Tropical cyclones and the added value of ICZM – Andhra Pradesh, India

an integrated approach reducing vulnerability

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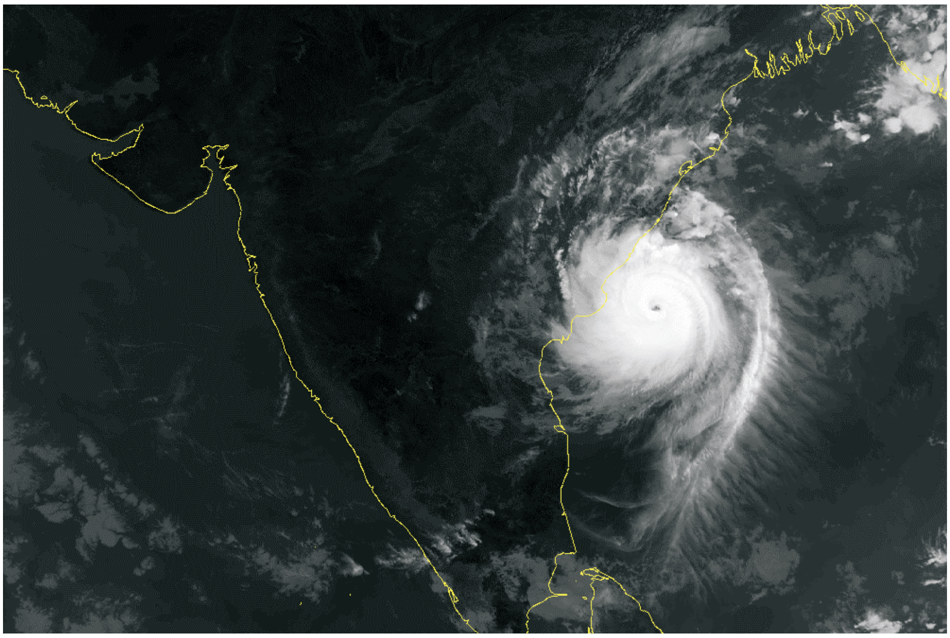
Summary

Strengthening early warning systems and planning Integrated Coastal Zone management (ICZM) were simultaneously and successfully applied on the coast of India. The number of casualties and damage by cyclones can be reduced by proper implementation of these approaches. Applying an ICZM programme together with the development of a decision support model, provided for the integration of disciplines, structure and synthesis of complex data sets and is forward looking. The benefit of such an approach is demonstrated in improved decision-making related to spatial planning and efforts to reduce poverty, which is one of the dominant factors in post- cyclone recovery.



Cyclone 07B* – *over the Godavari Delta, State of Andhra Pradesh, east coast India,
during 6-7 November 1996, with wind speed to 230 km/hour. (photo: National Geophysical Data Center / National Oceanic and Atmospheric Administration)

1. Coastal hazards, damage and human suffering

Tragic events such as Hurricane Katrina (2005), the Asian Tsunami (2004) and tropical cyclone Nargis that struck Burma (Myanmar) in May 2008 have highlighted the fact that coastal areas are hazardous places to live. Many low-lying coasts suffer 'natural' disasters owing to the highly dynamic environment. At the same time they have attracted human occupation because of their natural resources (such as fertile soils, fish stocks and navigation facilities). This paradoxical situation is likely to increase in the light of future climate change in combination with population growth.

Worldwide up to 120 million people on average every year experience tropical cyclones. Countries with substantial populations located on coastal plains and deltas with a relatively high vulnerability to cyclones include India, Bangladesh, Honduras, Nicaragua, the Philippines and Vietnam (Pelling et al. 2004).

Whereas the damage from cyclones shows an increasing trend in time, the loss of life seems to reduce somewhat over the years, although there are large differences between countries. For instance, in Andhra Pradesh there has been a marked reduction in casualties between two cyclones of similar intensity and landfall (1970 and 1990), mainly attributable to improvements in early warning systems and contingency planning for mass evacuation (Raghavan & Rajesh 2003). A similar improvement in warning and preparedness (e.g. cyclone shelters) is observable in Bangladesh. However, cyclone Nargis in 2008 with over 100,000 lives lost showed that not all countries have yet embarked on effective contingency planning with regard to cyclones.

What can be done? Hazards will continue to threaten societies, especially on the coast. Traditional engineering options, such as strong embankments and dikes, are not always effective or economically feasible. Other measures include better spatial planning, improved early warning systems and evacuation procedures, improved housing and community preparedness. Within the domain of disaster management there is increasing awareness that there are solutions using a combination of measures.

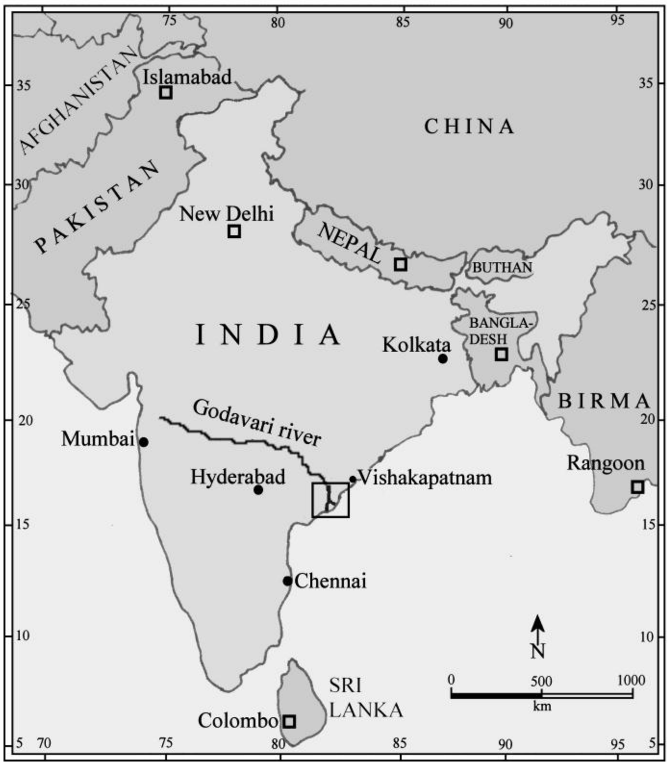


Figure 1: The location of the Godavari Delta in the State of Andhra Pradesh: *Twenty cyclonic depressions and tropical storms have crossed the Andhra Pradesh coastline between 1977 and 1996; the Expert Decision Support System (EDSS) was set up and calibrated in the Godavari delta.*

This CCC chapter focuses on the use of ICZM as a planning and management approach to reduce the vulnerability of coastal societies for tropical cyclones. It is largely based on many years of research in coastal Andhra Pradesh, India, but is also relevant for other countries that face similar tropical cyclone hazards.

2. Cyclone hazard and economic development in the State of Andhra Pradesh (AP), south India

Twenty cyclonic depressions and tropical storms impacted on the Andhra Pradesh (AP) coastline between 1977 and 1996, affecting the lives of millions of people. Thousands of people died and hundreds of thousands hectares of crops were lost (O'Hare, 2001). The November 1977 cyclone and its accompanying storm surge in the Krishna Delta (AP) was the most devastating recent event in India, killing 10,000 people in one night and destroying an area of more than one million hectares (Reddy et al.,2000). More recently, the November 1996 cyclone struck the Godavari Delta leaving 1,076 persons confirmed dead, while 1638 people were missing (Marchand, 2009). Figure 2 shows the mandals (municipalities) in the delta closest to the landfall. The coastal mandals counted the most casualties, however also in more distant mandals considerable number of victims were confirmed. The distribution of the vulnerabilities also displays a dispersed pattern, as can be seen in the Vulnerability Map (Figure 5).

The extent of damage and losses caused by a cyclone depends on a number of factors, amongst which the most important are the:

- Severity of the cyclone itself;
- Local geomorphology of the coastal area at the landfall point (e.g. the land level, the existence of mangroves, a sand spit, a lagoon etc.);
- Evacuation: infrastructure and preparedness of the local population;
- Effectiveness of the early warning systems.

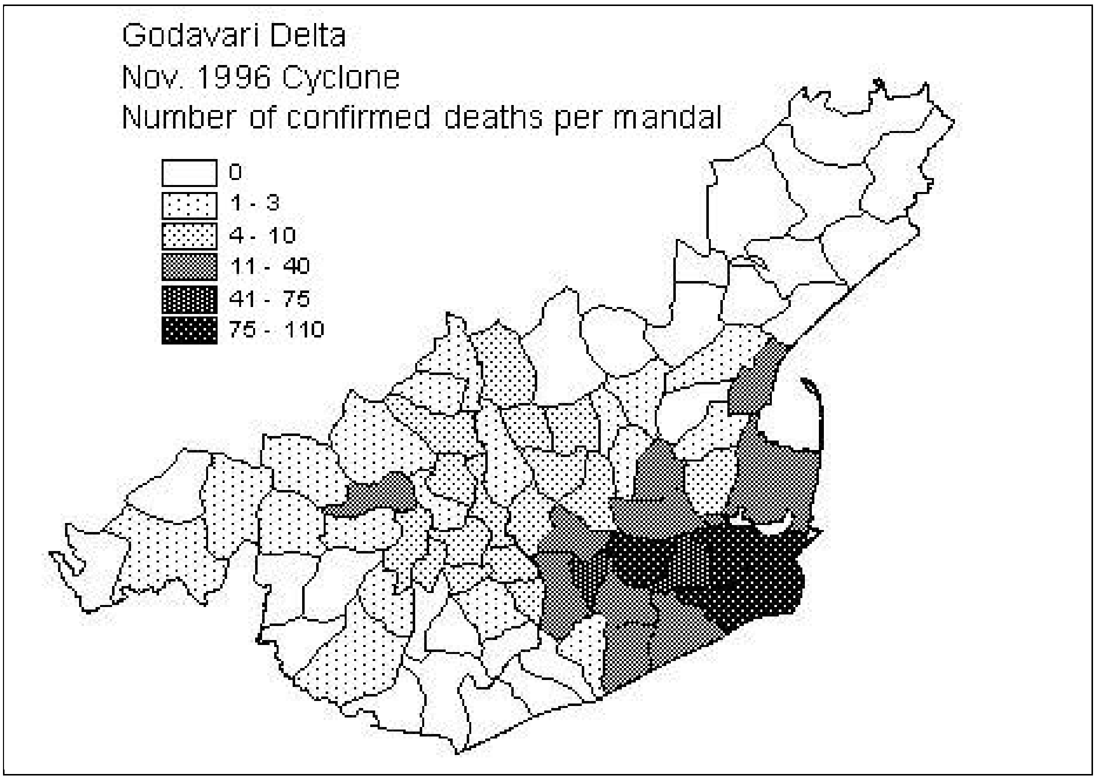


Figure 2: ***Mandal wise distribution of deaths in the Godavari Delta from the November 1996 Cyclone.***
(source: Offices of the District Collectors in Kakinada and Eluru ; Marchand, 2009)

Because of the combination of these factors, not every part of the Andhra Pradesh coast is equally vulnerable to cyclones and associated flooding. Deltas, pre-eminently low-lying areas are particularly susceptible to damage and loss of life because the combination of a cyclonic storm surge with high river discharges can lead to severe flooding.

Cyclones are one of several hazards in this coastal area. The other hazardous threats include drought, water pollution and salt water aquifer intrusion. These adverse environmental conditions significantly affect the ability, especially of the poorer sections of the communities to cope with the impact of a cyclone. Vulnerability to cyclones is not equally distributed among the society. It is highest in the communities and households that have the lowest incomes (Winchester 1992; Winchester 2000). This warrants specific responsibility with respect to a sustainable and equitable development of the coastal resources as a part of a disaster management strategy.

When the Andhra Pradesh Government commissioned the Cyclone Hazard Mitigation Project in 1999, it correctly put the emphasis for the reduction of vulnerability in the coastal areas on both early warning systems for immediate actions and ICZM for long term planning action.

The early warning part of the project produced a calibrated, dynamic model indicating the most likely areas that will be flooded by a storm surge based on a predicted cyclone track and point of landfall. This flood prediction enables government agencies and inhabitants to take precautionary measures such as evacuations, storage of food and water etc. This contributes to reducing the vulnerability of cyclone prone areas.

The main objective for the ICZM part of the Cyclone Hazard Mitigation Project was formulated as: "To envisage optimum utilisation of coastal resources, minimisation of impacts due to cyclone disasters and improvements in equitable quality of life levels while ensuring environmental protection and biodiversity conservation" .

3. A framework for ICZM in Andhra Pradesh

Over the past decades, population growth in the coastal zone of the State of Andhra Pradesh has greatly increased the pressure on the limited natural resources, such as land, fresh water, forests, fish and prawn stocks. There are clear signs of water quality deterioration, overfishing, fuel wood shortages and groundwater salinisation. Reduction of mangrove forests, tidal marshes and lagoons has made large parts of the coast more vulnerable to the destructive forces of a cyclonic storm surge. Combined with the increased number of people living close to the sea as well as their increased economic activity, this has led to an increase of the total number of people and value of assets at risk.

Improved early warning is essential in reducing the number of casualties due to cyclonic disasters. However, this alone cannot prevent serious damage to properties and infrastructure. Therefore long-term measures are also required in order to reduce the vulnerability of coastal Andhra Pradesh. Such measures need to be based on a sound understanding of the socio-economic structures and natural coastal processes.

The key to reducing the cyclone vulnerability of the coastal population is to understand implications for different economic groups. For example the same event in the same place affects poorer households more than it does the economic better-off. Poverty alleviation is therefore a major factor in reducing the vulnerability to cyclones. This is best achieved by developing the coastal areas and its resources in such a way that they become more accessible and attractive for public and private investments. At the same time, the coastal areas should be made healthier and safer.
ICZM is a framework that helps with long-term sustainable development, taking into account the environmental carrying capacity and equity in terms of resource use and economic profit. It provides decision makers in both the public and private sectors with information that enables them to optimise resource use.

An ICZM Framework provided a supporting model for planning decisions at local and regional level. This identified a number of strategic options.
The key recommendation was that reducing vulnerability should involve a policy of poverty alleviation and protecting the most vulnerable land uses in the coastal zone. Sustaining private agricultural sectors that are already growing actively and contributing significantly to enhanced levels of employment, as well as increasing public investments for the improvement of drinking water conditions are the most important development issues for the next five years. Other priority policy elements include investment in primary health care, education, roads and communication, water management, flood control and drainage improvement and coastal forestry.
The ICZM Framework also addresses the institutional settings. The Framework is mainly operating *within* the existing planning and priority system, already set by government (e.g. "The Vision 2020 framework" - CGG, 2003, and the *Janmabhoomi* programmes), and is broadly within current institutional structures. The Framework also acknowledges

that village-based organisations are key institutions from which to build long-term sustainable cyclone vulnerability reduction programmes.
The ICZM Framework furthermore, provided the necessary facilitating tools. One of these tools is an Expert Decision Support System (EDSS), a model of coastal development and vulnerability, exploring scenarios and strategies at different levels.

4. A model for coastal development and vulnerability

Delft Hydraulics/Deltares in cooperation with AP Government developed a model (Baarse & Marchand, 2003; Marchand *et al.*, 2006) that predicts physical and socio-economic vulnerabilities. These predictions are calibrated and validated with information based on fieldwork analysis. The model calculates the interactions between the impact of natural events, environmental and socio-economic processes at different spatial and temporal scales. The model links the socio-economic character of the coastal zone to land use and all related activities that generate income. It is sensitive to both planned (crop selection) and unplanned (cyclone disaster) land-use changes and estimates annual agriculture production, income, resource use and waste generation.

The Godavari Delta

The model has been calibrated for the Godavari Delta (Figure 1), a coastal area that is relatively more prosperous than other parts of the Andhra Pradesh coast, but also more prone to cyclones. For instance, the cyclone 07B that landed in November 1996 near Kakinada (Figure 3) resulted in a tragic loss of over 1000 lives, 44 billion Rs (around 880 million US$) of crop losses and 6 billion Rs (120 million US$) of damage in the housing sector.

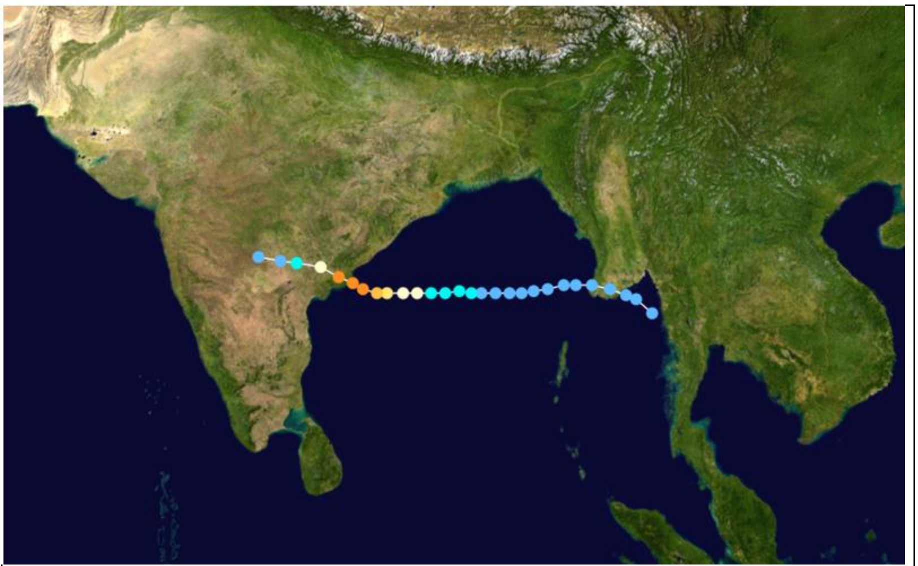


Figure 3: ***Cyclone 07B – November 1996 – track.***
(source: background image: NASA; tracking data from the Joint Typhoon Warning Center; http://en.wikipedia.org/wiki/File:Cyclone_07B_1996_track.png)
Color scheme from the Saffir–Simpson Hurricane Scale:
TD TS 1 2 3 4 5

This damage equals around one third of the Gross Domestic Product of the Delta. As the recurrence period of this severe cyclone is about 50 years, this represents an annual economic risk of around 1 billion Rs, i.e. 0.6% of the GDP for the Delta.

Rate of economic recovery

The model calculates the recovery of the asset values and income of households one year after the cyclone. The model shows that for a severe cyclone such as 07B in one year the average recovery of assets value could be more than 95% of their pre cyclone levels for the better-off households. However, the average recovery for the lowest income groups in the rural areas could be as low as 50% of their pre cyclone levels demonstrating the differential nature of vulnerability. This finding from running models supports our key definition of vulnerability – the degree of inability to cope with or recover from a disaster (cyclone), such as defined in IPPC, 1991 and Blaikie et al., 1994.

Changes explored in land & water use

The model explored a number of development scenarios affecting different land and water uses, and population growth for the next 20 years in the Godavari Delta (Marchand & Mulder, 2007). The relationships between agricultural practice and employment potential and between development and environmental destruction were defined. The model runs suggest that land development and diversification is more likely to support sustainable development than the continuation of the traditional rice agriculture and related investments for irrigation. Investments in the power sector, better roads to markets, and more credit facilities and education, however will diversify and increase the resilience of farming.

Two crucial issues need further attention: (i) the reversal of environmental degradation, and, (ii) the opportunities for more equitable growth with the introduction of new land uses.

The diversification programmes, dealing with changes in the use of resources and labour require careful planning and management, accompanied by environmental protection policies controlling water pollution and replanting of mangrove forest.

Flooding and storm, casualties and damages

The model also analysed several measures directly aimed at vulnerability reduction. Model runs showed that 'maximum flood protection' against storm surges increases safety, but would hardly reduce the damage to assets, mainly caused by high winds. Maximum flood protection and evacuation improvements reduce the number of casualties considerably. Improvements in the road and warning systems, and the provision of more cyclone shelters will decrease the expected casualties by half.

The majority of the assets (crops and houses) are static and vulnerable to flooding and storms. Therefore, relief funds given as grants to households that have suffered losses remain of utmost importance to reduce vulnerability to assets and income. In the model, there are several levels of grants available. A 'medium grant', defined as the provision of relief funds that compensate for 70% of losses incurred by poor households and 50% compensation for medium income households would cost on average of 2 billion Rs and would reduce the number of people vulnerable to financial loss by 60%.

5. Added values of EDSS - ICZM project

We started the coastal program in Andhra Pradesh under the assumption that the principles of ICZM would have a benefit to disaster management. Now, after having studied the problems in the coast, developed an EDSS model and formulated recommendations it is possible to look back and identify the these benefits.

Interdisciplinary approach

This basic integrated interdisciplinary approach has been very important. The team consisted of Indian and Dutch experts from both the natural and social sciences. They undertook field visits, contributed to workshops and collaborated on desk studies. This greatly improved our understanding of the complex problems and feasibility of potential solutions.

Lively and serious discussions led to a balanced and scientifically sound assessment of current practices and recommendations for enhancing a sustainable and socially justified development. This fruitful cooperation resulted in an extensive knowledge base on coastal issues, documented in 14 Technical Reports and 11 Supporting Documents.

Integrating model

However useful this wealth of information may have been, it did not directly provide guidance for the future sustainable development of the coastal zone vis-à-vis vulnerability. For this, the model proved to be a valuable additional instrument as it synthesized data and acquired knowledge on the relationship between the coastal environment, its inhabitants and hazards. The model provided a structure. Large amounts of data from the various sectors and disciplines became visible and operational. It proved to be a vehicle through which a better understanding of the current vulnerability was gained. An example of this is the explanation of spatial differences in vulnerability (see Box). Hence, by combining and presenting data in a way that could not have been done through a mono disciplinary approach, the model was able to contribute to a truly integrated synthesis.

Box:

In the middle of the Godavari Delta lie two mandals (communities) next to each other: Atreyapuram and Kadiam (see Figure 5), neither administrative unit has a high risk of flooding or wind hazard. Nevertheless, Atreyapuram ranks considerably higher in terms of vulnerability than Kadiam. How can this be explained? Closer examination of the socio-economic structure of the mandals revealed a high dependence of the local economy on banana's in Atreyapuram: the 1250 ha of banana plantations contributed to 38% of the total income. Kadiam on the other hand has only 300 ha of banana that contributes only 5 % to the local economy, which is largely dominated by three large factories. Since banana is highly vulnerable to damage by high winds, the impact of a cyclone is much higher for Atreyapuram than for Kadiam.

Figure 4: ***Banana plantations of Atreyapuram****, near the Godavari River, vulnerable for hazardous winds.*
(photo: Google - Image ©2011 DigitalGlobe Data SIO, NOAA, U.S.Navy, NGA, GEBCO ©2011 Google)

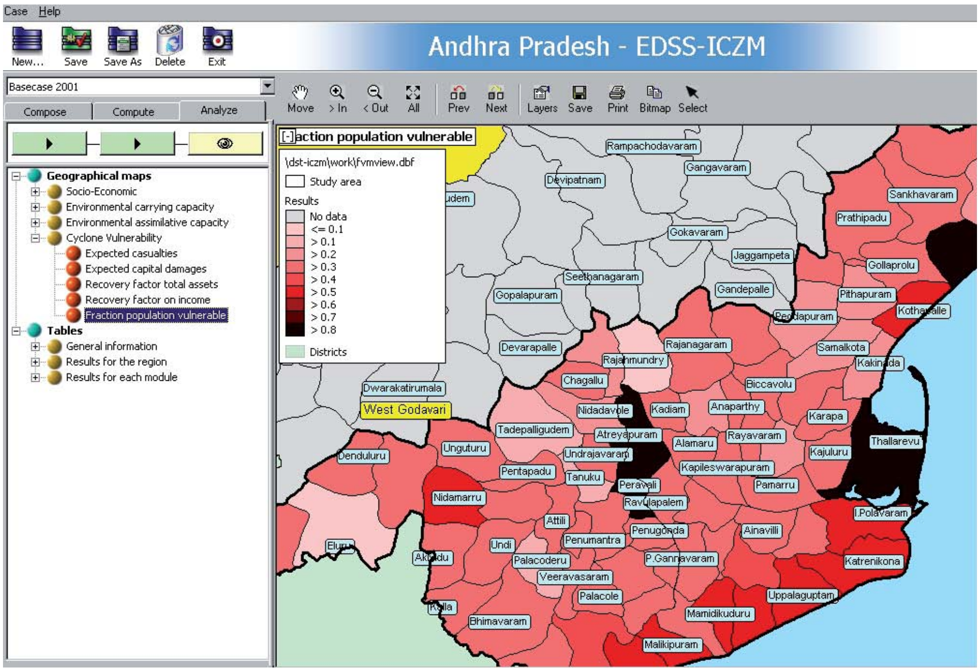


*Figure 5: A v**ulnerability Map for the Godavari Delta** - Basecase 2001: the fraction of population vulnerable for cyclones. The population is multiple vulnerable : in the inland district Atreyapuram the inhabitants are vulnerable for high wind damages and in the coastal district Thallarevu for severe flooding associated with the landfall of cyclones.*

Long term future explorations

The analytical capabilities of the model were used to explore different and plausible future ('scenarios') and measures that can be taken. Such a scenario analysis does not aim to predict the future, but rather to identify the range of measures the government can take. This approach tests the usefulness and robustness of these measures (Groves & Lempert, 2007). The value of the model lies in the increased understanding of the long term functioning of the coastal system. The model does not provide readymade choices, but facilitates informed decision-making..

The ICZM Framework and model results is not a blueprint or Master Plan prescribing in detail what the coastal zone should look like in future. The sheer number and complexity of issues and the huge extent of the coastal zone require initiatives at many different levels and by many different stakeholders. These initiatives would follow concerted decision making by stakeholders, each having their own specific responsibilities. The bedrock of ICZM is that it requires the collaboration of all coastal zone stakeholders in the conception and implementation of a development model that reflects the many and varied mutual interests of the coastal populations.

6. Conclusions

The dual approach to reduce the vulnerability for cyclones by strengthening early warning systems and implementing ICZM was successful. The number of casualties and damage by cyclones can be reduced by proper implementation of these approaches. The implementation of an ICZM programme centred around the development of a decision support model, providing integration of disciplines, structure and synthesis of complex data and predictions for the future. It brought together a large variety of information on natural processes, hazards and socio-economic issues. This Expert Decision Support System (EDSS)-ICZM combination allowed an exploration of future long-term scenarios and strategies, as well as estimates of short-term loss of life and damage from hazards such as cyclones. The benefit of such combined integrated approach is also demonstrated in improved decision-making related to spatial planning and efforts to reduce poverty. Poverty is one of the dominant factors in post- cyclone recovery.

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- **More information on Andhra-Pradesh-Cyclone-Hazard-Mitigation-Project:** http://www.deltares.nl/en/project/101461/andhra-pradesh-cyclone-hazard-mitigation-project & http://www.wldelft.nl/proj/pdf/3uk00147.scherm.pdf
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