lowest score out of eight similar coastal suburbs identified in the Gold Coast, depicting a situation of relatively lower capacity of the coastal community to adapt to extreme events and climate change.

3.3 Adaptive capacity of coastal communities

The determinants of adaptive capacity of coastal communities were further explored in the Sunshine Coast Regional Council, Moreton Bay Regional Council and Gold Coast City Council municipal areas. Various stakeholders, who included coastal decision makers, were engaged via three participatory workshops in September 2010. Systems thinking [7] and Bayesian Belief Network [8] methodologies were used by the stakeholders during these workshops to explore the determinants of regional adaptive capacity. Such determinants are important for enabling the adaptive capacity and therefore leveraging the reduction of overall vulnerability.

Systems thinking was used to create, with the contribution of participants to the workshop, a collective and shared mental model of the system of concern. Based on a set of predetermined issues related with climatic (e.g. sea level rise, increasing storm surges) and non climatic population growth) changes, participants were asked to identify and connect other elements of the system based on their perception. This process generated one conceptual model per workshop. Each of the developed conceptual models was then analysed using dedicated software (Vensim; www.ventana.com) to highlight the 'connectivity' of the different model elements. This process facilitated the identification of critical issues within the system that could be further evaluated using Bayesian Belief Network (BBN) modelling [9].

During the BBN modelling, stakeholders developed an a-cyclical (i.e. uni-directional) multi-level hierarchical tree highlighting the cause-and-effect relationships acting on the 'critical' issue. This information was then used to model the behaviour of the system and to identify critical determinants of adaptive capacity.

This integrated approach of systems thinking and BBN modelling allowed the identification of a set of variables that could be correlated with the current adaptive capacity of SEQ's coastal areas to climate change, including infrastructure maintenance, emergency response to extreme events, and socio-economic characteristics of the region. For example, in the Gold Coast municipal area, the capacity to maintain current coastal infrastructure was a major concern for workshop participants involved in the planning sector. The subsequent BBN that was developed around this issue highlighted that coastal infrastructure was dependent on a combination of socio-economic and environmental factors: (i) the availability of funds for maintaining the infrastructure, (ii) the role of government policies and (iii) changing exposure to extreme events. In this case, the main determinants of adaptive capacity for maintaining coastal infrastructure were: community demands, property value, political will, reaction to extreme events, provision of information, adapted design, and retrofitting buildings (Figure 4).

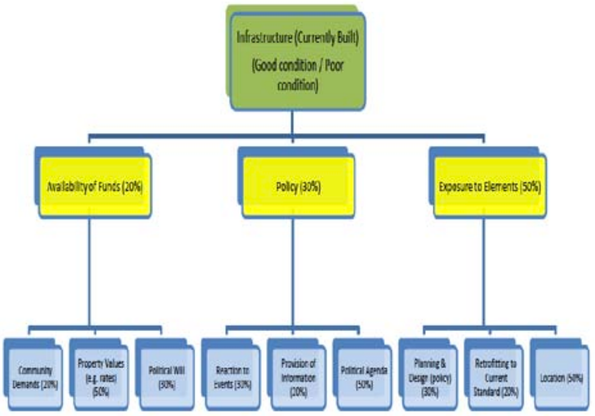

Figure 4. Hierarchical tree of determinants of adaptive capacity for coastal infrastructure in the Gold Coast.

3.4 Developing adaptation pathways and options

Further analysis of the system conceptualization model was performed to identify broad adaptation pathways to climate change. This was done by applying a structural analysis approach, classifying the system's elements based on their influence over the system and by identifying elements that could be considered as an adaptive response [10].

Results of this process showed a wide range of adaptive responses identified by stakeholders across the three local government areas including:

- Adaptation of urban planning
- Increasing social cohesion
- Design standards for houses under extreme events
- Implementation of insurance markets
- Improvement of emergency evacuation procedures
- Infrastructure repair and maintenance
- Infrastructure redesign

Based on the outcomes of this analysis, the most influential of these adaptive responses were used to develop adaptation pathways in the form of short narratives [10].

These outcomes are being used to inform the development of more detailed adaptation options for coastal areas, a major task within the SEQ CARI project that will be performed during the period June-September 2011. These adaptation options will be tested against specific climate change projections and possible socio-economic scenarios for the future, using scenario planning techniques [11]. This approach will verify the effectiveness of proposed adaptation options by incorporating feedback received during consultative workshops with end-users.

4. Conclusion

The outcomes of the research projects "SEQ CARI" and "Future Coastlines" are providing valuable information for understanding the vulnerability and adaptive capacity of the study region and for identifying associated adaptation options. On one hand, the hotspot determination exercise allowed the identification of priority areas for intervention across the SEQ region and was used to focus the analysis on one specific case study area (Palm Beach, Gold Coast). Here we applied state of the art techniques to understand coastal behaviour under future sea level scenarios that enabled an assessment of the overall vulnerability of the coastal community to be made. Awareness that the reduction of vulnerability to climate change effects should be pursued by leveraging adaptive capacity (refer Figure 1), participatory research involving stakeholder workshops was carried out by applying systems techniques to explore the stakeholders understanding and perceptions within three coastal case study areas. The results show that adaptive capacity is determined not only by the financial means of the community but also by factors such as political will, reaction to extreme events, community demands and provision of information. Leveraging adaptive capacity will be the key to implement specific adaptation options, currently under investigation. At this stage, broad adaptation pathways, as listed in section 3.4, have been identified and will be used to advance the identification of specific adaptation options for coastal areas.

5. Acknowledgements

This research is part of the Queensland Smart State Future Coastlines, modelling impacts of extreme events on coastal environments (Griffith University, CSIRO, Australian Bureau of Meteorology and DHI) and of the South East Queensland Climate Adaptation Research Initiative (Queensland Government, Commonwealth of Australia, CSIRO, Griffith University, University of the Sunshine Coast and University of Queensland).

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