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# Modelling the future eco-geomorphological change scenarios of coastal ecosystems in southeastern Australia for sustainability assessment using GIS

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## ABSTRACT

The existing situation of the coastal ecosystem in southeastern NSW Australia has been affected by global sea level rise and human activities. These impacts have led to several changes and have caused losses some of the unique coastal ecosystems, such as coastal wetlands. Coastal environments include unique ecosystems that are placed at complicated elevation levels. They has controlled by tidal stressor, where very complex eco-geomorphic and hydrologic processes accurate, and they are mostly occur in estuaries and deltas.

The project applied future climate change scenarios (sea level rise); to see how the climate change will impacts the eco-geomorphic aspects of coastal ecosystems, for risk assessment and sustainability. By applying IPCC-AR5 scenarios, results show that the study site (as Comerong Island as a case study) is under pressure effects at the moment 2015, and about 18% of the island will be covered by the sea water by 2050. But, greater influences will apparent at the study site resulting in approximately 43% of the island being lost in 2100. That will led to a broad scale application, the simulation and classification of LiDAR data, topographic layers and remote sensing data in ArcGIS depends upon the various IPCC scenarios for ecosystems sustainability.

**Keywords:** Ecosystems, future scenarios, remote sensing (RS), conservation.

## 1 INTRODUCTION

The Earth as a planet has had balanced life circle ecosystems for millions of years. Although it has faced fluctuating weather conditions, like glaciation followed by warm periods, the ecosystems have become balanced and stabilised during the Holocene epoch, especially within last 4000 years in Australia (Troedson et al., 2004; Watson, 1999; Michener et al., 1997). However, during the last century the industrial, population and information revolution has put very high stressors on the ecosystems and even overloaded them, threating the ecosystems balance and even its loss. These changes are reflected in several aspects nowadays, for example Temperature increases during the 21st century as a result of $CO_2$ emissions and climate change and mean sea level rise (Pachauri et al., 2014), have significant threatened on many ecosystems especially costal environments such as wetlands.

Global mean ocean and sea level started to rise globally since the nineteenth century, but significant rises have occurred within late decades after 1950s and it has been estimated that it will be continue rising during twenty first century. It is expected to rise (for the range of emission scenarios) by 26 cm – 55 cm by 2100 under low estimates, whereas it is expected under high estimates to rise up to 52 cm – 98; according to IPCC AR5. Moreover, under the most popular projections, it is very likely that the oceans levels rising rates will pass the records of 1971 – 2010 according to the current global warming rates and gases emissions which will led to increasing losses the ice sheets (Michener et al., 1997; Pachauri et al., 2014; IPCC, 2013; Church et al., 2013).

Therefore, scientists and organizations have started applying many different tools and scenarios to explain the existing and the future situations, and what is likely to happen as sea level rises.

Approximately one third to half of the major coastal environments on Earth have been degraded, including eastern Australian coastal wetlands, during the past decades. An additional 6-22% of coastal wetlands are expected to be lost by the end of $21^{st}$ century, with little anthropogenic contribution, by applying different natural affect scenarios (Nicholls et al., 1999). Moreover, losses of

36-70% by 2080 are expected by combined natural and human affects scenarios (Nicholls, 2004; Michener et al., 1997; Wall, 1998; Nicholls et al., 1999).

### 1.1 Case study

Comerong Island in southeastern NSW, Australia (Figure 1) is used as a case study to show the influence of mean sea level changes on changing the Island elevation and ecosystem.

Comerong Island is located at the end of the Shoalhaven River-Crookhaven Heads, represents an example of unique habitats that influenced by climate changes on changing shorelines and vegetation extent.

This Island is mostly made of sand, and it has unique coastal wetlands that have existed for thousands years east of the Southern Highlands are now degraded in their ecological abilities and geomorphological processes by human settlement and sea level rise. Resulting in a series of changes in the coastal wetlands and its unique habitats like saltmarshes and mangroves.

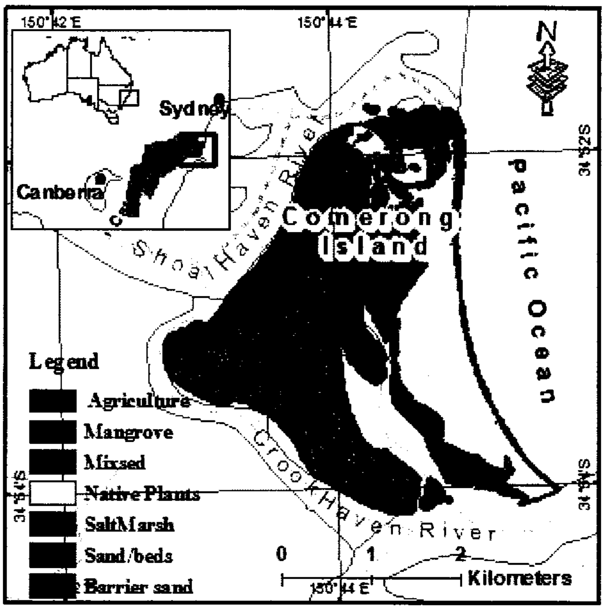

Figure 1: Study site, Comerong Island in southeastern NSW Australia, with a complicated mostly subtidal eco-geomorphic system created by tidal and river interactions, with its unique habitats.

## 2 SETTING

This paper has focused on southeastern NSW (Figure 1) to investigating the future responses to the environmental changes of Global Mean Sea Level Rise (GMSLR). Several parameter of the coastal ecosystems need to be addressed in order to estimate and apply the modelling approach. Meanwhile, it should be understood that tidal planes (levels) up an estuary will change depending on the estuarine type and shape. For these reasons, future sustainability of coastal ecosystems should be considered.

### 2.1 Methodology

The proposed methods based on; LiDAR data point clouds that reflecting the Island elevation surface (ground level), incorporated with the IPCC-AR5 scenarios that estimating the future situation of the sea levels around the island. According to IPCC-AR5 sea level estimated to rise by 26-98 cm by 2100, which need to estimate the future sustainable approach applicable to the eastern Australian coast. Generally, the processes at Comerong Island, and the level of influence that each process has on its coastal wetland growth/persistence, need to be understood. The major processes for coastal wetlands are likely to be GMSLR and sedimentation (with erosion to a lesser extent); other factors, such as salinity, rainfall and flooding, are unlikely to have a major impact on the distribution of coastal environments. It will make changes to the long-term average which will drive habitat distribution in the future.

Getting accurate results needing to model a range of scenarios of the IPCC-AR5/SYR/ RCP8.5, which concluded to tested extremes projections estimates in average that consider GMSLR by 62 cm as an average, which is a reasonable approach within the Comerong island area. Thus, this paper has quantified the range of predictions in mean estimate levels for 21$^{st}$ century. Each factor is applied independently to the existing wetland mapped for another study on "the historical and existing situation" at the same study site. A sedimentation rate is a secondary component depending on a number of factors such as catchment contributions. Therefore, using empirical data is the safest approach to gain results that reflect the existing situation and its future.

This study is based on manipulation of the LiDAR data and comparison with measured tidal planes at the nearest tidal monitoring station. The paper is focused on hydrodynamics and geomorphic processes, which have been influenced by sea level rise and considerable modification of the mean levels of the tides. This elevated tidal level was then applied at the model boundary, relating it to the Comerong elevation surfaces. This is a hydrodynamic numerical model used for modelling rivers, estuaries, coasts, flooding and so on, using some aspects of the ArcGIS toolbox, to create a contours and Triangulated Irregular Network (TIN) and then DEMs, as showing in the figure 2 below as example applied on south part of the study site.

Figure 2: Methodology applied to the LiDAR data of the south part of Comerong Island. Started as point cloud data on the left side, converted to the contours and TIN in the middle and then created the DEMs on the right side.

The LPMA_LiDAR survey that covered Comerong Island are simply reflecting the surface elevation by recording the high (Z value) based on zero level (by incorporated of actual mean sea level and ground base stations). The Comerong recorded elevation surface ranged from (-0.17 to 9.75) meters, which resulted in generating DEMs by TIN and contour spatial analyst tools. So, by increasing the water level (according to; IPCC-AR5 = 26 to 98 centimetres), the Island will have its new borders and shape. In the other worlds, manipulation of LiDAR data to define areas inundated by finding the influence-able contour lines of the zones that will effected by increasing the zero levels, and changing it to 0.26 or/and 0.98 meters as a base level depending on the scenarios.

## 3 RESULTS AND DISCUSION

Based on IPCC/AR5 projections this paper start with quantifying local GMSLR and sedimentation rates and then applies these in GIS analysis tools. Detailed of a geomorphic assessment of erosion within the coastal zone of the study site has been done as well. It has started by looking at historical mapping and aerial photos to determine how the local area/shoreline has changed to see which areas are eroding and by how much (i.e. a rate of m per year), and then applying the future to long term scenarios on the resultant situation.

This paper provides significant, detailed and accurate results of a case study about the future vulnerability to GMSLR. By applying the future changes scenarios for eastern Australian coastal ecosystems in a geomorphic context according to IPCC-AR5 scenarios for sustainable and risk assessment. A new modelling method of RS and GIS has been used for the study site. It used a standard LiDAR survey that has been done via NSW Government in 2010, by airborne using the Leica ALS50-II that integrated with RCD105 digital camera. The accuracy of this data is; 1point cloud (minimum density) per sq. meter as spatial resolution, and below 30cm of the vertical accuracy to create DEMs with 95% confidence (LPMA, 2010).

Applying the paper methodology has resulted in clear and significant future vulnerability and changes expected to affect Comerong Island at the current stage based on 2010 LiDAR data, and within next 50 and 100 years. Results show that Comerong island is under pressure effects at this stage 2015 (as showing in red colour in figure 3-B compared with "LiDAR taken time 2010" Figure 3-A), and it will be covered by the sea water about 18% by 2050 (figure 3-C). But, greater influences will apparent at the study site resulting in approximately 43% of the island being lost in 2100 (figure 3-D), for the average of rise scenarios (62 cm rise) including its unique and sensitive habitats. Ground losses will occur particularly within the low elevations of the Island surface, which covered by mangrove and saltmarshes.

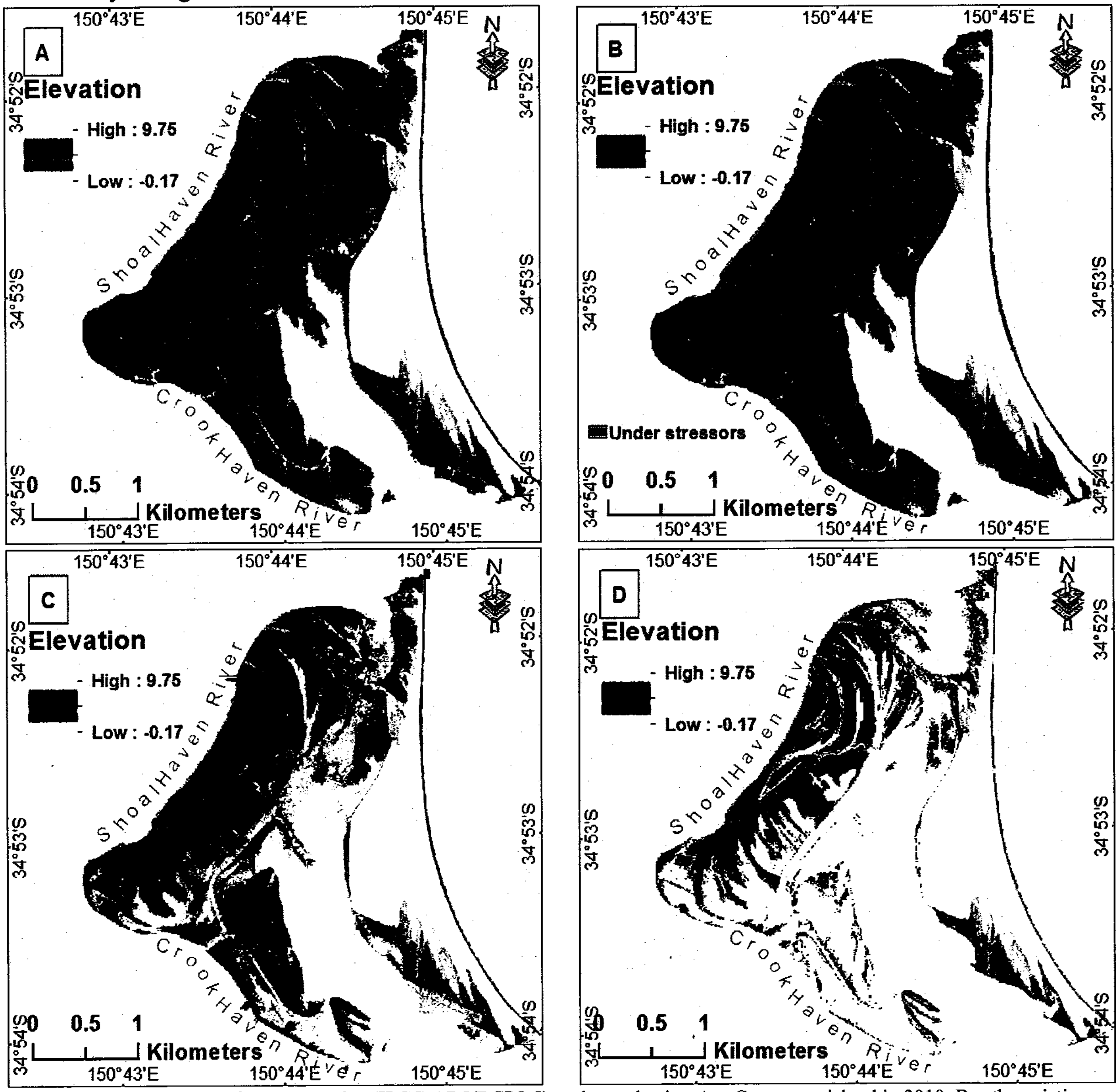


Figure 3: Applying the future scenarios (IPCC-AR5/RCP8.5) to the study site; A = Comerong island in 2010, B = the existing situation (with threated shorelines in red highlighted) C = Comerong island on 2050 and D = Comerong Island in 2100. Source : (LiDAR data. 2010. Copyright © Land and Property management authority "LPMA", NSW Government, Australia).

Grain size analysis of 113 sediment samples showed that Comerong is mostly Sandy Island (approximately 96.4%), which means, that GMSLR will have greater effects on Comerong Island and such ecosystems by increasing erosion rates, and decreasing the deposition at the same time.

## 4 CONCLUSION

The Global Climate Changes as resulted from the gas emissions, which going to increase in the near future and even stay the same, would have more negative effects on the earth's ecosystems. It is clear that Comerong Island has already been affected by GMSLR that laded to increasing erosion rates and decreasing the sediment delivery. The situation has become worse since incorporated with human settlements that control most of the sediment resources on the catchment area. Using advanced and suitable data and modern software with recognised climate changes scenarios is highly recommended, which will allow a better understanding the influences of GMSLR on coastal ecosystems.

The GMSLR is virtually certain will continue after 2100 for hundreds years according to the current and the future emissions. Highly confidant scenarios of IPCC-AR5 estimating the sea level will rise more than 98 centimetres (IPCC, 2013) in about 70% of the world parts, including southeastern Australia by the end of this century (Church et al., 2013).

The southeastern Australian coastal zones would face strong challenges from ecosystems stressors during the 21st century. Most of the Earth's oceans will be very likely to rise in its levels, which means that we will have new seas borders leading to changing the continents shape as well. Moreover, depending on the future amount of gas emissions, the coming centuries could have more sea level rises after 2100.

LiDAR and modern RS data incorporated with high software analysis would be more effective tools to get accurate results that could be offered to help manage the environmental conservation targets for ecosystems sustainability.

This approach is very suitable to apply to the Comerong Island study site. In addition, some other approaches could be applied, such as ecological responses to temperature, radiation and so on whereby GIS can be used to classify the vegetation changes using NDVI and CLIMAX software.

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