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## Sea Level Rise: Evaluating adaptation strategies and options

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### Abstract

As the reality of Climate Change draws closer, discussions among scholars and policy makers are beginning to shift from climate change mitigation to adaptation. One of the climate change impacts which raises urgent concerns, especially among millions of people living in coastal communities around the world is sea level rise. Whether it is city planners in New York, coastal dwellers in Lagos or rice farmers in seaside Indonesian villages, the question of how to adapt to projected rise in future sea levels is an important one. Drawing upon a wide spectrum of existing literature, this study outlines three common adaptation strategies (retreat, accommodate and protect) that have been proposed, and presents a comparative assessment of all three strategies. In addition, the criteria that may be employed to evaluate alternative options when faced with the decision of choosing specific sea level rise adaptation measures are also discussed. The analysis brings to light the merits and demerits of each of the retreat, accommodate and protect strategies. It also explains effectiveness, efficiency, performance under uncertainty, sustainability and equity as the criteria that should be used to evaluate alternative adaptation options. This study concludes that the options available to coastal communities to adapt to sea level rise are many, but so are the factors to consider. Successful adaptation to sea level rise will require careful and meticulous planning.

**Keywords:** Climate Change, Sea level rise, Adaptation, Retreat, Accommodate, Protect.

### Introduction

In simple terms, sea level rise can be described as an increase in the average level of the surface of Earth's oceans from which heights and depths are measured. It is believed to be caused mainly by anthropogenic global warming which results in ocean thermal expansion and increased glacial melting in high-latitude regions (Warrick and Oerlemans, 1990; Withey *et al.*, 2016). Although sea levels rose in the nineteenth and twentieth centuries, they are projected to rise even faster in the twenty-first century (Church *et al.*, 2013). However, the exact degree of future rise is uncertain. While the Intergovernmental Panel on Climate Change Fourth Assessment Report forecasts a total rise in the range of 18 – 59cm between 1990 and 2100 (Meehl *et al.*, 2007), higher estimates have emerged in literature (Nicholls *et al.*, 2008), leading to the conclusion that a global mean sea level rise exceeding 1m in the twenty-first century is not impossible (Nicholls, 2011). In terms of impacts, sea level rise could lead to increased occurrence of flooding of people, land, infrastructure and coastal habitats; thus causing direct loss of economic, ecological, cultural and subsistence values as well as other effects related to changes in water management, salinity and biological activities (Klein & Nicholls, 1999). Increasing proportion of global coastal population and growing values of coastal assets at risk of loss or damage to frequent and heavier floods are especially imperative concerns.

Given the enormity of these impacts, and given that the rate of sea level rise is not expected to abate anytime in the near future, the need for timely and meticulously planned adaptation is evident as it is pressing. However, the current body of knowledge on sea level rise adaptation, though abundant, is quite verbose for practical, real-world application. This study therefore reviewed the existing literature to provide a synopsis of sea level rise adaptation strategies and options.

## Results and Discussion

### **Retreat, Accommodate and Protect**

Retreat refers to the planned or managed withdrawal from hazard-prone sections of the coast (Alexander et al, 2012). It may involve the actual or planned removal of existing development as well as the prevention of future development in high-risk areas (SFRPC, 2013). The idea is to pull back from the sea and seek refuge behind natural ecological defences (Abel et al, 2011). Measures that may be employed to achieve retreat include acquisition of coastal lands by government, land use restrictions, prohibited reconstruction of property damaged by storms (Dronkers et al, 1990); allowing development to take place on the condition that it will be abandoned if necessary (Titus, 1991); establishing or increasing set-back zones (Sterr et al, 2003); and removal of government subsidies for coastal developments in vulnerable areas (Ehler et al, 1995).

Accommodate seeks to allow the continued or extended use of hazard-prone areas but with reduced sensitivity or exposure or both to sea-level rise (Harman et al, 2015). Often, there is little or no attempt to prevent the land from being flooded, rather current designs are modified through various measures to allow the infrastructure system to stay intact. In this strategy, natural system effects are allowed to occur and impacts on humans are minimized by adjusting human use of the coastal zones via flood-resilience measures (Nicholls, 2011). These flood-resilience modifications may include erecting emergency flood shelters, elevating buildings on piles, converting agriculture to fish farming, or growing flood- or salt-tolerant crops (Knecht 1975); early warning and evacuation systems, improved drainage systems and hazard insurance (Sterr et al., 2003). The proliferation of elevated houses in New Orleans, United States following Hurricane Katrina in 2005 is a good example of the accommodation strategy in practice.

Protect places emphasis on preventing the occurrence of sea level rise impacts using hard engineering structures such as seawalls and revetments (King et al., 2016); soft engineering structures such as nourished beaches, dunes and created or restored wetlands (Nicholls, 2011); and indigenous options such as afforestation, coconut-leaf walls and coconut-fibre stone units (Sterr et al, 2003). Though, these measures can be applied alone or in combination, depending on the specific conditions of the site, hard engineering structures have so far proven to be the most common sea level rise response (Harman et al., 2015). The idea is to maintain shorelines at their present positions and protect the adjacent coastal areas from damage (Ehler et al., 1995). The Maeslant and Thames barriers respectively protecting against surges from the Rhine River (in the Netherlands) and River Thames (in London) are examples of protection strategy in use.

**Table 1: Comparative analysis of the Retreat, Accommodate and Protect strategies.**

	Accommodate	Protect	Retreat
Mode of Operation	Improves resilience of coastal populations by increasing their ability to cope with impact.	Reduces vulnerability to impact by decreasing probability of impact occurrence.	Reduces vulnerability to impact by limiting damage caused.
Key requirement	Ability and willingness to effect lifestyle changes.	High levels of technology, in most cases.	Availability of spare land or host communities to retreat into.
Effects on Coastal Ecosystems	Allows coastal ecosystems to adapt naturally.	Could lead to a loss of coastal ecosystems through coastal squeeze.	Allows coastal ecosystems to adapt naturally.
Economic implications	Has potential compensatory economic benefits, as inundated land may be used for new income generating purposes. Requires economic costs such as those incurred in implementing land use changes, buildings modifications, and setting up reliable warning infrastructure.	Economic benefits will accrue from preventing loss of income and physical damage to natural and man-made resources. But costs of building and maintaining protective structures, plus revenue lost to any cultural, social and environmental changes could be massive.	Loss of lives prevented is invaluable. However, withdrawing populous communities from highly productive agricultural lands, or valuable coastal investments can be very costly.
Socio-cultural impacts	Accommodating change may create less desirable living conditions or may require lifestyles changes that are difficult to implement.	Protection measures may cause negative externalities in nearby coastal areas unprotected by the protection structures.	Increased pressure on infrastructure in host communities may disgruntle the hosts, which can create hostilities between host and retreating populations.

## **Criteria for evaluating alternative adaptation options**

Often, adaptation to sea level rise goes beyond which strategy is suitable; it also includes specific which adaptation options to employ among a range of alternatives. This section presents criteria that may be used to evaluate such options. The underlying assumption is that all alternative options being considered in any given situation are technically feasible. There is no use evaluating an option that is not feasible given current circumstances.

### **Effectiveness**

With respect to sea level rise adaptation, the definition of the term “effectiveness” is site- and impact-specific. City planners in New York trying to adapt to potential flooding in Manhattan and local rice farmers in a coastal Indonesian village trying to adapt to saltwater intrusion will have different interpretations of effectiveness. However, effectiveness of alternative adaptation options may be assessed based on performance in terms of (i) increasing preparedness, resilience or adaptive capacity for sea level rise impacts or (ii) reducing exposure of the population concerned to sea level rise impacts (Adger et al, 2005). Measures such as reduction in the probability of occurrence of impact, values of properties or number of people removed from high hazard locations are some useful metrics for comparing the effectiveness of alternative options.

### **Efficiency**

Efficiency or cost effectiveness involves the evaluation of alternative adaptation options based on their benefit-cost ratios (Brooks *et al*, 2011). When making sea level rise adaptation decisions, it may be tempting to consider a less expensive option as a better choice from a financial perspective. However, a costlier option may be more efficient if it saves more lives or if the total value of assets protected from sea level rise impacts is higher. To make an informed decision, there is a need to express all costs and benefits of alternative options being considered in monetary terms.

### **Performance under uncertainty**

One of the reasons why adaptation planning against sea level rise has proven difficult is because the exact degree of future sea level rise is uncertain. Thus, performance under uncertainty is a key factor to consider when evaluating alternative options. Options whose success depends on accurately predicting sea level rise have a good chance of failing (Titus, 1991). A robust or no-regret option that does not require an accurate forecast (Titus, 1998), or one insensitive to uncertainty about future sea level rise (Carmin and Dodman, 2013), is ideally preferable to a ‘rigid’ alternative.

### **Sustainability**

This criterion, put forward by Grothmann and Patt, (2005), Repetto, (2008), Brown *et al.*, (2011) and Brooks *et al.* (2011), is concerned with evaluating alternative adaptation options based on their technical and institutional sustainability. The considerations here are (i) which option has the best chance of maintaining its technical relevance in adapting to future sea level rise, given shifting baselines? (ii) which option is least likely to increase vulnerability or drive maladaptation in the medium to long-term? (iii) which of the options are mandated institutions better capable to operate and maintain into the medium and long terms?

### **Equity**

Alternative sea level rise adaption options should also be assessed based on equity within and between generations of people, as proposed by Titus (1991), Titus (1998), Smit *et al.* (1999), Huq and Khan (2006) and Brooks *et al.* (2011). The need to evaluate alternative sea level rise adaptation options based on equity is especially important, considering that sea level rise is only a problem today because of the consequences of the actions of previous generations. The idea is to choose the option which distributes its costs and benefits among affected and potentially affected individuals in the fairest manners possible.

## **Conclusion**

Without doubt, sea level rise is an imminent threat to coastal communities in the twenty-first century, at the least. This paper identifies the retreat, accommodate and protect strategies as practical ways for coastal communities to approach the imperative tasks of adapting to actual and potential sea level rise impacts. A comparative analysis of the three strategies showed that each strategy appeals to different social, economic, technological and ecological settings, and that no single strategy fits into all kinds of settings. This article also presented five criteria that should be used to evaluate alternative adaption options namely effectiveness, efficiency, performance under uncertainty, sustainability and equity. The options available to coastal communities to adapt to sea level rise are many, but so are the things do consider. Successful adaptation to sea level rise will require careful and meticulous planning.

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