Natural resource management in mitigating climate impacts: the example of mangrove restoration in Vietnam

Nguyen Hoang Tri, WN Adger, PM Kelly

Climate change, coastal protection and the mangrove ecosystem

Tropical cyclones can cause considerable damage along the 3000 km coastline of Vietnam. One typhoon, in October 1985, was responsible for the loss of almost 900 lives, 3300 boats were sunk and over half a million people were rendered homeless. While this was a particularly extreme impact, over 400000 hectares of crops were lost in the coastal provinces of Vietnam as a result of tropical cyclone impacts over the ten-year period 1977–1986 (Thu, 1991). Protecting vulnerable coastal areas from typhoon impacts is, therefore, of high social and economic importance. Yet in a nation where resources are limited, affording adequate protection can prove difficult even in the present-day (Wickramanayake, 1994). From one to 12 typhoons a year have approached the Vietnamese coasts during recent decades (Kelly, 1996). In future decades, the characteristics of this risk may change as a result of global warming and there is concern that the frequency of occurrence may increase. According to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), regional changes in cyclone frequency may occur as ocean temperatures rise and the atmospheric circulation alters (Lighthill et al., 1994; Houghton et al., 1996). There are, however, many uncertainties and the IPCC concludes that no firm assessment can be made.

This uncertainty leaves decision makers in a difficult position. No firm assessment does not mean that the risk is minimal, and it is in the nature of extreme events that unpreparedness itself increases vulnerability substantially. What can be done to plan for an uncertain future? What does a precautionary approach to reducing climate impacts entail? Kelly et al. (1994) argue that a precautionary approach to climate impact mitigation...
and adaptation must involve identifying “win–win” situations in which action to reduce future risk also minimizes vulnerability in the present day; to climate change, to other environmental problems, or to social and economic threats. In this paper, we examine one such approach to coastal protection which takes advantage of a natural resource found along much of the coastline of Vietnam, the mangrove ecosystem.

Wetlands, such as the mangrove, cover 6% of the world's land surface and are found in all climates from arctic tundra to the tropics (Matthews and Fung, 1987). Wetlands provide humans directly and indirectly with ranges of goods and services, including staple food plants, fertile grazing land, support for coastal and inland fisheries, flood control, breeding grounds for numerous birds and fuel from peat. Despite being amongst the most productive ecosystems in the world, the global area of coastal mangrove forests has been decreasing through conversion for agriculture, forestry and urban uses, and due to extraction of timber for fuel, to the extent that many remaining significant areas are being protected under the Ramsar Convention. Mangrove swamps, dominated by 60 species of mangrove tree, are intertidal tropical and sub-tropical coastal wetlands (usually found between 25° N and 25° S). In Vietnam, large areas of mangroves have been converted to agriculture and, in particular, to shrimp aquaculture, causing ecological disturbance and enhancing instability in the coastal physical environment compared to the situation that prevailed under mature mangrove forests (Hong and San, 1993). Many aquaculture practices may be inherently unsustainable; see the critiques presented by Folke and Kautsky (1992) and Kelly (1996).

The various functions and services provided by mangrove areas have been documented and appraised (Lugo and Snedaker, 1974; Mitsch and Gosselink, 1993; Reimold, 1994). It has also been recognized in economic analysis that the functions and services provided by mangroves, and wetlands in general, have positive economic value and that these are often ignored in the ongoing process of mangrove conversion (Farber and Costanza, 1987; Barbier, 1993; Ruitenbeek, 1994; Swallow, 1994; Costanza et al., 1997). Mangrove wetlands display the features of public goods in that their use is non-exclusive, and they are converted to other uses because these functions are undervalued. Often mangrove conversion takes place through overriding traditional common management of the resources (Walters, 1994). Identification of the functions and services and the incorporation of these into policy and the encouragement of appropriate property rights, whether communal or private, are, therefore, necessary first steps in promoting sustainable utilization of such resources.

Initiatives by local institutions in many parts of the world are reversing the dominant trend of wetland loss by undertaking restoration or rehabilitation. Natural wetland restoration activities are undertaken for diverse reasons, such as for wastewater and stormwater treatment (Kent, 1994) or for the supply of resources for local use. Critical issues in promoting the adoption of such schemes, and hence their ultimate sustainability, include the timing of the costs and benefits and the assignment of property rights to the various stakeholders in the restoration process. In the instance under analysis here, the benefit of reduction in maintenance of sea dikes is an important issue, and forms a central argument for schemes where mangroves are planted in front of existing sea defenses.

This paper documents the economic rationale behind mangrove rehabilitation in a case study of three coastal Districts of Nam Dinh Province
in northern Vietnam. In these areas, mangrove rehabilitation is subsidized by international development agencies through income generating projects (see, for example, Save the Children Fund Vietnam, 1992), based largely on an assumed benefit to local communities. The desirability of mangrove restoration is quantified in this paper using data on the costs and benefits of certain functions and services. The results provide an initial assessment of the likely effectiveness of this response to the risk of cyclone impacts in providing enhanced protection as well as improving local livelihoods.

**Characteristics of Vietnam’s coastal zones and risks to mangrove integrity**

Nam Dinh Province is located in the southwest of the Red River delta in northern Vietnam (cc. 20°N, 106°E). The province includes three coastal administrative units – Xuan Thuy, Hai Hau and Nghia Hung Districts – and has a sea dike system to protect people, houses and crops. Freshwater reserves help mitigate against the impacts of saline intrusion, flood, storm and sea water rise. The total area of the three coastal Districts is approximately 72 000 ha. According to local hydro-meteorological stations, the annual mean temperature is close to 23°C with a maximum in the monthly means of around 28°C in July and a minimum of about 16°C during January–February. The annual mean monthly rainfall is close to 1 850 mm with a maximum of 330–350 mm during July–August and a minimum of about 25 mm during December–January. The rainy season extends from May to September. The tidal regime is daily with a mean amplitude of 3–3.5 m as far as the typical regime of Tonkin Bay is concerned. The area is affected by two main wind regimes: the northeast monsoon wind which occurs in winter and the south–southeast wind which occurs in summer (the rainy season). The area is towards the northern extreme of the mangrove range. At present, a belt of mangroves of approximately 8 410 ha (see Table 1) acts as a buffer for the sea dike system which has been built over the centuries to protect the intensively used agricultural land from coastal storm surges and floods.

The greatest number of typhoons and associated storm surges occurs in Tonkin Bay in September and October, the so-called ‘months of the shifting season’ when the monsoonal current changes direction. During these months, typhoons also land to the south on the central coast of Vietnam. At this time of the year, storm surges and sea level rise, as well as high waves and strong winds, may cause extensive damage to economic assets such as agriculture and aquaculture. Estimates of the magnitude of impacts in Nam Dinh Province from floods

<table>
<thead>
<tr>
<th>District</th>
<th>Present mangrove areas (ha)</th>
<th>Land estimated to be available for planting (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xuan Thuy</td>
<td>3 000</td>
<td>7 640</td>
</tr>
<tr>
<td>Hai Hau</td>
<td>200</td>
<td>641</td>
</tr>
<tr>
<td>Nghia Hung</td>
<td>5 200</td>
<td>9 826</td>
</tr>
<tr>
<td>Total</td>
<td>8 400</td>
<td>18 107</td>
</tr>
</tbody>
</table>

Source: Nam Dinh Province data.
Table 2 Socio-economic characteristics of the coastal areas in the three Districts

<table>
<thead>
<tr>
<th></th>
<th>Xuan Thuy</th>
<th>Hai Hau</th>
<th>Nghia Hung</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (ha)</td>
<td>16246</td>
<td>12985</td>
<td>9006</td>
<td>38237</td>
</tr>
<tr>
<td>Population (000 persons)</td>
<td>180.6</td>
<td>153.1</td>
<td>78.1</td>
<td>441.7</td>
</tr>
<tr>
<td>Number of households</td>
<td>35374</td>
<td>39380</td>
<td>19363</td>
<td>94117</td>
</tr>
<tr>
<td>Population density (people per km$^2$)</td>
<td></td>
<td></td>
<td>1076</td>
<td></td>
</tr>
<tr>
<td>Labour force (000 labourers)</td>
<td>83.2</td>
<td>70.8</td>
<td>26.3</td>
<td>180.3</td>
</tr>
<tr>
<td>Average yield for food crops (tha)</td>
<td>5.0</td>
<td>4.0</td>
<td>3.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Total food production (000 t rice equivalent)</td>
<td>47.0</td>
<td>29.0</td>
<td>16.4</td>
<td>92.4</td>
</tr>
</tbody>
</table>

Source: Nam Dinh Province data.

and typhoons for the 20 years between 1973 and 1992 show that there were more than 990 injured people, including fatalities, in total and over VND 470 billion damage (1993 constant prices) as a result of severe storms (VND = Vietnam Dong; US$1 = VND 11000).

Within Nam Dinh Province, the impacts of severe storms are generally concentrated within the coastal Districts. The total population of the three coastal Districts of Xuan Thuy, Hai Hau and Nghia Hung is 445,000, with a population density of 1076 per km$^2$ which is typical of the densely populated areas of the Red River delta plain. The economy of these Districts is primarily dependent on agriculture. Paddy cultivation, aquaculture and salt making are the major agricultural activities. Each of these activities is susceptible to, and differentially affected by, typhoon impacts. Other climatic extremes may also have significant consequences. Rainfall levels and sunshine hours, for example, affect the viability of salt-making. The socio-economic status of the coastal parts of the three Districts is summarized in Table 2.

Given the prevailing circumstances in the coastal Districts of Nam Dinh Province, and similar regions elsewhere, it is clear that mangrove rehabilitation can have a variety of benefits where the topography of the coastal shelf and other social, physical and ecological factors are appropriate. In such situations, mangrove rehabilitation can provide income where households are often severely constrained in cash income sources, as well as bringing about environmental benefits in terms of productive assets and reducing the impact of coastal storm surges. The following sections quantify an economic model of this form of natural resource management.

Economic framework for assessing mangrove rehabilitation and estimated costs and benefits

The economic framework

Economic analysis of resource use can be undertaken in order to assess the magnitude of benefits to local users of the resource. Some values of the goods and services can be assessed by observation of existing markets, but some of the functions and services of mangroves are indirect, or functional, benefits (see, for example, Pearce and Turner, 1990).

The crucial aspects of value for local decision-making, and for the differential impacts of global change, are the direct and indirect use
benefits rather than option and existence values which often accrue at the global scale to those not associated with management decisions. It should be noted that some economic benefits of the mangrove resource will increase in value over time, while others will remain constant or decline. For example, as agricultural development intensifies, the potential economic losses from storm surges increases, so the value of the coastal protection function of the mangroves will rise accordingly. Exogenous environmental change associated with global climate change may increase the frequency and intensity of storm surges, and hence the value of this function of the mangroves will rise. Regardless, in this analysis, we have assumed a steady-state situation as our primary concern is with the present-day and near-term future.

The economic cost benefit analysis of mangrove rehabilitation schemes in this case is of the form

\[
NPV = \sum_{t=1}^{\gamma} \frac{(B^T_t + B^{NT}_t + B^p_t - C_t)/(1 + r)^t}{(1 + r)^t},
\]

where \(NPV\) is the net present value (VND per ha), \(B^T_t\) the net value of the timber products in year \(t\) (VND per ha), \(B^{NT}_t\) the net value of the non-timber products in year \(t\) (VND per ha), \(B^p_t\) the value of the protection of the sea defenses in year \(t\) (VND per ha), \(C_t\) the costs of planting, maintenance and thinning of mangrove stand in year \(t\) (VND per ha), \(r\) the rate of discount and \(\gamma\) the time horizon (25 yr rotation).

Costs

Estimates of the costs of establishing the rehabilitated mangrove stands are presented in Table 3. These costs are estimated primarily based on the cost of labour for the activities described. Survey research was carried out in 1994 with the cost for a work day in that year being typically 2.5 kg of rice or VND 5 500. Planting of 1 hta of mangroves required 95 work days or VND 522,000, as shown in Table 3. The estimates are averaged across the three Districts, with variations in costs dependent on where the

<table>
<thead>
<tr>
<th>Impact or asset valued</th>
<th>Method and assumptions for valuation</th>
<th>Timing of costs and benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber benefits</td>
<td>Market data: Thinning (VND 180 per tree); extraction mature trees (VND 5000)</td>
<td>Thinning and extraction from year 6 with 3 year rotation</td>
</tr>
<tr>
<td>Fish</td>
<td>Market data: Mean price of VND 12.500 per kg; yield 50 kg per ha.</td>
<td>Fishing benefits from year 2 after planting</td>
</tr>
<tr>
<td>Honey</td>
<td>Market data: Potential yield estimated at 0.21 kg per ha.</td>
<td>Honey collected from year 5 after planting</td>
</tr>
<tr>
<td>Sea dike maintenance costs avoided</td>
<td>Morphological model: costs avoided = f (stand width, age, mean wavelength).</td>
<td>Benefits rising from year 1.</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting, capital and recurrent costs</td>
<td>Market and labour allocation data: Costs of seedlings and capital (VND 440,000 per ha); Workdays valued at local wage in rice equivalent (VND 5,500 per day).</td>
<td>Planting costs at year 1; thinning from year 6 on 3 year rotation</td>
</tr>
</tbody>
</table>

Note: US$1 = VND 11,000.
seedlings were obtained. The planting and handling fees for seedlings obtained from forests in the area under rehabilitation are not significant compared to costs for collecting, handling and transportation for other areas which increase depending on the distance from the seedling source site to the planting site. The seed mortality rate between time of collection and time of planting adds an additional cost factor. For some mangrove species, such as *Sonneratia sp*, *Avicennia sp*, *Aegiceras sp* and others, planting directly onto mud flats is unsuccessful due to the exposure to strong wind and wave forces which wash away the seedlings. The cost of raising such species in a nursery and transplanting them at eight months old is relatively high, with fees for maintaining the nursery, care, protection and transportation adding to overall expenditure. The costs of establishing a stand, including planting, gapping and protection, occur mainly in the first year. Maintenance, from the second year on, incurs an estimated annual expenditure of VND 82,500 per hectare. The cost of thinning occurs in years 6, 9, 12, 15, 20 and 25.

**Direct use benefits from rehabilitation**

The benefits from wood and fuelwood sources from the processes of periodic thinning and extraction are derived from observations in local markets, and are shown in Table 3. It is assumed that the stands are managed in a sustainable fashion. The timber benefits represent wood for poles and fuelwood. The benefits from direct fishing sources were estimated on-site. Fishing activities in the three Districts are undertaken through the use of simple fishing nets, simple tools or even by hand. Aquatic products include fish, crabs, shrimps and shell fish. The yield is estimated at approximately 50 kg per hectare within mature mangrove stands annually for all types of aquatic products. The average unit price in 1994 was around VND 12,650 per kg averaged across the products. There is some evidence that present exploitation of mangrove aquatic products in the Red River delta in general may be leading to declines in fish stocks, so the estimated yield estimates may be not be sustainable, although they are considered conservative for the Districts surveyed.

Honey from bee-keeping is derived from the flowers of a number of mangrove species, though the season spans a limited number of months. The honey from mangroves is obtained during the first flowering season of *Kandelia candel* from January to March and from July to September for other mangrove species and the second flowering season of *Kandelia candel*. The potential yield from this bee-honey source was estimated to be an annual minimum of 0.21 kg per hectare. Honey production is possible from five years after planting, though some species of mangrove can flower after three to four years, and even after one and a half years, from planting.

**Indirect use benefits from rehabilitation**

The planting of mangroves on the seaward side of the extensive sea dike system provides a benefit of cost avoided in maintenance of these defenses. Such maintenance takes place on an annual basis in the coastal Districts of Vietnam through the obligatory labour of district inhabitants organized by the district committees and paid for through local land taxes. These commitments draw a heavy burden on labour-scarce households and are a source of conflict regarding the inter-district allocation of labour contracts (Adger, 1996). The rehabilitation of mangroves to reduce the costs of maintaining the dike system, however, is perceived to have high short term
costs (Save the Children Fund Vietnam, 1992; Macintosh and Hong, 1995) as outlined above. Yet the benefits of rehabilitation have rarely been quantified and, when this has been attempted, it has often been without consideration of the indirect benefits.

The evaluation of the role of mangroves in protecting sea dikes is estimated from expenditure on their maintenance and repair in comparison with a case where no mangroves exist, with the control situation assumed to have similar morphological characteristics. In general terms, the greater the area of mangrove, the greater the benefit in terms of avoided maintenance costs. Establishing a precise set of relationships in order to estimate the benefits is not, however, a straightforward matter as the mechanisms by which mangroves protect the adjacent dike are complex. Mangrove stands provide a physical barrier, resulting in drag effects and the dissipation of wave energy. They also stabilize the sea floor, trapping sediment, and can affect the angle of slope of the sea bottom and again the dissipation of wave energy.

Studies in southern China have resulted in an empirical relationship through which the benefit, in terms of avoided cost \( B_p \), can be expressed as a function of the width of the mangrove stand as a proportion of the average wavelength of the ocean waves that the stand is exposed to and various parameters related to the age of stand (mangrove size and density) expressed as a buffer factor. The key parameters are illustrated in Fig. 1. The relationship was developed and tested in mangrove stands in southern China and has been calibrated in Vietnam through simulation (Vinh, 1995). We have used a simplified version of this relationship in estimating indirect use value in this study. Here, the buffer factor, \( \alpha \), is given by

\[
\alpha = \frac{2\pi R^2}{1.73b^2},
\]

where \( R \) is the mean radius of the canopy of an individual tree (m), which increases with age, and \( b \) is the typical distance between trees (m), which generally increases with time. As the stand matures, \( \alpha \) increases from a minimum of around 0.1 to close to 1.0 as the stand presents a more and more effective obstacle.

Observations indicate that a mature stand will avert 25–30% of the costs of dike maintenance assuming a stand width at least comparable to the characteristic wavelength of the incident waves. The relationship

![Diagram](image-url)  

**Figure 1.** Profile of rehabilitated mangrove stands showing parameters for estimation of avoided maintenance costs.
Figure 2. Relationship between percentage maintenance costs avoided and the ratio of stand width to the wavelength of the incident ocean waves ($W/\lambda$). Buffer factor, $x = 0.9$ (i.e. mature stand).

between percentage costs avoided and the ratio between stand width, $W$, and wavelength, $\lambda$, for a mature stand over a realistic range of values is illustrated in Fig. 2. It can be seen that, beyond a certain point, increasing stand width results in decreasing gains in protection. Typical wavelengths would be between 25 and 75 m, suggesting stand width should be of the order of 50–150 m.

For the Nam Dinh example, the model was calibrated using survey data on the annual costs of maintenance of sea dikes in each of the three coastal Districts and data on mangrove productivity (growth in terms of mean annual increment, height, canopy density) for *Rhizophora apiculata* (Aksornkoae, 1993). The model was tested for its sensitivity to various parameters including the costs of maintenance in the Districts and the design of the protection schemes in terms of the width of the stand in front of the sea dikes.

The model used here must be regarded as a provisional attempt to estimate the benefits associated with reduced maintenance costs. In particular, we consider the model may be overestimating the benefits when the stand is not fully developed or the width of the stand is much less than the incident wavelength. Nevertheless, uncertainties in this area may not be critical for two reasons. First, as will be seen, the direct benefits from use of the resources are considerably more significant than this indirect use value and, second, the value estimated here is only part of the true storm protection value, which must also include broader damage avoidance benefits, and is, therefore, a lower bound figure.

The model of maintenance costs avoided was used for the three coastal Districts to derive the indirect benefit of mangrove rehabilitation. The baseline costs of maintenance are incurred by the District Committees which keep detailed records of work days and expenditure on annual maintenance. Recent estimates of the number of person-days a year spent on dike maintenance were used in the calculations. As the results represent the average situation, the impact of the most severe storm surges on both the cost of maintenance and repair of dikes is not accounted for. It should also be noted that this model does not account for other damage costs associated with storm occurrence, such as agricultural losses.

**Comparing the costs and benefits of rehabilitation**

The full results of the cost benefit analysis are presented in Table 4. This cost benefit analysis is of a partial nature, comparing establishment and
Table 4 Costs and benefits of direct and indirect use values of mangrove restoration compared. Stand width = 100 m; incident wavelength = 75 m.

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Direct benefits (PV million VND per ha)</th>
<th>Indirect benefits (PV million VND per ha)</th>
<th>Costs (PV million VND per ha)</th>
<th>Overall B/C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>18.26</td>
<td>1.40</td>
<td>3.45</td>
<td>5.69</td>
</tr>
<tr>
<td>6</td>
<td>12.08</td>
<td>1.04</td>
<td>2.51</td>
<td>5.22</td>
</tr>
<tr>
<td>10</td>
<td>7.72</td>
<td>0.75</td>
<td>1.82</td>
<td>4.65</td>
</tr>
</tbody>
</table>

Notes: US$1 = VND 11000. B/C ratio = NPV total benefits/NPV costs.

extraction costs with the direct benefits from extracted marketable products and with the indirect benefits of avoided maintenance of the sea dike system. It is assumed that present-day conditions continue to prevail with respect to storm frequency and so on. The results show a benefit to cost ratio in the range of four to five for a range of discount rates. The low relative changes in benefit cost ratios illustrates that most of the costs, as well as the benefits of rehabilitation, occur within a relatively short time frame, with even the reduced maintenance cost beginning to accrue within a few years of initial planting.

Figure 3 illustrates that the direct benefits from mangrove rehabilitation are more significant in economic terms than the indirect benefits associated with sea dike protection over a range of realistic parameter values. As might be expected, the greater the stand width, the more important the direct benefits in comparison to the avoidance of maintenance costs (Figure 3a). Yet even at the lower end of the range of realistic stand widths, offering the greatest return per hectare given suitable conditions, the direct benefits dominate (Figure 3b). As discussed above, the sea dike protection estimates do not include the benefits of reduced repair after serious storm damage, nor the potential losses of agricultural produce when flooding occurs. Flooding associated with severe tropical storms can lead to large economic losses, as well as to loss of life, and a reduced probability of flooding associated with the protection from the mangrove itself would be an additional indirect benefit. This benefit has not been estimated to date, though production function approaches to estimating such benefits for naturally occurring mangrove stands are presently underway.

In any event, it is clear from Figure 3 that the direct benefits from mangrove rehabilitation mean that this activity is economically desirable, as evidenced by the positive Net Present Values (NPV) at all discount rates considered. NPV increases at each rate of discount. The increase in NPV associated with mangrove planting resulting from including dike maintenance savings would promote the desirability of planting. The results presented in Table 4 show that this indirect joint-product benefit of mangrove rehabilitation is significant in further strengthening the economic case for such action in these locations.

Conclusions

This paper has quantified, in a preliminary fashion, various economic benefits of mangrove rehabilitation tied to sea defense systems in three coastal Districts in northern Vietnam. The results from the economic
Figure 3. Net Present Value of mangrove rehabilitation, including value of sea dike protection, for two cases: (a) stand width = 100 m; incident wave-length = 75 m; (b) stand width = 33.3 m; incident wavelength = 25 m.

model show that rehabilitation is desirable from an economic perspective based solely on the direct benefits of use by local communities. The rehabilitation schemes have even higher benefit cost ratios when the indirect benefits of the avoided maintenance cost of the sea dike system, protected from coastal storm surges by the mangrove, are included. This analysis neglects a number of aspects which need to be incorporated in a full evaluation. In particular, no account has been taken of the economic benefits resulting from improved protection against storm damage, in terms of more sustainable agricultural yields and so on. There is also a need to test various assumptions, parameters and models used in the
analysis. Nevertheless, these initial results do suggest that there is a strong case for mangrove rehabilitation as an important component of a sustainable coastal management strategy which is proof against future, as well as present-day, risk.

There is a broader lesson which can be drawn from this analysis regarding approaches to the problematic issue of adaptive responses to long-term environmental change. As noted in the introduction, decision makers face difficult decisions in assigning priorities when faced with an uncertain future in a resource-limited present. We would argue that this difficulty can be minimized by adopting a precautionary approach which focuses attention on present-day or near-future benefits which will accrue regardless of the nature and magnitude of the impact of environmental change. In the example presented in this paper, mangrove rehabilitation provides immediate economic benefits to the local people, those most vulnerable to storm impacts, while reducing the potential for storm damage over the near and long term.

It should be noted that the result derived from this analysis is dependent on the nature of the control over these resources by existing users and local institutions. The presently widely observed conversion of mangroves for use in aquaculture occurs because the calculus of economic loss and benefit is often undertaken in the context of overriding existing traditional property rights to mangrove products and services. If such constraints can be overcome, mangrove rehabilitation has the potential, under suitable social and physio-ecological conditions, to provide ‘win–win’ situations whereby the dichotomy between short- and long-term concerns is avoided. It can be contrasted with one alternative course of action, building higher sea dikes, which, although it may ultimately be necessary if the threat of increased storm impacts materializes, provides limited benefits in the short–term.

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