Triggers for ICZM

Robbert Misdorp
climecoast@gmail.com

Summary
The coastal zone is a complex area to manage and requires a holistic integrated approach. The need for integrated management is driven by various triggers, such as the impacts of unprecedented, strong population growth, non-sustainable economic development and climate change. These are the main triggers driving coastal cooperation. Integrated Coastal Zone Management (ICZM) is recognised as the adaptive response option and is directed at the implementation of sustainable and no-regret, resilient coastal measures. Integrated coastal programmes deliver simultaneously economical and environmental benefits, and the earlier they are applied the less casualties and damages will result.

"No generation before ours had enough information to understand the urgent need for action. No generation after ours will have the opportunity"

Jennifer Morgan, Director, Climate and Energy program, World Resource Institute, WRI – Year Report 2009

Contents

1 Introduction

Many coastal zones of the world have been impacted by human activities and will undergo continued profound changes in the near future. Due to its mixture of many functions and resources with often high population densities, the coastal zone is a complex area to manage and requires a holistic integrated approach. Three main triggers driving ICZM programmes are the increasing population density in the coastal zone, the impacts of strong economic development and climate change. These triggers create strong pressures affecting society and the natural coastal resources. For instance, the positive effects of strong economic development accompanied by investments e.g. in infrastructure and industry are clear - the increase of economic wealth and the decrease of poverty. Strong economic growth is, however, often accompanied by negative effects leading to damage of valuable resources and degradation of the environment.

One could argue that these changes will be accommodated and that nature is dynamic and will restore herself. However the combined impacts of human activities are moving beyond the natural limits of accommodation. Many countries are living beyond their means in terms of natural resource use and are consuming not only the surplus production but also nature's capital itself. The resource accounting tool Ecological Footprint (see EF website) indicates that the global situation had dramatically changed for the year 2005, with a majority of countries becoming ecological creditors: their Footprints exceeding their own bio-capacity. Moderate UN scenarios suggest that if current trends continue, the world will need implementation of severe adaptive measures.

This CCC chapter describes the main triggers, their impacts on the functioning of the coastal zone – thereby explaining the need for ICZM and some examples of integrated management practices demonstrating their economic and environmental benefits.

2 Three main triggers for an integrated Approach

2.1 The first trigger: Strong demographic development

2.1.1 Strong population growth

Population growth is an important driver leading to pressures on coastal resources and causing environmental change. Population growth leads to an increasing and competing demand for food, water, energy and space putting pressure on natural resources. The faster the population grows the greater the competition for declining space and resources.

The world population is increasing exponentially (Figure 1) and growth was particularly strong during the second part of the 20th century with a doubling of the world population in only 40 years.

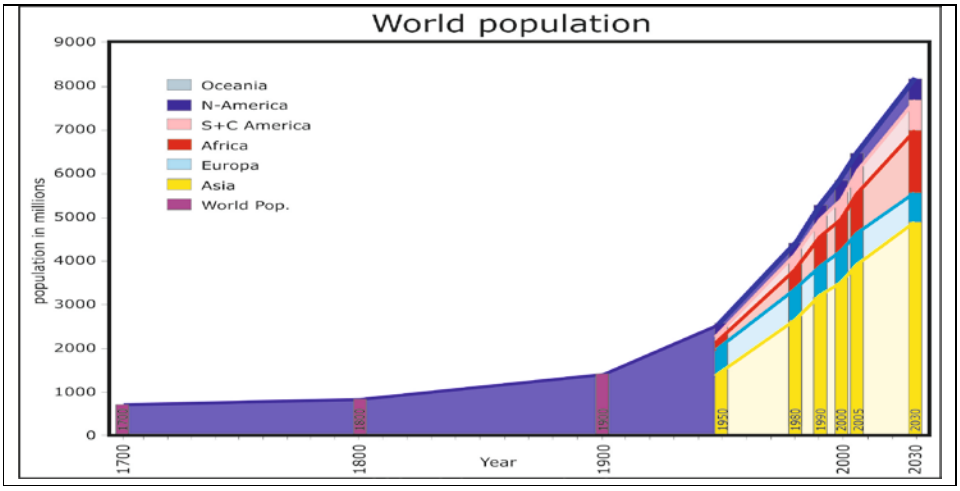


Figure 1: ***World population 1700 – 2030****: exponential growth. (source: R.Misdorp based on J.Bradford DeLong, 1998 + WRI database)*

By 2030, the world population is expected to be more than 8 billion inhabitants (WRI website) and that is more than 4 times as many inhabitants as in 1930. The 2012 UN projections show a continued increase in population in the future up to 2050, however with a decline in population growth rate.
The population of Asia amounts to about two-thirds of the present world population and is growing very rapidly.

2.1.2 Population density in coastal areas

About 50% of the world's human population lives in the coastal zone within 100 km from the sea. The average population density in the coastal zone is twice as high as the global average.
More than three billion people rely heavily on coastal and marine ecosystems, habitats and resources for food, building materials and sites, and agricultural and recreational areas. The coastal areas are also used as a dumping ground for sewage, garbage, and toxic wastes.

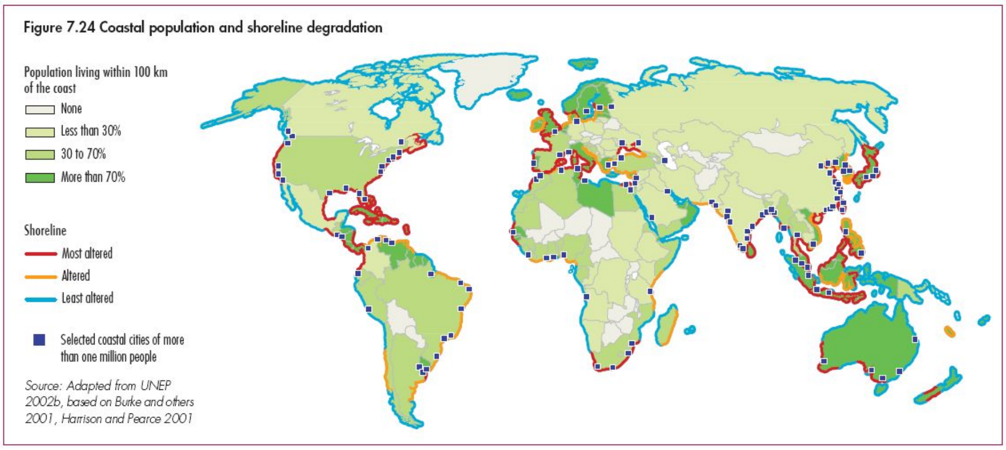


*Figure 2: **Coastal shoreline degradation** is often a problem in densely populated areas. (source: GEO4, 2007)*

The coastal population is growing more rapidly than in inland areas, due to the combined effect of birth rates, migration and large-scale urbanisation. Of the world's 33 world megacities (= more than 10 million inhabitants), 21 are located in the coastal zone, most of them in Asia. Coastal urbanisation in Asia has been rising faster than in any other continent, especially during the last two decades of the 20th century and this trend is likely to continue to at least 2030.
The population pressure on the world coastal zone is seriously damaging the resource base itself in many coastal nations (Figure 2). Coastal urbanisation often involves large scale pollution and increased risks of flooding due to increased population density and fast, short-term economic development and capital investments. Examples of long-term solutions demonstrate the economic and ecological benefits of no-regret, resilient adaptation.

2.1.3 Example: rapid coastal urbanisation in China

An example of large-scale urbanisation in the coastal zone is represented by China. *S*ome 100 million people moved from inland areas to the coast during the last twenty years. This process of massive coastal urbanisation will continue in the next decades. This wave of coastal urbanisation will not only result in a massive expansion of the current cities, but also hundreds of new cities have to be built in order to accommodate this mass migration. This scale of coastal urbanisation is unprecedented in the world.

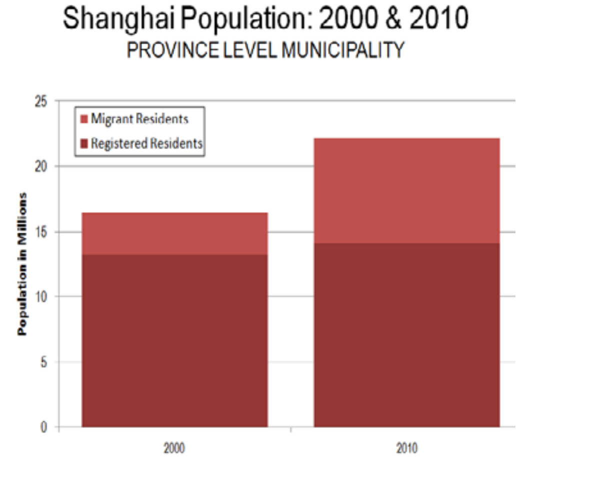


*Figure 3 and 4: **Shanghai - urban expansion**, registered population and migrant residents. (sources: National Geographic Magazine. and New Geography)*

The rapidly expanding area and population of the city of Shanghai (Figures 3 and 4) is an example of the massive urbanisation. The population of the city of Shanghai was 24 million in 2013. Shanghai has been one of the fastest developing cities in the world for the last decades, mainly due to large scale influx of migrant residents from other provinces and regions.

China's rapid coastal urban development is leading towards spatial and ecological conflicts, negatively affecting the economic use of the coastal zone. Existing rivers are drying up because water is extracted by upstream cities and industries. Ground water is exploited for agricultural use and many water systems are polluted due to rapid development and inefficient waste water treatment. Furthermore, low-lying coastal areas are vulnerable to the impacts of climate change such as accelerated sea level rise accompanied by salt water intrusion and an increased frequency of storms and risk of flooding. Moreover, considerable sections of the Chinese coastline are affected by large scale land fills (Yan et al., 2015).
Recognition of these issues is motivating China to take action to rehabilitate the most degraded areas.

2.2 The second trigger: strong economic development

2.2.1 Fast economic growth

During the last half century the world economy has grown at an unprecedented rate. The growth of global economic wealth can be, expressed in terms of Gross Domestic Product (GDP) per capita (Figure 5a). Amazingly, during the 20th century the average global GDP/capita doubled within only 30 years.
Most countries are characterised by growing GDP/capita. This growth rate is even faster than that of the population. However, the level of economic wealth and the growth rate differ strongly among the continents (Figure 5b). Notably, the scope for growth in Asia is large.
The extraordinary growth in economic output contributes to combating poverty and can increase the resilience of coastal population in times of stress. Economic development is an important factor in reducing the vulnerability to coastal hazards, as demonstrated in Andhra Pradesh, India (see CCC II-3-4). This development is desirable but is all too often accompanied by unsustainable resource use and subsequent degradation of the natural resources upon which we depend. In a sustainable situation only the interest of the natural capital, the fruits are consumed. However, it is becoming more and more clear that we are consuming the natural capital, the stock itself, in a destructive way. We are not only eating the apples but we cutting down parts of the tree. In terms of fisheries: we are eating too many small fish, before they are able to spawn and produce the next generation (see Ecological Footprint Atlas - EF).

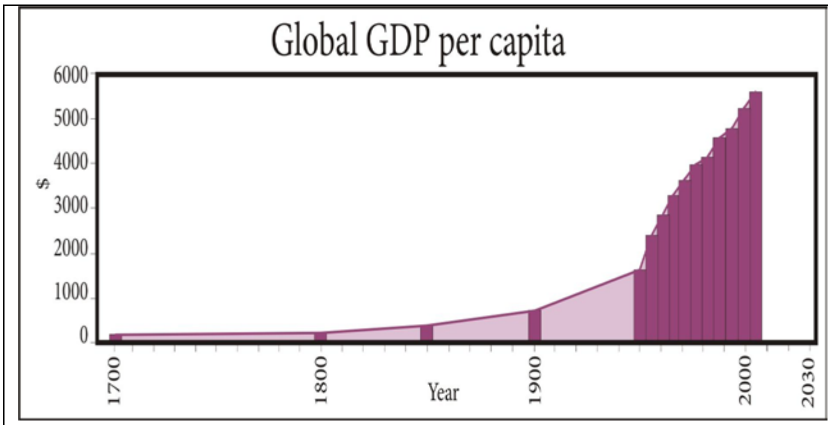


Figure 5a: ***Long term World GDP/capita: 1700 – 2005****, strongly growing economic wealth with an unprecedented short doubling time of about 30 years during the second half of the 20th century. (source: R.Misdorp based on J.Bradford DeLong 1998 for the period 1700 – 1950: in 1990 International $ and WRI database for 1960 – 2005: in 2000 constant US$)*

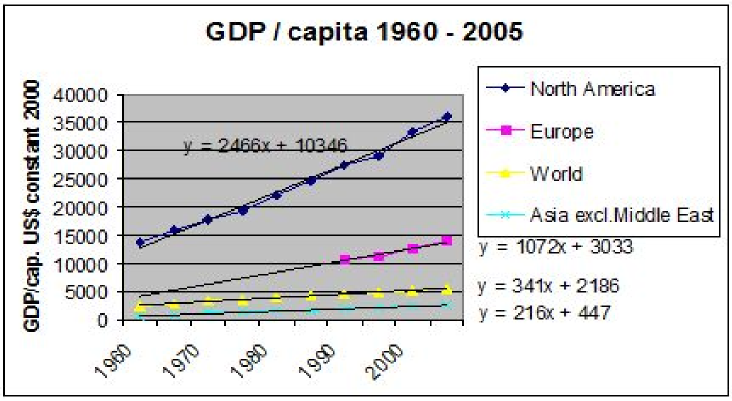


*Figure 5b****: Gross Domestic Product per capita among three continents and the world: 1960 – 2005****, the increase in economic wealth, unequally distributed among the continents. (source: R.Misdorp based on WRI database).*

2.2.2 Example: rapid growing tourist industry

Many examples of degradation of the natural resources are at hand ranging from air, water and sediment pollution by intensive industry and agriculture to excessive coastal and marine fishery.
The explosive growth of the tourism sector also puts considerable pressure on coastal habitats and ecosystems, resulting in an increased competition for space with nature and fisheries (Box III-2-2).

Box III-2-1: Tourist development – a specific example of strong growth rate

One of the economic sectors, influencing coastal development is tourism. Half of the international tourist arrivals for leisure, recreation, and holidays are in the popular coastal areas.
The tourist industry has been characterised by spectacular growth in the last half century, increasing from 25 million international tourist arrivals in 1950 to 922 million in 2009 (Figure 6). This corresponds to an annual average global growth rate of 6.8%. By 2020, international tourist arrivals are expected to reach 1.6 billion. This very strong increase in the tourist industry generates a rapid growth in income for the destination countries. The total receipts from international tourism, including international passenger transport, amounted to US$ 1.1 trillion in 2008, which is about 3% of the world GDP and just over 6% of worldwide exports of goods and services. The tourism income for some coastal (island) nations can reach even 50% of the GDP. Worldwide more than 75 million people are directly employed in the tourism sector.
Such explosive growth of the tourism sector puts considerable pressure on coastal habitats and ecosystems. There is also a strong and increasing demand for fresh water. Untreated waste water threatens coral systems, which are a favourite tourist attraction. These side effects pose a challenge for governments and the tourist industry. The Seychelles provides an example of combining nature conservation with a high level of tourist income (about 50% of its GDP) in an economically profitable and sustainable way (see chapter CCC II-5-1).

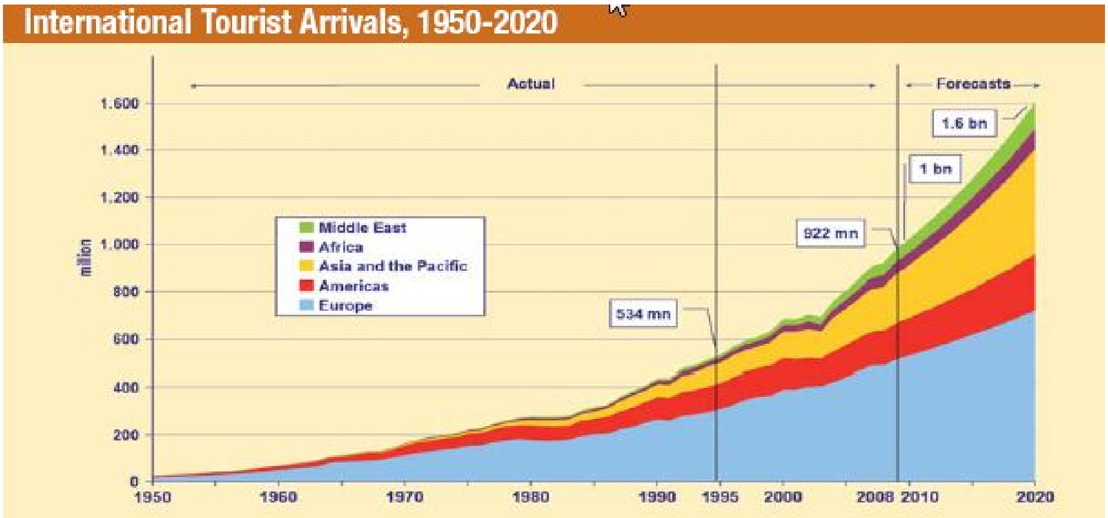


*Figure 6: **International Tourist arrivals 1950 – 2020**, from 25 million in 1950 to an expected 1,600 million arrivals per year in 2020,an impressive and staggering increase. (source: UNWTO, 2009)*

2.3 The third trigger: climate change

2.3.1 Strongly increasing concentration of atmospheric greenhouse gases

The third trigger for an integrated approach is climate change, caused by the strong increase in the concentrations of the atmospheric green house gases (GHG) such as carbon dioxide (CO_2) and methane (CH_4). This increase, since the beginning of the 20th century, is strong compared to the natural changes during the Quaternary period. The CO_2 concentration ranged between 180 and 280 parts per million (ppm) during the last 800,000 years including several cycles of glaciation and deglaciation. In that narrow band of only 100 ppm, large scale glaciations and interglacial, warm periods alternated over a long period (see Figure 7).

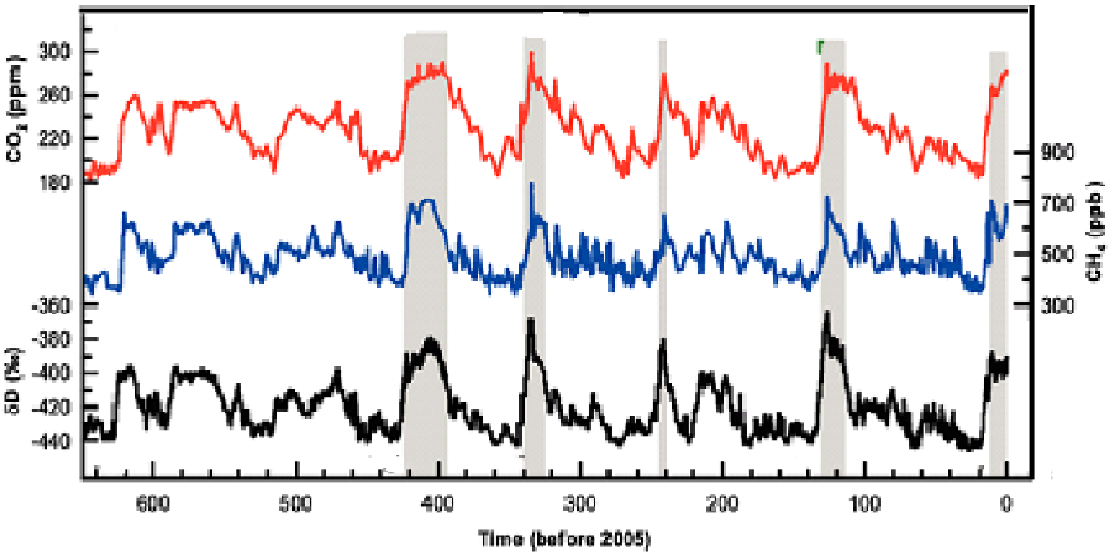


Figure 7: Variation of Greenhouse gases and deuterium during the last part of the Quaternary era:

- *carbon dioxide (CO_2 in parts per million-ppm , red) and*
- *methane (CH_4 in parts per billion- ppb, blue)*
- *deuterium (δD in promille, black) a proxy for temperature.*

Shading indicates the major interglacial, warm periods. Derived from air trapped within ice cores from Antarctica *over a period of 650,000 years; X-axis: Time in 1000 years before present. (source: IPCC-2007- WGI- 6.4.1.)*

The upper limit of the CO_2 concentrations during the warm interglacial periods was 280 ppm throughout the Quaternary period.
During the maximum ice extent of the last glaciation (18,000 years ago), the CO_2 concentration was 180 ppm and the global sea level was 120 meters below its present level. The sea rose quickly during the subsequent period of warming (mainly between 18,000 – 5,000 years ago), while the CO_2 concentration rose from 180 to 280 ppm.
There is still some discussion about the uncertainties regarding the degree of human influence on the present climate change. However, all scientists and policymakers concerned agree that the concentration of the greenhouse gases in the atmosphere is rising very quickly. The present CO_2 level in the atmosphere has reached 400 ppm. The rapid increase, from 300 to 400 ppm has been realised in less than 60 years (Figure 8). The present concentrations of the major GHG substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years (IPCC, 2013).

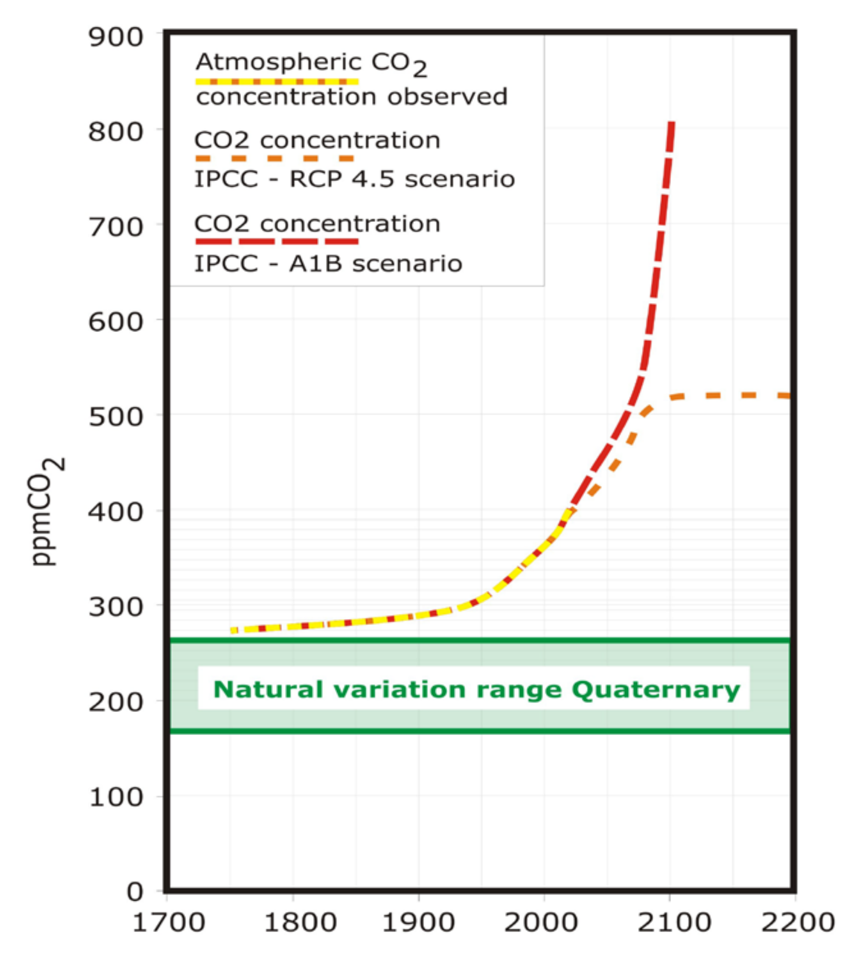


Figure 8: ***The rapid increase of atmospheric carbon dioxide (in parts per million -ppm CO_2)*** *during the period 1750 – 2013 AD. The A1B emission scenario IPCC, 2007; the RCP 4.5 emission scenario IPCC, 2013. (source: R.Misdorp based on pre-1990 data in: B. Moore & D. Schimel and the Keeling Curve 1958 – 2007 in P.Tans & R.Keeling, and IPCC 2007 and 2013)*

2.3.2 Scenarios for future GHG concentrations

How will the Greenhouse gases (GHG) concentrations develop in future? Two sets of scenarios illustrate the possible trends in the concentrations of CO_2:

- Some of the IPCC 2007 scenarios envisage a doubling of CO_2 or even a tripling of the pre-industrial level in the year 2100. See the IPCC A1B scenario (Figure 6) reaching more than 800 ppm.
- Four recent Representative Concentration Pathways - RCP emission scenarios (Moss et al. 2010) have been adopted by IPCC (IPCC-SPM, 2013). One of these, the RCP4.5 scenario, is one up from the lowest emission scenarios for CO_2. RCP4.5 is a stabilization scenario, achieving the goal of

limiting emissions by the introduction of a set of global GHG emissions pricing and mitigation measures (Thompson et al. 2010; see also paragraph CCC III-2-5). The CO_2 concentration is envisaged to increase at first and is then followed by a stabilisation at a level of 525 ppm CO_2 during the centuries to come (Figure 8). The RCP4.5 stabilisation of the CO_2 concentration in 2080 corresponds to a temperature stabilisation of 2.5^0 C relative to pre-industrial times (IPCC 2013, WG1, Chapter12).

These two sets of IPCC scenarios envisage high levels of CO_2 by the year 2100. Even if the RCP4.5 stabilisation level of 525 ppm CO_2 is reached by stringent mitigation efforts, this level is well beyond the maximum natural level of 280 ppm.

The consequences of such envisaged high levels of GHG concentrations make detailed impact analyses of climate change at a local level urgent as well as the identification and preparation of adaptive measures for coastal areas.
Adaptation will become more and more important if the implementation of mitigation measures is late and/or ineffective. ICZM is internationally recognised as the adaptive response mechanism for low lying coastal countries (see paragraph 4.1).

Summarising - the three main triggers:
Looking at the amazing long term graphs (Figures 1, 5a and 8) of the rapidly growing population, economic development and GHG emissions, one wonders: Can these steep rising curves continue to rise in his way and at what costs?
The scenarios for future atmospheric Greenhouse gases (GHG) emissions, for instance, are all moving to levels far above the natural maximum levels, making extrapolation of the impacts a challenging and risky business. Before executing adaptive solutions, more detailed impacts studies should be undertaken particularly at local levels.
In the next paragraph some impacts of the three main triggers are discussed.

3 Impacts of the triggers

3.1 Demographic development and spatial footprint

The rapid coastal urban development can easily lead towards spatial and ecological conflicts, negatively affecting the economic use of the coastal zone. This is the case in many coastal states. Existing rivers are drying up because water is extracted by upstream cities and industries. Ground water is exploited for agricultural use and many water systems are polluted due to rapid development and inefficient waste water treatment. Furthermore, low-lying coastal areas are vulnerable to the impacts of climate change.
Of course, rapid urbanisation requires the rational and integrated spatial planning of coastal areas preparing for the implementation of sustainable coastal measures to avoid degradation and decrease the spatial footprint.

3.1.1 Demographic pressure in the Chinese coastal zone

The rapid urban development in the densely populated coastal areas has created severe problems related to the management of the coast, water and land resources. In China, this process of massive coastal urbanisation will continue and accelerate in the next decades. The increase in coastal population density will increase the risk of flooding, which will be furthermore exacerbated by the impacts of climate change. Another effect of increased population density is the effect on water quality of the coastal rivers and creeks.
In search for space, new coastal land has been developed as large scale land fill projects for port and industry development, for salt panning and mari-culture (Yan et al., 2015), with impacts on the coastal wetlands, species diversity and water quality.

There is a growing recognition in China that long-term economic and social vitality depends upon a more efficient and effective use of the natural resources, coupled with improved human and environmental health. To address the pressure from rapidly growing population in the coastal zone, China is preparing holistic and sustainable strategies for urban development. These strategies must contribute to a better environment for people and improved conditions for nature as well as creating opportunities for local and regional economic development (see CCC II-2-4).
In this context, three coastal urban master plans for the construction of "Eco-Cities" have been produced. New land will be developed according to the principle of 'Building with Nature' (see CCC III-3-3-1).

*Figure 9: **Artistic view of the Caofeidian Eco-City,***
Bohai Sea, the coastal master plan combines economic development, renewable energy & transport, land & water, work & recreation in an attractive urban design with a high degree of sustainability. (source Royal Haskoning DHV)

These plans are based on a new integrated approach combining urban and harbour planning with water management and transport with zero or low CO_2 emissions, strongly reducing the ecological footprint. The results of these planned pilots will determine whether the integrated concept of Eco-Cities can be implemented on a large scale in China and beyond.

3.1.2 Socio-economic pressure in the Netherlands

Growing population densities and coastal urbanisation

The Netherlands is a low-lying, deltaic and dynamic country. The population, the economy and capital investment are all rapidly growing. About half of the country's surface lies below mean sea level and more than 50% of the Dutch population lives in the five coastal provinces, encompassing only 38% of the total surface area.

The population density in the Netherlands is among the highest of the world, with an average population density of 495 inhabitants/km^2 in 2011.

Two of the five provinces bordering the sea (Noord- and Zuid-Holland, Figure 10), have a much higher population density of 1140 inhabitants/km^2 over a large area of 5470 km^2.

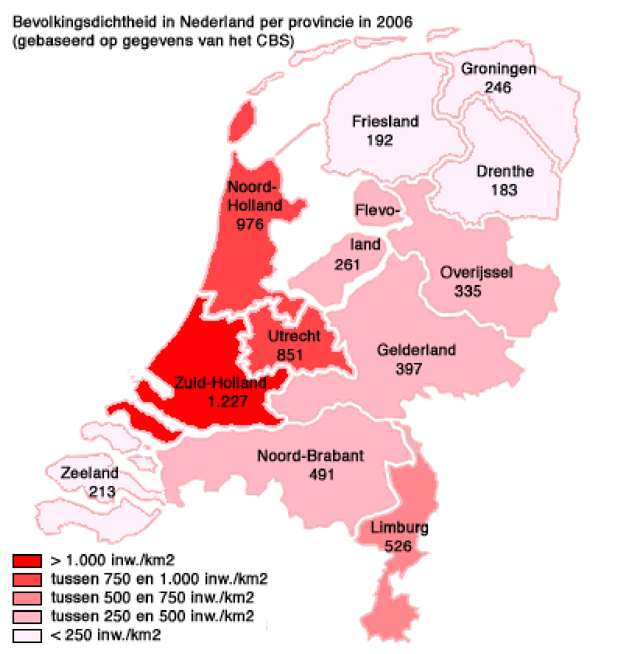


Figure 10: ***Population density in the Netherlands*** *per province 2006. (source: CBS*

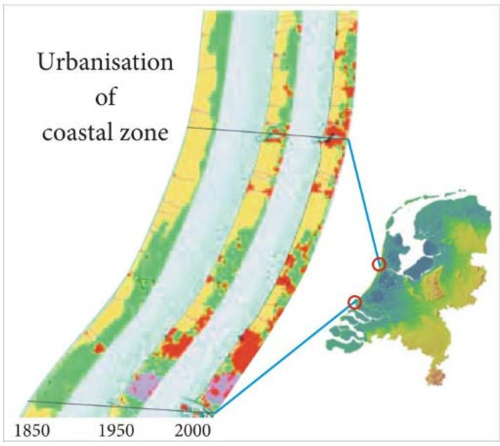


Figure 11: ***Increasing urbanisation*** *(in red) of the sandy Holland coastal zone, 120 km long, between Hoek van Holland and Den Helder, the Netherlands. (source: Min.V&W + Min.VROM, Min EZ, Min LNV, 2002)*

The population density of the Netherlands increased from 300 inhabitants/km^2 in 1950 to 495 in 2011. The low-lying West-Netherlands is characterised by a high degree of urbanization with 75% of the inhabitants now living in an urban environment (Stat Line).

The trend towards increasing population density and coastal urbanisation is an ongoing long- term process. The small towns and villages in the120 km long Holland coastal area have been growing and strongly expanding in surface area since 1850 (Figure 11).

In the Netherlands the population pressure is high, and this is reflected in the strong and growing demand for housing. The number of housing units in the Netherlands has increased by 220% over the last 60 years (Table 1). This indicates a considerable growth in spatial footprint per inhabitant of the Netherlands, particularly in the more densely populated coastal zone.

Table 1: ***Population, houses and property values in the Netherlands*** *- (source: CBS StatLine)*

	Population	# Houses	Value of houses	# Houses per 1000 persons	GDP/cap in $ constant 2000
	in millions	in millions	100% = 2001		
1951	10.200	2.291	7.8%	225	6,000
2011	16.656	7.266	128.0%	436	26,000
Rate of growth 1951 - 2011	**60%**	**220%**	**1500%**	**95%**	**330%**

Growing Gross Domestic Product and Capital investment

The coastal zone of the Netherlands encompasses considerable economic and ecological values. Many towns and cities, harbours and industrial centres are situated in the low-lying coastal zone. The Port of Rotterdam harbour is the largest harbour in Europe. The international Amsterdam- Schiphol Airport is located at 4.5 m below mean sea level. Both gateways contribute about 13% to the GDP. The coastal zone accommodates tourism and also provides services such as the (last stage) filtering of drinking water. The sandy beaches and dune fields are both a natural habitat and natural sea defence. Where beaches and dunes are absent, dikes, dams and storm surge barriers protect the hinterland from floods.

The GDP (Gross Domestic Product), amounting to $836 billion (2012, nominal US$), ranks the Netherlands at the 17th place globally, produced by a population of 16.7 million (http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal).
The Gross Domestic Product per capita, an indicator of economic wealth, was € 33,200 in 2011 and is growing constantly and significantly, by a factor three over half a century (Figure 12).
This high level of GDP involves a high level of capital investment, which is located for the largest part in the flood sensitive, low-lying part of the Netherlands.

The estimated capital investment in the low lying coastal area of the Netherlands is in the order of several trillion Euros (10E12 €). The economic value of the total real estate in the Netherlands is growing very rapidly: see the value of houses 1951 – 2010 (Table 1). This long term, enormous increase rate of Dutch property value was also recently confirmed by a threefold increase during the last 15 years from € 0.7 trillion in 1997 to € 2.2 trillion in 2012 (CBS – Statistics).

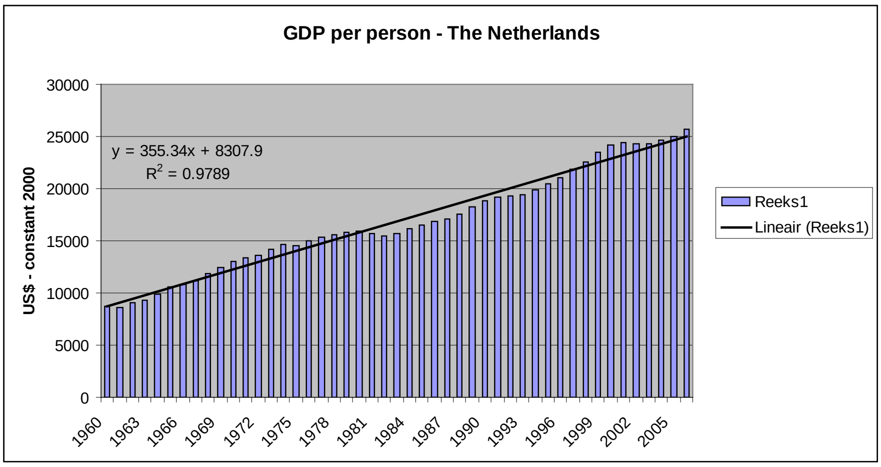


Figure 12: ***The development of Gross Domestic Product/capita for the Netherlands: 1960 - 2010*** *in US$ constant 2000. (source: WRI –Earthtrends)*

Summarising, the socio-economic pressure in the low lying Netherlands is high due to:
1) Fast growing population density: large area with more than 1100 inhabitants/km^2 in the two low-lying coastal provinces of Noord and Zuid Holland;
2) The strong growing value of capital investment (houses, infrastructure, industry) in the western, low lying part of the Netherlands is high, several trillion Euros.

3.2 Non-sustainable economic development and fisheries

During the last half century the world economy has grown at an unprecedented rate. This development is desirable but is all too often accompanied by unsustainable resource use and subsequent degradation of the natural resources upon which we depend. In a sustainable situation only the interest of the natural capital, the fruits, are consumed. However, it is becoming more and more clear that we are consuming the natural capital, the stock itself, in a destructive way. We are not only eating the apples but cutting down parts of the tree. In terms of fisheries: we are eating too many small fish before they are to spawn and produce the next generation.
Many examples of degradation of the natural resources are at hand ranging from air, water and sediment pollution by intensive industry and agriculture to excessive coastal and marine fishery.

In this chapter, the effects of strong economic growth is illustrated by the marine fishery industry. The non-sustainable exploitation of the marine resources has a destructive impact reducing the productivity of the marine fishery itself.
Responding with innovative, adaptive programmes and measures that are well planned and executed can have positive effects for the short and long term. Participatory approaches of co-management, reducing the fishing fleet, creating artificial reefs and managing aquaculture ponds in a sustainable way are examples of win-win responses. Long-term, balanced measures are facilitated by an integrated management framework. Examples of these solutions are mentioned in paragraph 4.2.
In view of the large magnitude of the coastal and marine fishery's problems, it is clear that these examples should be considered as a first step towards restoring the marine environment and the fishery sector.

3.2.1 Marine litter and ghost fishing

Marine litter consists of human-made material that is found in the marine environment. It includes everything from kitchen waste and plastic detergent bottles to oil barrels, fishing nets, broken fridges and redundant machinery. Plastics form the most abundant, persistent, non-biodegradable fraction of the marine litter, which gradually fragments into smaller pieces. These micro plastics act like a sponge, absorbing and accumulating pollutants, and enter the marine food web and the commercial fishes.
Marine litter becomes abundantly visible on the shores but according to divers and fishermen marine litter is also present everywhere in the sea, even at great depths. Research was conducted in two large areas of marine debris concentrations: in the North Atlantic Subtropical Gyre and in the North Pacific Ocean, where the pieces of plastic outweigh surface plankton by a factor of 6 to 1 (Coastalwiki).
The amount of garbage and plastic litter is growing. About 20,000 tonnes of litter per year is being dumped in the North Sea alone (see KIMO website).
The impacts of marine litter on the economy, the environment and public safety is large.

Figure 13: ***Stomach content in an albatross chick remains,*** *Midway, 2009.* ***(*** *Copyright: Chris Jordan)*

Marine animals become easily entangled and trapped in our garbage, and it can destroy delicate sea life like coral and sponges. In addition, sea turtles, seabirds (Figure 13) and marine mammals mistake plastics for their favorite food and ingest marine debris.
Propellers of ships regularly get entangled in litter, resulting in damage, stranding during stormy weather and lost operating time. A Dutch shrimp fishing vessel was stranded rudderless on the Pettemer North Sea Dike, in the Netherlands, with a fishnet in its propeller during the stormy night of 17th October 2013 (Figure 14).

Figures 14a and 14b: ***Stranding of a shrimp trawler on the Pettemer North Sea Dike****, due to entanglement of a fishnet in its propeller, 19 October 2013 (source: Marc Alberts)*

Derelict drifting fishing gear continues to trap marine animals (Figure 15). Often these traps trigger a chain-reaction when larger predators come to eat the smaller ones that have been ensnared, only to get tangled in the mess themselves.
Several valuable initiatives touching upon this severe problem of litter have been executed within an international and coordinated framework. Sustainable integrated solutions made a difference and involved many stakeholders.

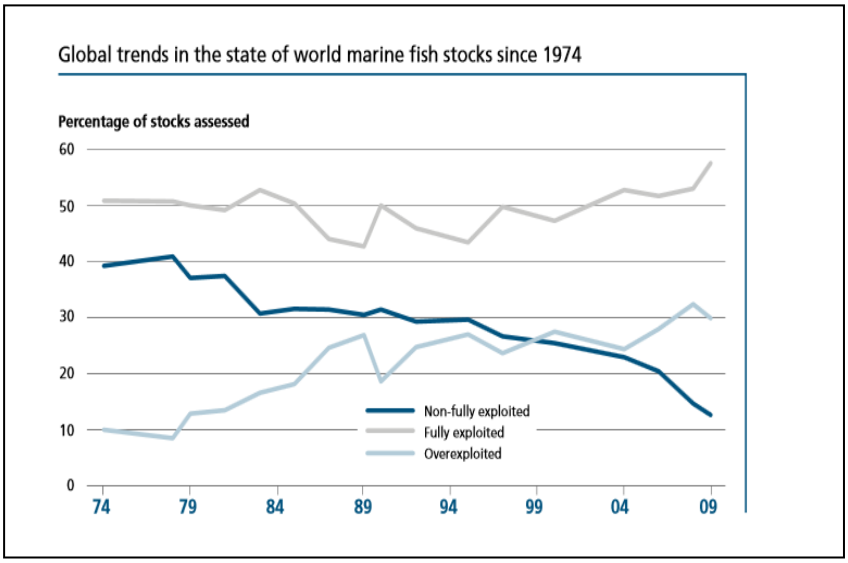
*Figure 15: **Ghost fishing** - lost or discarded fishing gear continues to unintentionally kill many fishes, crustacean and other marine life. (source: Overfishing)*

3.2.2 Overfishing and bycatch

Overfishing is considered to be the worst impact by humans on the oceans. The UN Food and Agriculture Organization estimates that more than 85% of the world's fish stocks were overfished and fully exploited in 2009 (Figure 16). Less than 15% of the global fish stocks are being sustainably exploited. If these data and trends continue to hold, global fish stocks will crash by around 2050 (UN Press Conference, 24 May 2010).

By catching fish faster than they can reproduce, we are harming the standing fish stocks and the entire ecosystems that interact with those species, from the food they eat to the predators that eat them. These losses make the ecosystems more vulnerable to other disturbances, such as pollution and impacts of climate change.

Figure 16



Mankind is facing a serious depletion of commercial marine fish stocks.
World per capita food fish consumption increased from an average of 9.9 kg (live weight equivalent) in the 1960s to 18.4 kg in 2009, and to 18.6 kg in 2010 (FAO, 2012) outpacing the world population growth rate. About two thirds of the fish consumed is 'wild' catch inland and marine), the rest coming from the strongly growing production of aquaculture
Fish constitutes an important source of nutritious food for a large part of the world's population.

The annual world fish consumption per capita doubled in the period from 1960 – 2000. At the same time the world population more than doubled. This resulted in a spectacular fivefold increase in marine fish catch in 40 years, with a maximum marine fish catch of 72 million tonnes in 1995 (Figure 17).

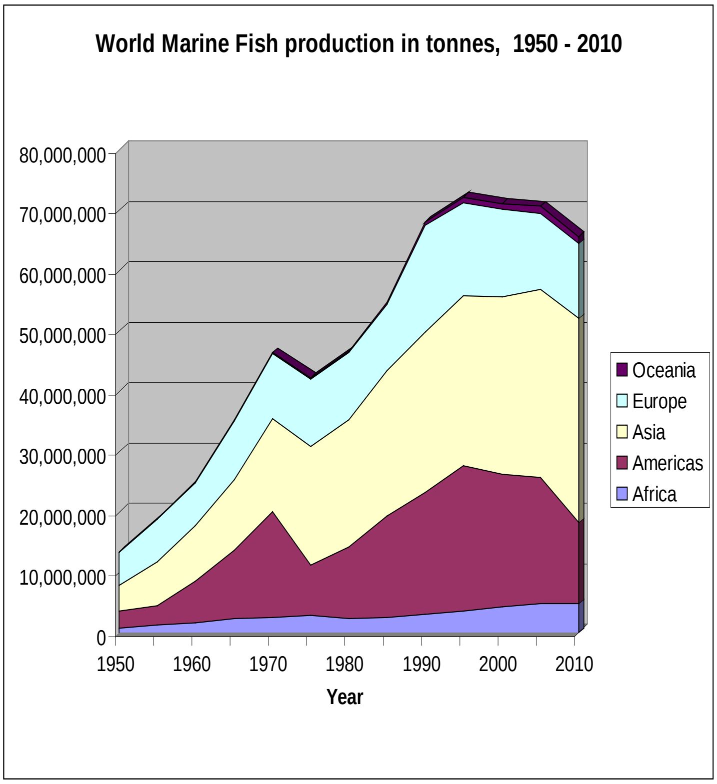


Figure 17: ***World Fish catch in marine waters*** *1950 – 2010. (source: R.Misdorp based on FAO-faostat)*

The above rate of growth varies strongly per region. The amount of fish caught in Africa is gradually growing, but Asia and particularly China have contributed the most to the remarkable world growth rate in fish production. Europe already reached its maximum rate of marine fish production in 1990, and the Americas in 1995

Since 1995, the global marine fish catch has been declining, caused by the decreasing fish stocks and the effect of (inter) national fishery policies adopted by most countries in Europe and the Americas and by some countries in Asia (FAO, 1999). But although the global marine fish catch has been decreasing, the numbers of marine fishermen and motorised and non-motorised marine fishing vessels are still increasing. This has reduced global fishing productivity expressed as marine fish caught per vessel and per fisherman, by 16% and 32% respectively, in 15 years (Table 2).

Table 2

Marine fishing productivity		**1995**	**2000**	**2005**	**2010**
Global mar. catch / vessel	tonnes/vessel	18.03	17.37	16.91	15.05
Global mar. catch / fisherman	tonnes/fisherman	2.54	2.17	1.92	1.71
Data: FAO-faostat, FAO 2012					

The depletion of the fish stocks and the degradation of marine resources and the environment pose a major threat to the food supply of many hundreds of millions of people in the coastal zone.

Bycatch discards are a destructive side effect of non-selective fishing. Marine animals are caught unintentionally during fishing (Davies et al. 2009). Dolphins, marine turtles, seals, seabirds, sharks, juvenile commercial fish, non-commercial fish, corals – hundreds of millions of marine animals of non-target species – are caught each year by fishing boats and long lines, and then discarded dead. Estimates of bycatch reach to an average of 40% of the total marine fish catch, peaking at 60%. This implies that several tens of million tonnes per year of marine animals are lost. These numbers are indicative, minimum bycatch estimates.

Obviously, few industries would tolerate such a level of waste of about 40% year-on-year and such a lack of sustainable management (Davies et al. 2009). The scale of this mortality is such that bycatch contributes to serious fishery declines and negatively impacts commercial fishery productivity itself, in addition to destroying the structure and function of entire marine systems.

Summarising the enormous extent of overfishing and bycatch:

- 85% of global marine fisheries production is non-sustainable and
- Many tens of millions of tonnes of marine animals are discarded dead yearly.

Several international agreements and policies are aiming to protect global fish stocks. However meaningful measures are urgently needed to combat this devastating overfishing and bycatch.
A complete overhaul of fisheries policies requires global and local cooperation, a long-term vision and an integrated framework to achieve a sustainable fishing system.
Intensified international, national and local management efforts should result in binding agreements on catch sizes, selective fishing, marine law enforcement, capacity building and strengthening the application of marine biological research.

3.2.3 Aquaculture and Thailand

Global marine fish production increased strongly during 1950 – 1995 (Figure 18). In 2010, total global food fish production was 149 million tonnes, of which 89 million tonnes was from wild catch (marine: 77; inland: 12) and 60 million tonnes from aquaculture (inland: 42; marine: 18).

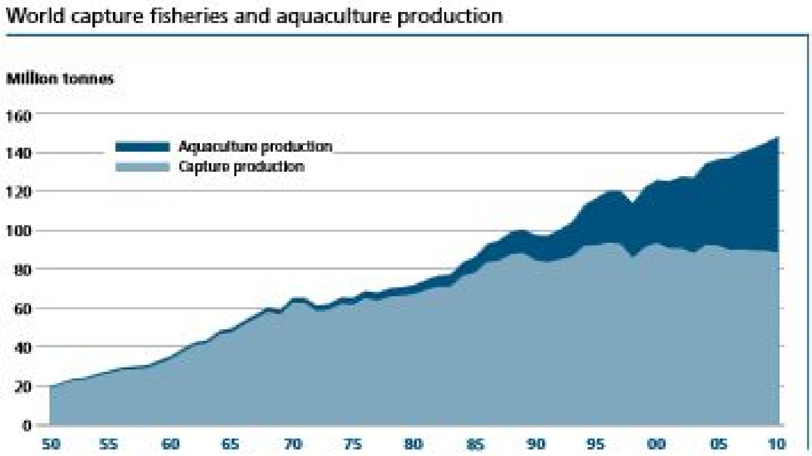


Figure 18: ***Global fish catch and aquaculture fish production****. (source FAO, 2012)*

Aquaculture production has been growing very fast, increasing more than fivefold since 1990 and providing substantial protein food resources to coastal inhabitants. This rapidly growing marine aquaculture is often seen as the substitute for the dwindling marine fish catch.
However, aquaculture production is vulnerable to the impacts of diseases and environmental conditions, and intensive aquaculture itself often affects the surroundings negatively.
The negative consequences are often due to poorly managed operations. Excess nutrients and chemical pollution can enter into the open ocean when fish feed, excrements and medicines are released.

Examples of the negative impacts of fast growing aquaculture production are found in Thailand.

Thailand is one of the world's leading shrimp farming nation with a high level of very high-yield shrimp production (> 4 tonnes/ha annually) and provides valuable lessons.
In the period 1970 – 2000, three Boom-and-Bust cycles of intensive shrimp cultures occurred. The rapid development of shrimp farming caused severe degradation of the coastal environment. The negative effects of intensive shrimp farming include:

- Valuable rice paddies and mangroves forests are lost during the construction of the shrimp ponds;
- Pollution due to excess use of food, fertilisers, antibiotics, pesticides and dumping of shrimp pond sludge;
- Acidification of the pond soils through oxidising pyrite;
- Salt water intrusion negatively affect the neighbouring agriculture areas.

Figure 19: ***Black tiger shrimp (Pennaeus monodon),*** *this species was replaced in Thailand by the white shrimp in the beginning of this century, ncreasing productivity to even higher levels. (photo: CORIN – Coastal Resources Institute, Hat Yai, Thailand)*

Thai Shrimp farming:
Southward migrating Boom-Bust waves

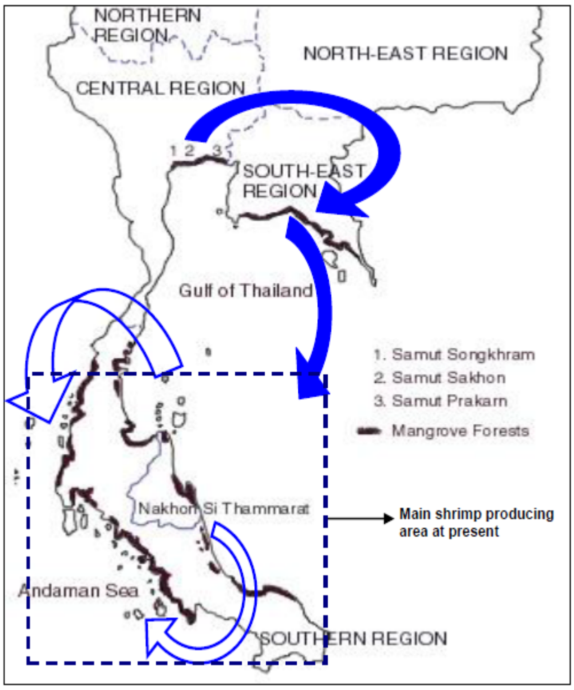


Figure 20: ***The southward migrating Boom-Bust waves****, reaching the southern province of Nakhon Si Thammurat along the Gulf of Thailand and the coastal areas of the Andaman Sea. (source: S.Boromthanarat)*

These impacts are so severe that the Thai fish farm companies abandon their shrimp ponds, leaving the coastal areas barren and moving to the next coastal area to start a new cycle of intensive farming practices (Figure 20).
These 'wastelands' cover large areas, for instance more than 40,000 ha in the Upper Gulf of Thailand alone during the 1990s, leaving a useless coastal zone behind and coastal residents without a livelihood.

Summarising, the large-scale, non-sustainable exploitation of marine resources has severe destructive impacts, including a severe reduction of the productivity of the marine fishery itself as well as the degradation of the entire marine ecosystem and a wide range of valuable coastal and marine resources. Responding with innovative, adaptive programmes and measures, well planned and executed, can have positive effects for the short and long term. Win-win responses such as participatory approaches involving co-management, downsizing the fishing fleet, creating artificial reefs, and managing aquaculture in a sustainable fashion have already been applied successfully. However, in view of the large scale of these coastal and marine problems, the examples of responses given here merely serve to mark the beginning of a long road towards solving these global challenges.

3.3 Climate change: melting of Greenland Ice Sheet and Sea level Rise

3.3.1 Impacts of climate change

The impacts of global climate change will severely affect the population of the coastal zone of the world in a variety of ways; see the five IPCC Assessment Reports (IPCC 2013). The impacts of climate change on the coast come from both sides - the land and the sea.

Some general impacts of climate change on land, particularly in the tropics, are (IPCC- FAR – 2007 - WGII – Asia: Chapters 10, 6):

- *Diseases and heat stress*: Rising temperature and rainfall variability will increase the frequency of occurrence of diseases (cholera, diarrhoea) and heat stress;
- *River systems*: Changes in rainfall patterns, affecting river discharges and water levels, agriculture, shipping and risks of flooding;
- *Agricultural productivity* may increase due to increased CO_2 concentration and may decrease due to intensified drought, flooding, soil degradation and salt water intrusion.

From the sea:

- *Coastal wetlands*: sea level rise (SLR) and increased temperature will affect intertidal areas, mangroves and coral systems: 1-2^0 C above average seasonal maximum is critical.
- *Accelerated Sea Level Rise (ASLR):* estimates of the rate of sea level rise, ranging from 0.4 – 1.3 m/21st century, are also influenced locally by glacial rebounds, tectonics and coastal soil compaction.
- *Storminess:* future tropical cyclones will become more intense, with heavier precipitation, due to the ongoing increase in tropical sea surface temperatures.
- *Salt water intrusion* into coastal water systems will increase as a result of intensified seepage and landward encroachment by the sea.

Specific impacts of global warming are discussed below, e.g. the increase in the summer melt of the Arctic Sea Ice and the melting of the Greenland Ice Sheet contributing to sea level rise.

3.3.2 Summer melt of the Arctic Sea Ice

The summer melt of the Arctic Sea Ice (ASI) is increasing significantly and is very much a seasonal phenomenon. The winter ice cover starts to melt In April and the ice sheet starts to grow again at the end of

September. The surface area subject to summer melt has rapidly increased during the last decades (Figures 21 and 22).

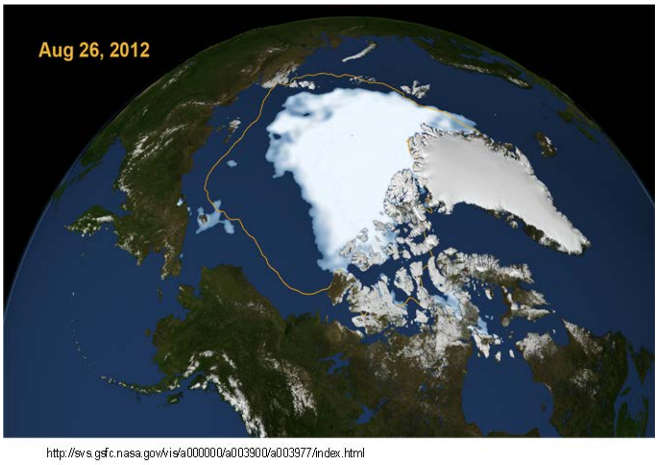


Figure 21: ***Arctic Summer Ice extent****, August 26, 2012 compared to the average sea ice minimum from 1979 – 2010 in orange. (source NASA - GSFC/SVS)*

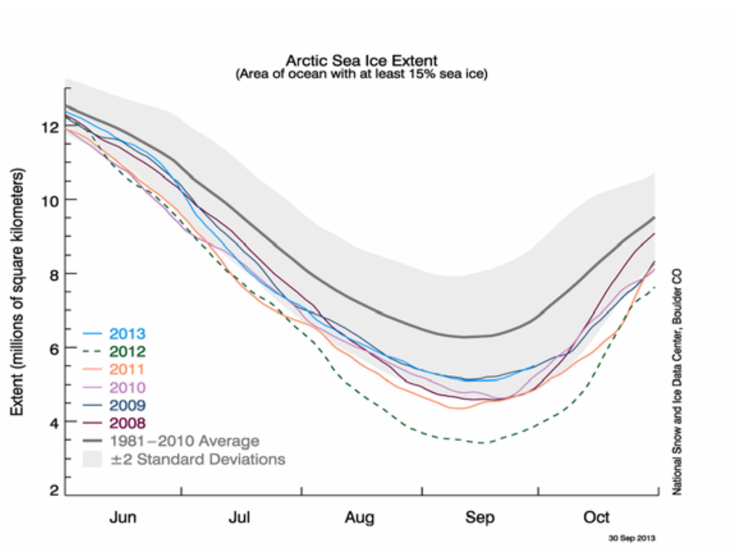


Figure 22: ***Daily Arctic Sea Ice extent in millions km²****, seasonal variations and increased summer ices melting during five years compared to average 1981 – 2010 grey line; note the September 2013 values coincide with those of 2009 (source NSIDC)*

Spectacular satellite observations on the age (NSIDC) and thickness of the Arctic Sea Ice (ASI) show a significant decrease in the average thickness during the last years, resulting in a substantial decrease in the volume of the ASI during recent summers, in line with the results modelled by PIOMAS. The reduced decrease in 2013 may possibly be related to the positive North Atlantic Oscillation.

If we extrapolate the decrease of ASI summer ice volume (Figure 23), we see within a few decades the Arctic Sea may no longer be covered by ice in the summer.
One of the main effects of the disappearance of summer ice in the Arctic Sea is the strong decrease of the albedo value. White ice and snow surfaces are highly reflective and have an albedo value of 0.9, compared to a black water surface with a value of 0.06.
This decrease of albedo results in greater absorption of solar radiation during the summer and an increase in the sea surface temperature of the Arctic Sea, not only now but also in the future

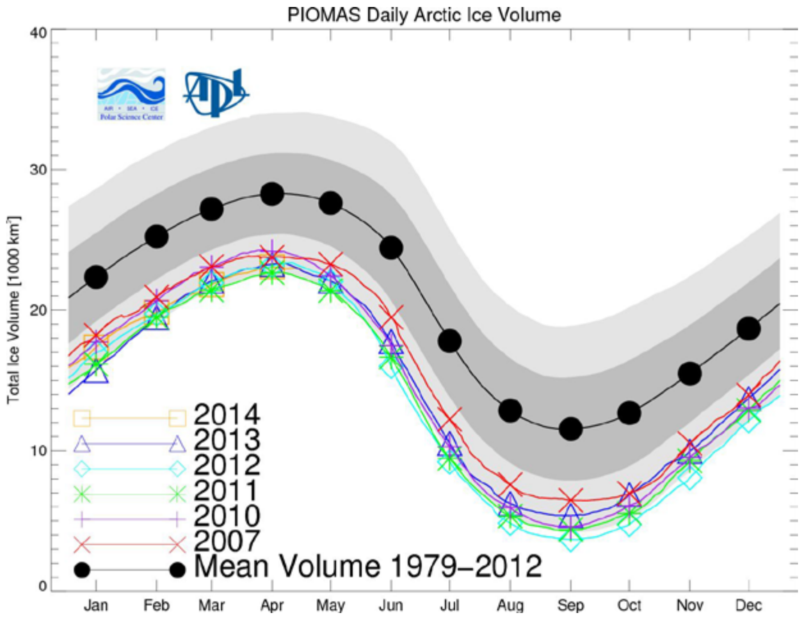


*Figure 23: **Arctic Summer Ice volume** in 1000 km^3 , seasonal changes and general annual decrease during the last years. (source PIOMAS - Pan-Arctic Ice Ocean Modelling and Assimilation System)*

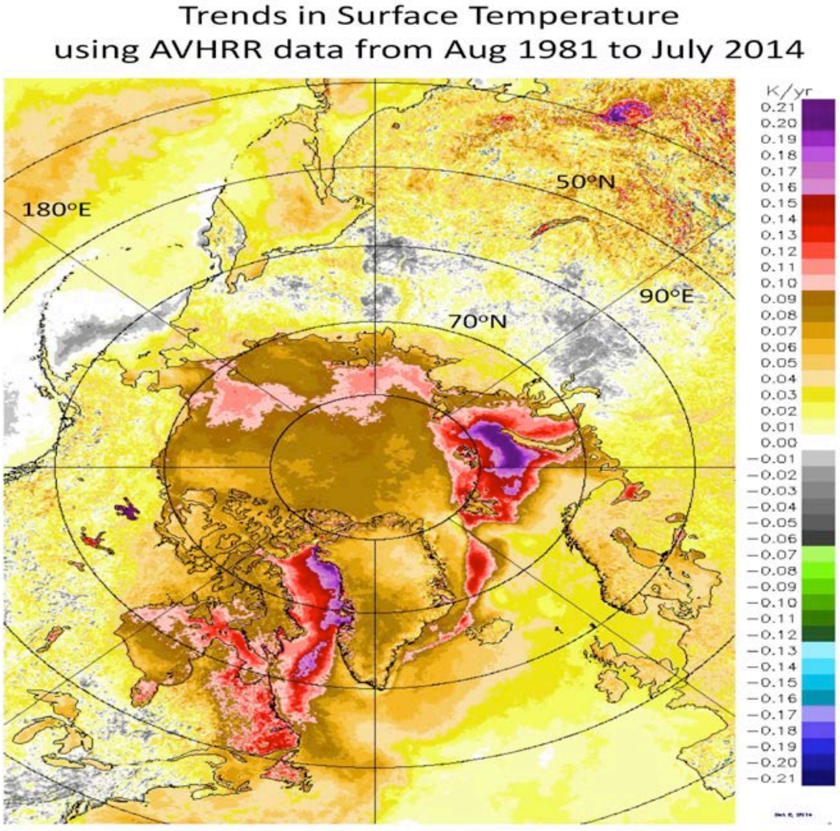


*Figure 24: **Surface Temperature Changes** in degree Kelvin per year – Arctic Sea Region: satellite observations 1981 – 2014. (source: Josefino Comiso,* Cryospheric Sciences Laboratory, Goddard Space Flight Center, *NASA)*

Large parts of the Arctic region are already warming rapidly with about 1^0 Kelvin/decade for land and ocean surface temperature during the last three decades (Figure 24). Areas with high increase of temperature are located west of Greenland and around Nova Zembla.

This warming of the Arctic region will affect the rate of melting of the Greenland Ice Sheet.

3.3.3 Melting of the Greenland Ice Sheet - GrIS

The Greenland Ice sheet (GrIS, Figure 25) is very large, with a maximum length of 2600 km, width of 1100km and thickness of 3.5 km. The surface area of the GrIS is 1.8 million km^2 and its volume is 2.8 million km^3. Geographically the GrIS extends from 60^0 N to 83^0 N, making this Ice Sheet the closest land ice mass to the equator and most susceptible to melting. The importance of the melting of the Greenland Ice Sheet (GrIS) contributing to the Global Mean Sea Level Rise (GMSLR) is growing at the cost of thermal expansion during the last three decades (Figure 26).

If the entire GrIS were to melt, it would lead to a global sea level rise of about 7 m (IPCC, 2001).

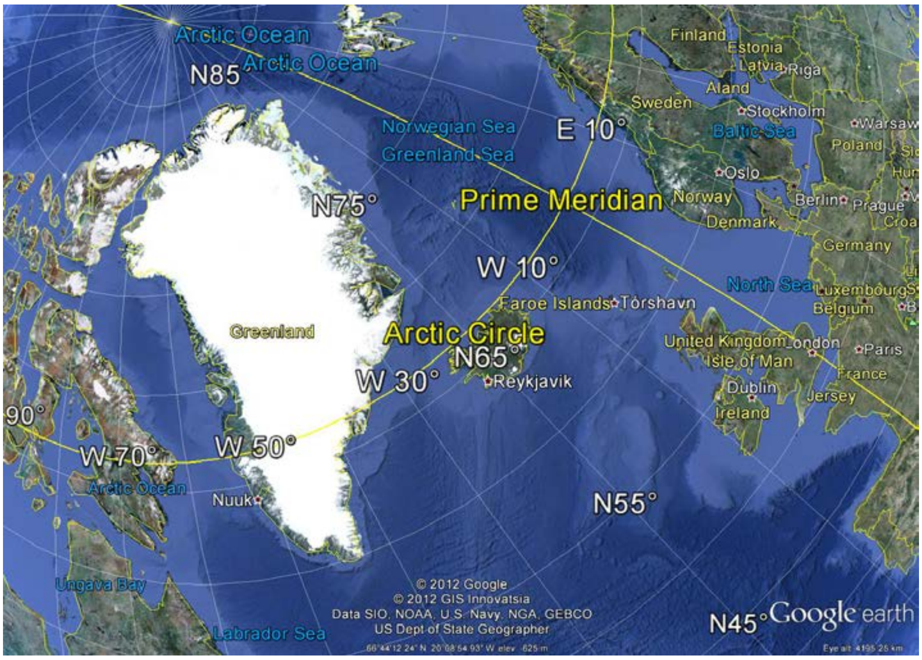


*Figure 25: **The vast extent of Greenland** (source Google Earth: @2012 Google 2012 GIS Innovatsia Data SIO, NOAA, U.S. Navy, NGA, GEBCO US Dept of State Geographer)*

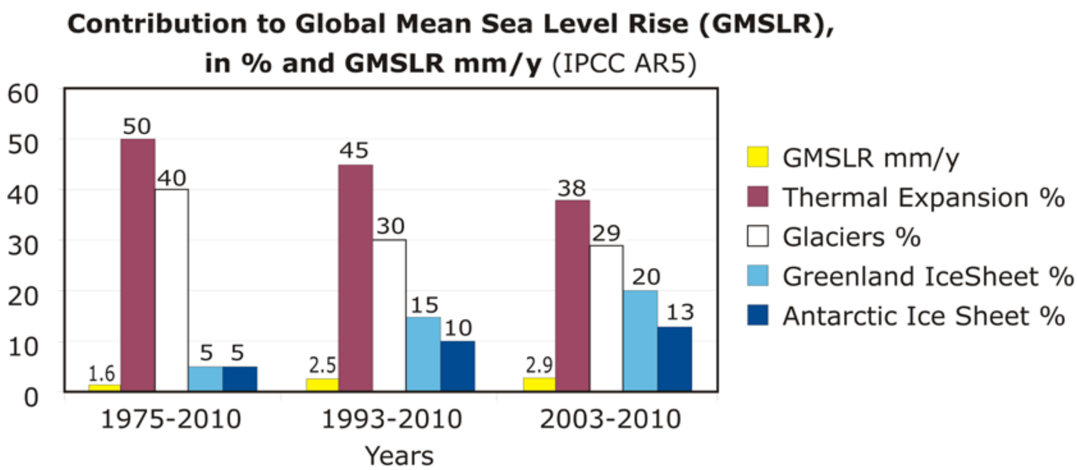


*Figure 26 : **The shifting contributions to Sea Level Rise** by thermal expansion, glaciers, and Greenland and Antarctic land ice masses.(source R.Misdorp adapted from IPCC, 2013)*

Flow lines, 'ice streams', show how the ice is moving from the inner parts towards the coastal margins (Figure 27. The deepest part of the ice is more than 300 m below sea level. Great GrIS instability could occur if the relative warm sea water reaches the lowest parts of the ice sheet.

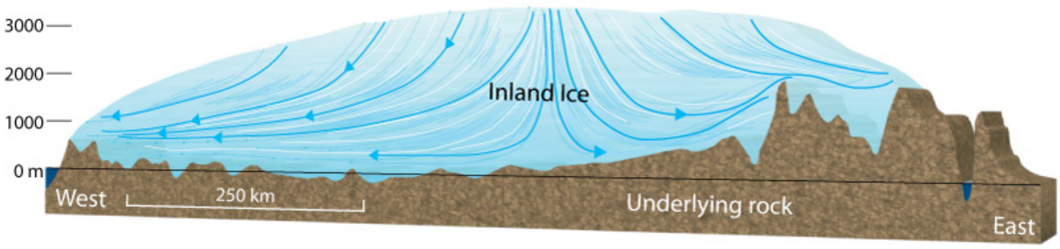
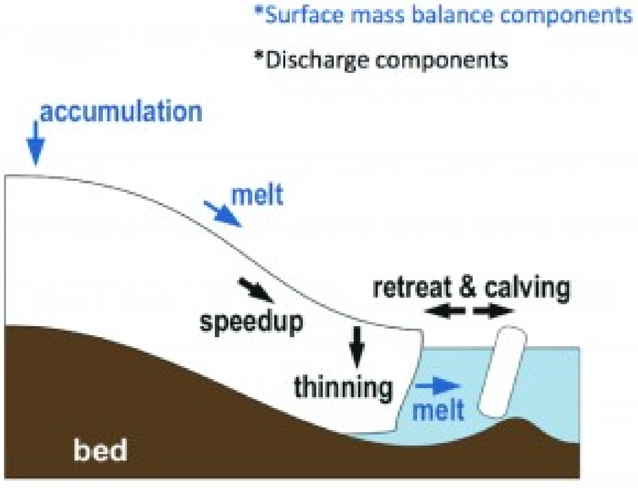
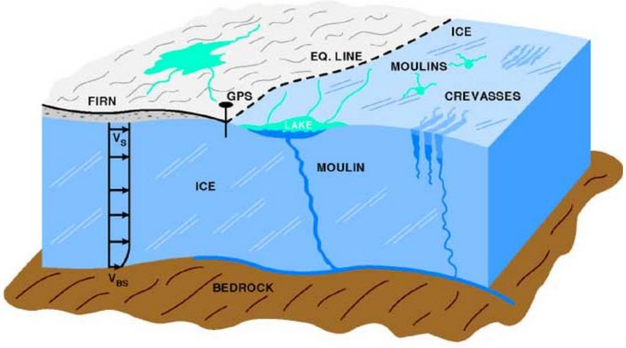


Figure 27: ***Cross section of the Greenland Ice Sheet.*** *(Illustration: Carsten E. Thuesen)*

The two processes acting to reduce the Greenland Ice Sheet volume are:

1. Surface mass melting = converting ice into water: supra-glacial lakes via moulinss → thinning the ice sheet;
2. Discharge: flowing to and calving of the ice front via icebergs → retreat of the ice front.

	*Figure 28a:* ***Two ways of GrIS volume changes.*** *(source: Twila Moon)*
	*Figure 28b:* ***Schematic representation of the dynamics of the GrIS*** *and the various melting processes on and in the GrIS, transferring heat downwards to the bedrock. The EQ. line is the border between the firn area wheret snow accumulates and the sea-ward ablation area where melting is dominant. (source: Zwally, et al., 2002)*

Surface mass melting

Summer melt water streams in the ablation zone (area below the equilibrium line = EQ.Line, Figure 28b) flow into large vertical 'moulins' (Figure 29). These moulins transport water, i.e. heat, to the bedrock and this may enhance lubrication and increase the internal instability.
The so-called "Supra-glacial" lakes (Figure 30) are another increasingly important mechanism melting the GrIS. The estimated number of these summer 'Supra-glacial' lakes ranges between 10,000 and 100,000. The July 2012 observations made it clear for the first time that these 'Supra-glacial' lakes are draining on a large scale within a short time… a matter of four days (NASA, 2012).

This large scale draining may destabilise the land ice internally (CIRES, 2013), increasing the instability of the entire GrIS through increased slip sliding on the lubricated bedrock.. The whole lake's (relatively warm) contents can reach the base of the glacier in as little as 2–18 hours. Special attention is needed for such processes near the western part of the GrIS where the bedrock is located below sea level (Figure 27).

Figure 29: ***Summer melt streams on the surface of the Greenland Ice Sheet*** *transferring heat downwards via 'moulins', to the bedrock, which may increase slip sliding of the ice masses via increased lubrication. (photo: Roger J. Braithwaite, University of Manchester, UK, 2008)*

Figure 30: ***Supra-Glacial Lakes*** *on the Greenland Ice Sheet; in the summer of 2012, many of these lakes drained to the bedrock, The largest lake in this image is about 3 miles at its widest. (source: I. Joughin/UW Polar Science Center, Geology Times)*

Working in the other direction, the observed draining of the lakes also decreases the surface covered by water and therefore increases the albedo during the rest of the summer.
These melting processes are complex and difficult to predict by mathematical modelling.

Discharge and calving of the ice front via icebergs – glacier retreat

The Greenland Ice Sheet is drained by more than 50 major glaciers. One of the main glaciers, Jakobshavn / Ilulissat Glacier with its Iceford, drains 6.5% of the GrIS and produces around 10% of all Greenland icebergs. The Ilulissat Glacier front has retreated almost 40 km since 1850, corresponding to an average retreat rate of 0.7 m/day, based on analyses of maps and satellite images. A tenfold increase has been observed since the year 2001 (Figure 31).

*Figure 31: **The retreating front of the Ilulissat Glacier, 1850 -2007**, with a period of more or less stability) between 1950 – 2000 followed by an acceleration up to 10m/day in the 2000s. Location: Jakobshavn Iceford, West Greenland (arrow= 50 km; source: Museum of Ilulissat; Jan Visser; NASA August 2007*

Another way of measuring the discharge process is to survey the horizontal ice flow velocity of the ice sheet to the sea by means of “fixed” GPS stations. These ‘early’ 1996 – 1999 GPS observations were made at one location near the Equilibrium Line at the Swiss camp (Figure 28). The average year-round flow velocity observed was 0.32 m/day (Zwally et al. 2002).

RADARSAT satellite observations mapped the flow velocity over much of the GrIS for the winters of 2000/2001 and 2005/2006 (Joughin et al., 2010) **.** These observations show that the large horizontal velocities are limited to narrow, well-defined trunks of outlet glaciers such as the Ilulissat Glacier area 1 – 3 km/year (2 – 8m/day) flow velocity. Most of the western areas and some parts of North Greenland show horizontal velocities of 100 – 200 m/y (blue colour velocity fields), which corresponds to 0.3 - 0.5 m/day.

During the period 2009 – 2014, the five year mean velocities (Figure 32) reach higher values than the winter speeds (2000/2001 and 2005/2006).

Maximum values of the five year mean velocities are more than 5 km/y = 14 m/day (Figure 32). A large number of the 55 surveyed marine-terminating outlet glaciers (2009- 2014, Moon et al., 2014), especially the lower parts, are moving with a velocity of more than 1 km/yr = 2.5 m/day, while large parts (blue coloured) are moving with about 200 m/y = 0.5 m/day.

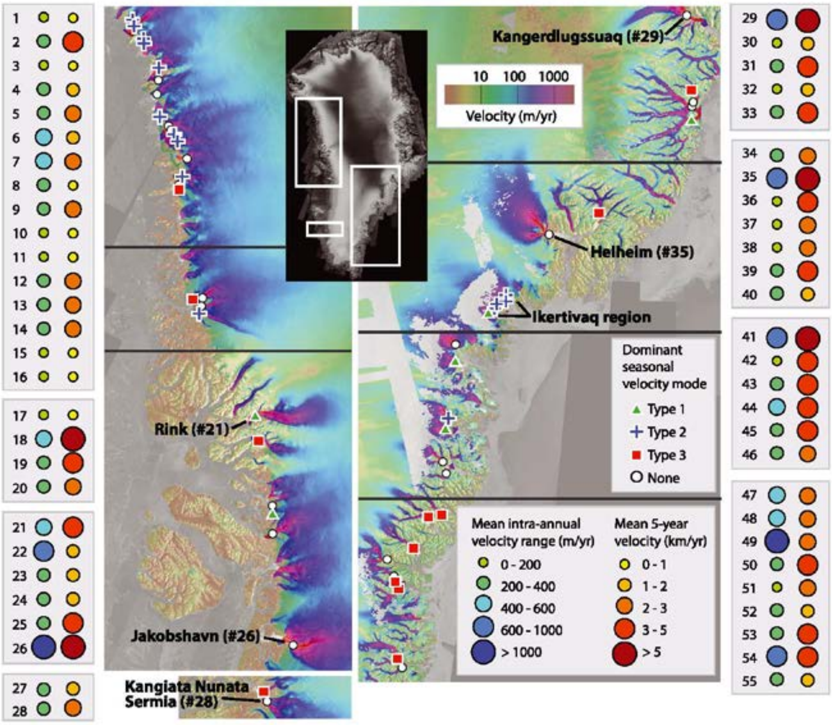


*Figure 32 : **Five year mean velocity** of 55 studied, marine-terminating outlet glaciers Greenland from 2009 through 2013. (source: Moon et al. 2014)*

*Figure 33: **Animation of a slipping glacier** by draining of a Supra-Glacial Lake (source: [Promice, Denmark](#))*

The animation of slipping glaciers by the draining of supra-glacial lakes shows how abrupt the lubricated movements of calving ice front can be. However part of the drained water may also contribute to the gradually formation of large sub-surface water reservoirs. Sudden draining of such large scale reservoirs can increase the annual melt largely, such as was likely the case in the year 2012. During the following winter the ‘stopper’ of the reservoir may be refrozen again and subsequent the large scale sub-surface cavities could be refilled again during the following summer, resulting in a relative small contribution to the net annual melt budget. The year 2013 is characterised by such a low net melt quantity. Such possible multi-annual cycles in the melting process are difficult to model.

Ice Mass balance

Preliminary mass balance calculations for the Greenland Ice Sheet (GrIS) show fast thinning near the coast, at an average rate of about 0.2 m/y. The rapid thinning of the outlet glaciers reached maximum values of about 0.5 m/year during the period 1998/9 – 2005, e.g. at Jacobshavn ("J" in Figure 31).

Although large differences exist between the different methods used for mass balance observations and modelling, an increase in net loss is becoming more pronounced. It was less than 10 GTon in the 1990s, increasing to a value of 170 Gton of ice by 2003-2007. Two 2012 updates of surface mass balance observations show a strong increase of net mass loss of the GrIS of more than 500 Gton (Table 3).

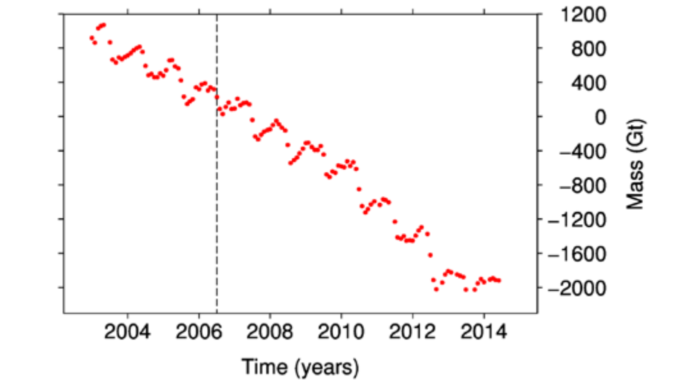


*Figure 34: **Monthly changes in the total mass** (in Gigatonnes) of the Greenland ice sheet estimated from GRACE measurements since 2002; all the mass changes are relative to June 2006. (source: polar portal)*

Two net loss values for 2010 and 2012 were obtained by using two different instruments for satellite observations:

- MODIS = Moderate-resolution Imaging Spectroradiometer on board of the Terra satellite launched in 1999) and the Aqua - satellite (launched in 2002);
- GRACE: Gravity Recording And Climate Experiment satellite launched in 2002.

Table 3:

Period/year	**GrIS - Net Ice loss Gton/y**	**References**
1992 - 2002	**7 ± 3** (ERS radar& airborne laser altimetry)	Zwally et al., 2011
2003 - 2007	**171 ± 4** (ICESat Laser Altimetry)	Zwally et al., 2011
2010	**300** (MODIS) **423 ± 89** (GRACE)	Tedesco et al., 2013 (a)
2012	**400** (MODIS) **575 ± 89** (GRACE)	Tedesco et al., 2013 (a)

This 2012 mass loss is the largest annual loss rate for Greenland in the GRACE record (Tedesco et al. 2013a). The mass loss during the 2013 summer melt season is however considerably smaller than during the 2012 summer (Tedesco et al. 2013b).

The Greenland Ice Sheet is very susceptible to accelerated melting due to its geographical position, and it has been melting at an increasing rate during the last decades. Detailed surveys on ice thickness and bed topography along the entire periphery of Greenland reveal the submarine glacial valleys extend deeper below sea level and farther inland than previously observed (Morlighem et al., 2014). These detailed observations imply that the GrIS is more vulnerable to ocean thermal forcing than earlier thought.

3.3.4 Melting of Antarctic ice masses

The extent and volume of the ice masses on Antarctica is about an order larger than on Greenland.

The Transantarctic Mountain range is separating the West Antarctic ice mass from the Eastern Antarctic one (Figure: 35a).

If the entire West Antarctica Ice Sheet (WAIS) melted, the sea would rise globally with more than 5 m. (NASA News, 2014). Although the Amundsen Sea region is a fraction of the whole West Antarctic Ice Sheet, the region contains enough ice to raise global sea levels by 1.2 meters (NASA News 2014).
This Amundsen area is specifically vulnerable to the regional ocean current, which delivers warm water to grounding lines and the undersides of ice shelves in the region (Figure 35b and c).
Changes in wind and water circulation (e.g. the Antarctic Circumpolar Current) is bringing more, relatively warm water to the frozen coast of West Antarctica.

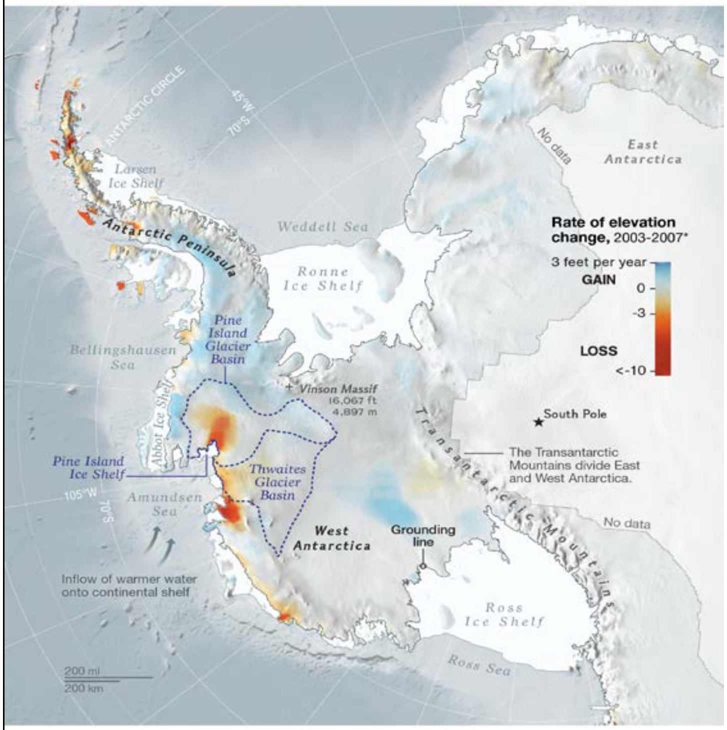


Figure 35a: ***West Antarctic glaciers (Pine Island and Thwaites) are thinning****: more ice is released to the sea than replaced by new snow.*

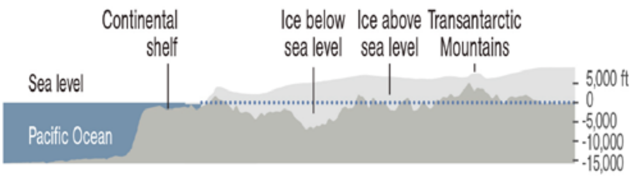


Figure 35 b: ***Cross section of the Amundsen Sea region****: much of the ice slides on a bed that is below sea level, where relatively warm ocean water is contributing the thinning of the ice shelves from beneath;*

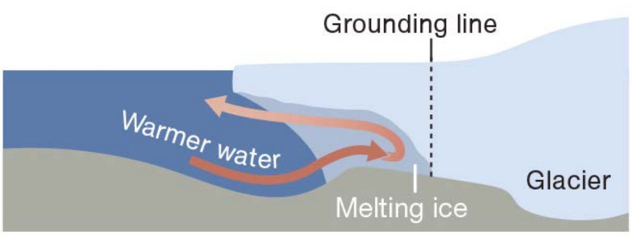


Figure 35c: ***The warmer water circulation*** *is melting the ice and causing the glacier to slip more quickly into the ocean. (source: Hamish Pritchard & Peter Fretwell – British Antarctic Survey; Stanley Jacobs – Lamont-Doherty Earth Observation; NOAA; Eric Steig & Ian Joughin – University of Washington; National Geographic News)*

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Changes in wind and water circulation (e.g. the Antarctic Circumpolar Current) is bringing more, relatively warm water to the frozen coast of West Antarctica.
The time span involved in the rapid melting of the WAIS glaciers, accompanied with more than 1 mm SLR/year, is presently estimated between 2 and 9 centuries (Joughin et al., 2014).

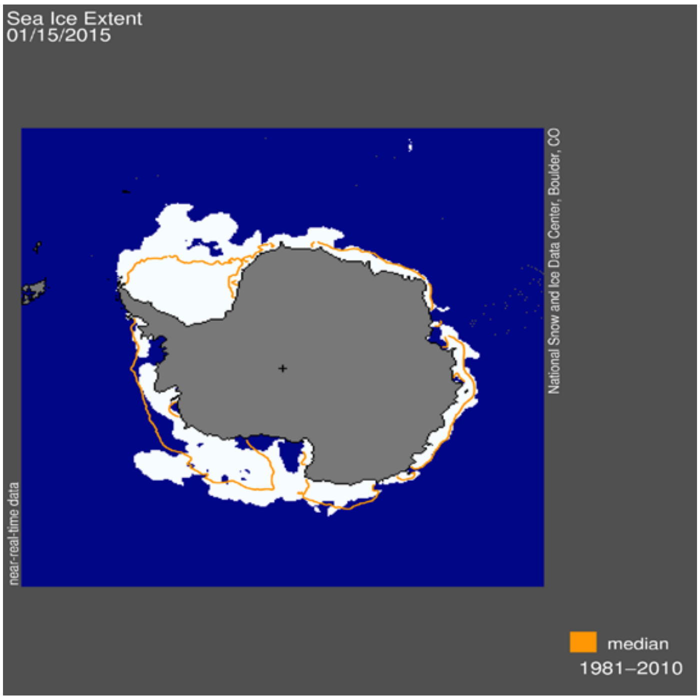

*Figure 36: **Antarctic Sea Ice extent , 15 January 2015**, note the large areas free of sea ice bordering the glaciers along the Amundsen and Ross Sea – WAIS. (source: NSIDC, January 2015)*

One could state regarding the contribution to sea level rise*: Antarctica is still a sleeping giant.*

3.3.5 Accelerated Sea Level Rise (ASLR)

Accelerated Sea Level Rise is envisaged as being one of the most important impacts of Climate Change for coastal nations. The term ASLR is used to describe rates significantly higher than the present (global) averaged rate of SLR (15 – 20 cm/century) which began in the mid-19th century. ASLR is a projected figure and is used in scenario – impact – response studies.

If ASLR does take place, it will seriously threaten the safety of coastal inhabitants and investments due to the increased risk of flooding and coastal erosion.
The rate of melting of the Land Ice Masses will increasingly determine the long-term planning for the use of coastal resources and space, and it will also influence the design criteria for adaptive coastal measures.
The important melting processes leading to abrupt and large-scale calving are difficult to model mathematically. The IPCC estimates of envisaged rates of ASLR are mainly based on non-abrupt extrapolations and range between 20 – 80 cm/century (IPCC 2013).
The increasing rates of surface melt and calving of the GrIS during the last two decades are the reasons for making the following ASLR black- box sum (Box CCC III-2-2).

The Dutch Second Delta State Commission (2008) has taken 1.3 m ASLR/21st Century as a worst case scenario for analysing the effects of Climate Change in an integrated fashion. It identified adaptive measures for the entire (low-lying) Netherlands. Its Chairman, Prof. Cees Veerman, wrote in his CCC Statement: "Nowadays, we assess the impacts of climate change and we realise that responding needs extra vigilance, additional overarching, integrating institutional arrangements, a long term Delta Programme and the creation of reserve funds, embedded in a Delta law:

"Is this acute, no… is it urgent, yes."

This urgency has to be shared with the Dutch inhabitants. This notion forms an important part of the integrated planning and sustainable implementation of the Dutch Delta Programme, guided by Delta Commissioner Wim Kuijken.

Box III-2-2: 'Abrupt' or Linear melting of GreenIand Ice Sheet (GrIS):

That is the question …. critical for all low lying coastal areas of the world

Let us make a rough, black-box sum in 6 steps:

1. Suppose 'Abrupt' means: 1/7 part (= 400,000 km^3 ice) of the volume of GrIS will melt in one century by the two processes: thinning and calving;

2. Assume the following division of the Greenland melting:
   - 2/3 of this volume of ice will be transferred into water by calving of the GrIS, and
   - 1/3 of the volume of ice will melt by thinning;

3. Consider the dimensions of the 1/7 part of GrIS situated in the coastal zone = 400,000 km^3 = active GrIS periphery of 8,000 km * width of 80 km * averaged thickness of 0.62km;

4. The 'Abrupt' melting involves:
   - Calving: 2/3 of 80 km wide area has to move in one century to the sea = 2.2m/day, which is less than 5 times the velocity observed in large parts of the seaward moving glaciers surveyed during the 2009-2014.
   - Thinning: needs to melt 1/3 of 400,000 km^3/100y = 1,333 km^3/year over a coastal surface area of 80 * 8,000 km^2 = 640,000 km^2 → a rate of thinning of 2.1 m/year. This is a factor 4 more than the rate of thinning (0.5m/y) observed in large parts of the marine-terminating outlet glacier areas, observed during 2009-2014 (Moon et al.,2014) .

5. So if we take into account the observed acceleration of thinning and melting of the GrIS during the last decades, and the growing importance of the concept of slipping glaciers:
   an 'Abrupt' melting of the Greenland Ice Sheet is not unlikely;

6. The 1/7 GrIS melt means a global Sea Level Rise of 1 m. Considering the other contributing factors (e.g. the envisaged increased melting of the 'sleeping giant' Antarctica and the thermal expansion of the warming oceans), the following statement seems rather a conservative one:

   a global Accelerated SLR of 1.5 m in the 21st Century is not unlikely.

The above deliberation does not take into account the effects of the thawing of the Arctic permafrost and the subsequent release of the potent GHG: CH_4, which is starting to become an important additional accelerator of the climate change process……

3.3.6 Vulnerability to sea level rise and increased risk of flooding

Vulnerability Assessment

Rapid social developments and unsustainable economic developments increase coastal degradation and risk of flooding. This may result in large losses of property and lives in intensely urbanised areas. The majority of the fast growing mega cities of the world are located in the coastal zone and notably in Asia.

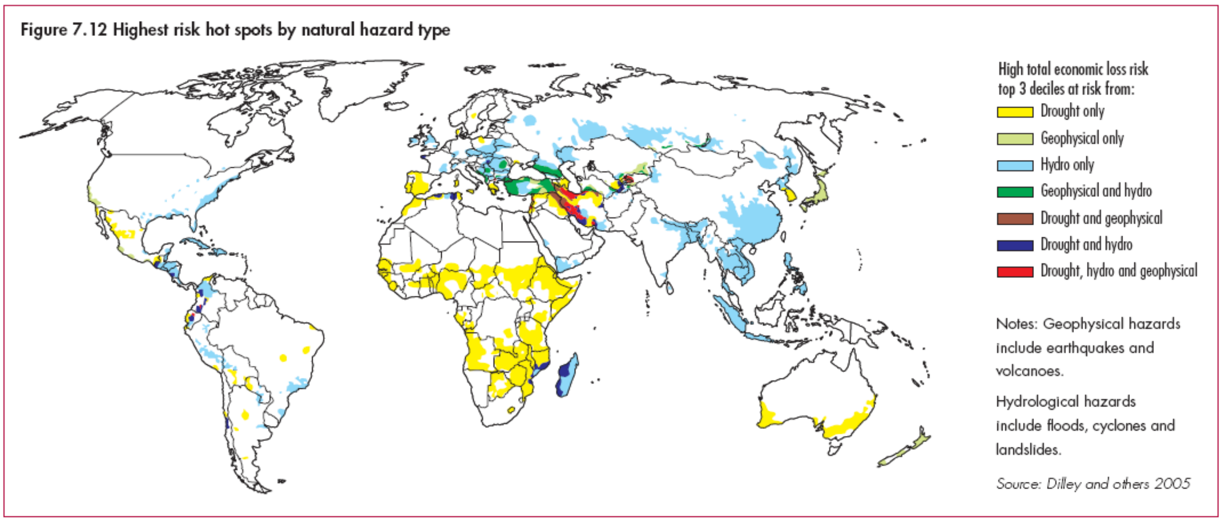

*Figure 37: **Global distribution of highest risk hot spots** by natural hazard type;Yellow: drought; Light Blue: flood (GEO4, 2007)*

Assessing vulnerability involves evaluating a nation's or region's ability to cope with the consequences of the world's three main challenges: rapidly increasing population density, non-sustainable economic development and climate change.

Over the past 20 years, natural disasters have claimed more than 1.5 million lives and affected more than 200 million people annually (Much Re 2004b). One of the main drivers of increased vulnerability to hazards is global environmental change. Natural hazards, such as earthquakes, floods, droughts, storms, tropical cyclones and hurricanes, wildfires, tsunamis, volcanic eruptions and landslides, threaten everyone, but they hurt the poor most of all (see also CCC II-3-4 India). Two-thirds of all disasters are hydro-meteorological events, such as floods, storms and extreme temperatures. More than 90 per cent of the people exposed to disasters live in the developing world. Between 1992 and 2001, floods were the most frequent natural disaster affecting more than 1.2 billion people, especially those in Asia and in the coastal mega-cities (Geo4, 2007; Figure 37).

In many countries with low-lying coastal areas, these issues will become all the more urgent because of the likely effect of a changing climate and the accelerated sea level rise on coastal erosion over the next few decades. The impact will be especially high in the developing world, where about three quarter of the people exposed to natural disasters live.

A multiplicity of environmental, political, social and economic factors exacerbate vulnerability and the risks associated with environmental change and natural disasters.

In the early 1990s, a very first Common Methodology: "The Seven Steps to Assessment of Vulnerability of Coastal Area to sea level rise" (IPCC, 1991), was developed under the auspices of the IPCC. This Vulnerability Assessment Common Methodology has been implemented by almost 100 coastal countries, which reported their preliminary findings during the World Coast Conference 1993 (see WWC'93 Conference Report).

In order to define and assess the vulnerability of a coastal area to ASLR in measurable terms, it is crucial to apply the concepts of values at risk, at loss and at change. Values at risk involve people, capital investment and subsistence values and is expressed as the consequence of natural hazardous events multiplied by the probability of occurrence of these events without taking the system response into account. The concepts of the values at loss and change are mainly applied in the context of agricultural production and ecosystems, and include the system response to the ASLR, e.g. increased salt water intrusion.

This 1991 Vulnerability Assessment methodology has also been applied on a global scale. The 'Global Vulnerability Assessments for population, wetlands, rice production and coastal protection measures' encompasses 179 coastal nations and provides a first global overview of impacts of a 1 m ASLR (GVA, 1993).
Although the data used in the GVA predate 1990, the GVA is still the only global and consistent data base on sea level rise impacts available to date (Bosello et al 2007).

Some results of the Global Vulnerability Assessment (GVA) of the effects of 1 m ALSR:

- *People at Risk of flooding:* Worldwide, some 20% of the people living below the annual storm-surge level experience annual flooding. These represented about 45 million people in 1990. The number of people "at risk" in the Asian Coastal Regions is highest when compared with other coastal regions, because of their high coastal population densities.
  The future increase of Population at Flooding Risk due to a 1m instantaneous ASLR and increased population growth (over a period of 30 years) will in the European Coastal Regions amounts to a few hundreds of thousands persons per year, whereas in the Asian Coastal Regions, an estimated 80 millions persons will be "at risk" of flooding.
  The future increase in the population at risk in the European Coastal Regions will be caused for 70% by a 1m ASLR and for 30% by the anticipated population growth. In the Asian Coastal Regions, it is the other way round; the large increase in the estimated Population at Flooding Risk will be caused for 72% by population growth and 28% by a 1m ALSR (Figure 38). This difference in contributing factors is important for identifying the appropriate adaptive coastal measures.

- *Coastal wetland at loss*: Worldwide, 300,000 km2 of coastal wetlands (salt marshes - 25%, intertidal areas - 30% and mangrove forest - 45%) were classified as of 'International importance' in 1990. Asia encompassed a third of the world's coastal wetlands. Estimates show that in seven of the eleven (UNEP) Coastal Regions the coastal wetlands will be drowned by a 1 m ASLR and the percentage of "at loss" will vary between 25% and 75%. In the Asian region, it is estimated that about 40,000 km^2 of wetlands will be 'at loss" due to 1 m ALSR, which is about half of the existing wetlands in Asia. On the other hand, coastal wetlands connected to sediment sources, especially in tidal areas, can grow with SLR. Preliminary estimates on threshold sedimentation rates of subsiding tidal flats in the Dutch Wadden Sea are in the order of 1 cm/year. These observations are important for creating self adapting 'Building with Nature' flood risk reduction solutions;

- *Rice area "at change" and rice production "at loss":* One of the food resources most endangered by sea level rise is rice. This is especially true in Asia, where two-third of the population is dependent on rice as a basic source of calories and protein. The 14 coastal countries of South, Southeast and East Asia (excluding Japan) account for 85% of the world rice production. In terms of population equivalents, this production nourished 1.9 billion people in 1990.
  The effects of 1 m sea level rise are expressed as rice area "at change". A tentative indication of the possible rice production "at loss" has also been calculated (Figure 38). The impact on the (85% of the)

world production of rice: 11% of the rice area is “at change”, and 4% of the production is estimated to be “at loss”.
In terms of population equivalents, about 75 million coastal inhabitants could face the disappearance of their daily food source if no adaptive measures are taken in time.
Vietnam, Bangladesh, and Myanmar will be in serious danger, with the percentage of loss of rice production ranging from 20% to 9% respectively. The 3% estimated loss in China represents 5 million tons of rice “at loss”, corresponding to nourishment for about 25 million people.

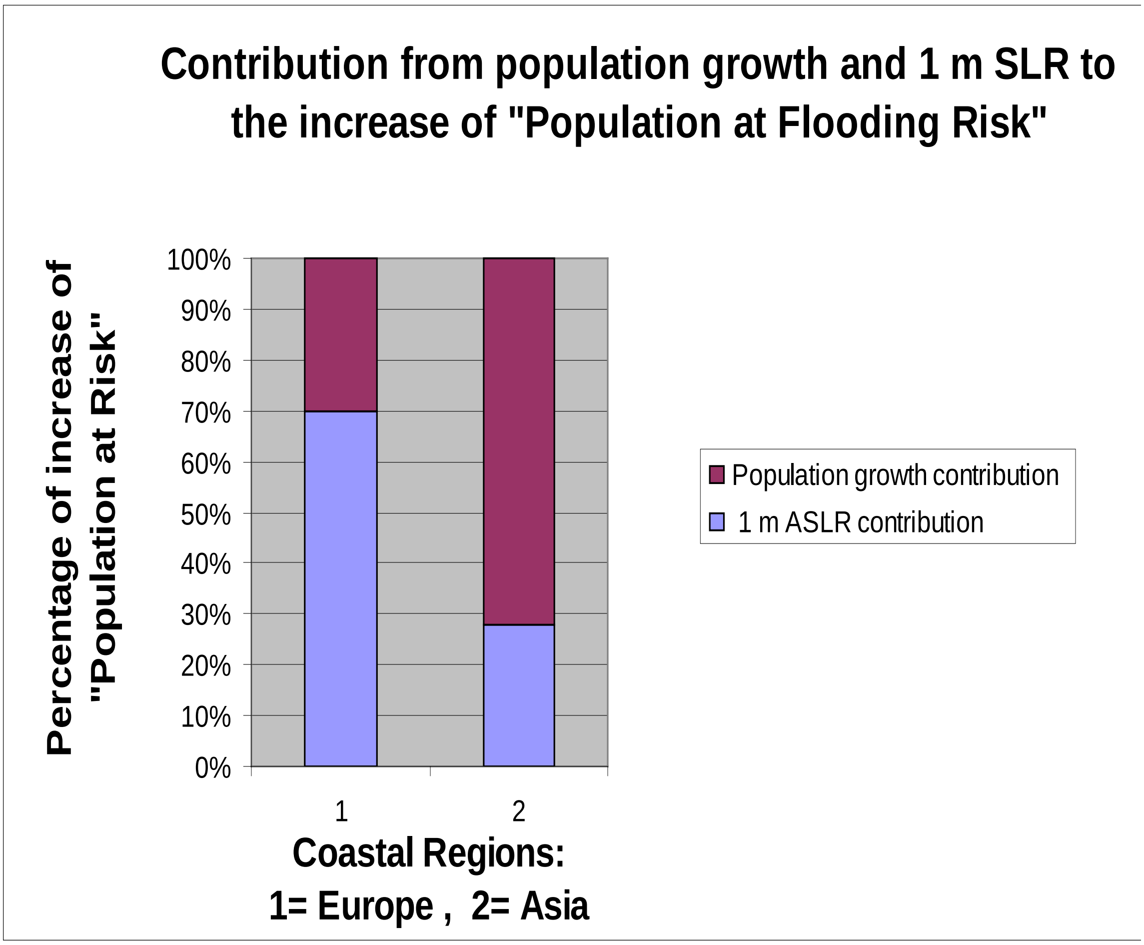

Figure 38: ***The relative impact of population growth and ASLR*** *on the increase in the estimated future Population at Flooding Risk. (source: GVA, adapted R.Misdorp)*

- *Global preliminary estimates of the costs* of adaptive coastal protection measures are expressed as a percentage of GNP. The states in three Coastal Regions, the Asian Indian Ocean Coast, the Islands in the Indian and Pacific Oceans, are the highest scoring of the 20 UNEP Coastal Regions. Their adaptive costs are 10 -15 times the global average estimated cost for protection based on preliminary analyses of the 179 coastal countries.

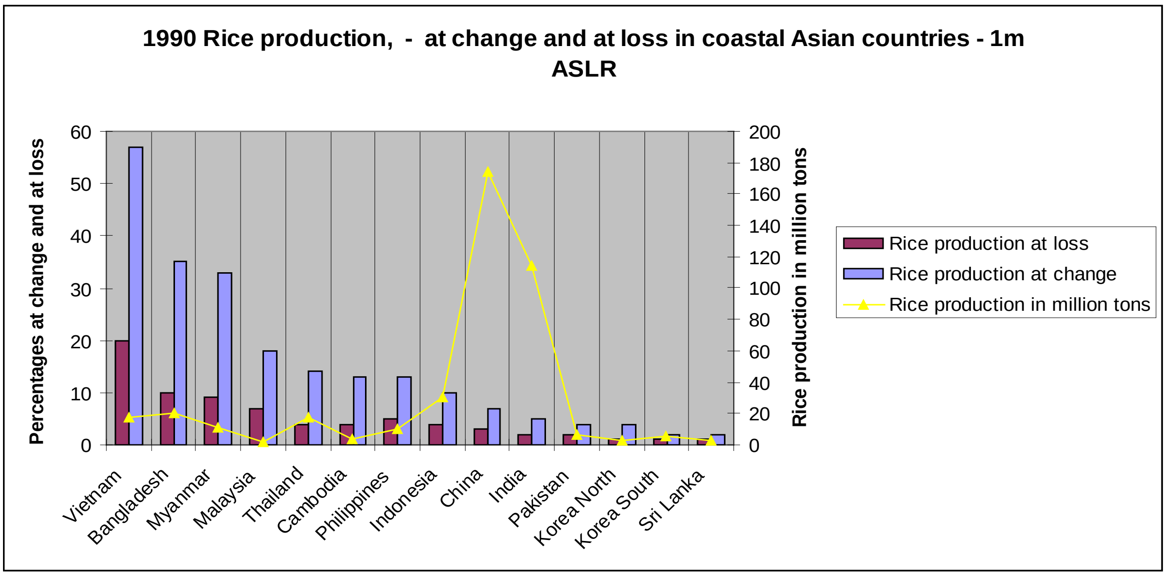

Figure 39: ***Rice production (million tons in 1990), and Rice production "at loss" and Rice paddies (area) "at change"*** *under influence of 1 m sea level rise. (Source: R. Misdorp, based on GVA, 1993)*

The Global Vulnerability Assessment (1993) indicates that Asia could be the continent most vulnerable to Accelerated Sea Level Rise (ASLR). Increasing information on the role of other impacts of Climate Change, such as the increase of tropical storms/cyclones, changes in precipitation and evapo-transpiration patterns affecting river regimes, the deltaic areas and liveability in the coastal zone, confirms this picture. Other factors like subsidence of coastal areas can have similar impacts. A number of Asian coastal countries can be classified as critical vulnerable to a 1 m ASLR (IPCC 1991 and WCC'93**).**
UNEP 2005 also showed that several, densely populated Asian coastal countries are scoring highly in terms of vulnerability classification.
It is therefore only logical that the Asian continent is so prominently present in the CCC publication.

Increased frequency of flooding - the Netherlands

An indication of the consequence of 0.3 m, 1.0 and 1.5 m ASLR on flooding frequency is given in Figure 40, this is an preliminary indication because the morpho-dynamic adaptation to ASLR has not been taken into account.
The increased flooding frequency due ALSR varies strongly from area to area depending on the hydraulic and morphological conditions of the coastal zone.
As a first estimate, the frequency of occurrence of the high water level (HWL) of 2.9 m above mean sea level at Hoek of Holland, the Netherlands, will greatly increase with ASLR:

- the present HWL of 2.9 m occurs once in 10 years;
- the future 2.9 m HWL with 0.3 m SLR will occur once in the 7 years;
- the future 2.9 m HWL with 1.0 m ASLR will occur seven times per year;
- in the worst case scenario of 1.5 m ASLR, the 2.9 m HWL will occur 40 times per year.

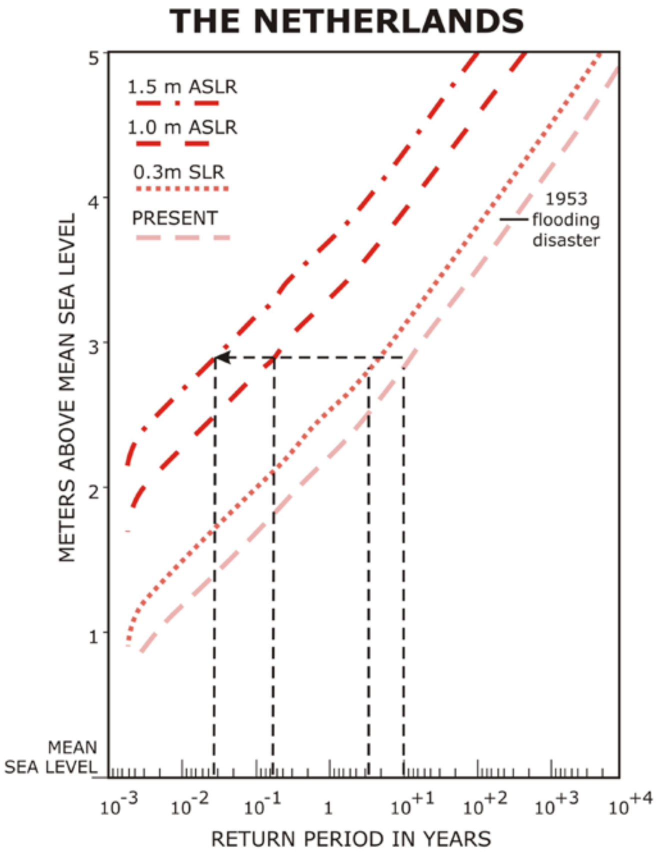

*Figure 40: **Decreasing return period of surge heights** in years (increasing frequency of occurrence of high water levels) under influence of 0.3, 1.0 and 1.5 m ASLR, at Hoek of Holland, the Netherlands. (adapted by R.Misdorp, source IPCC, 1992)*

This preliminary estimate indicates, the frequency of high water level occurrence (the probability of occurrence) may increase substantially as a consequence of ALSR if no adaptive measures are taken. The 1.0 m ASLR may increase the frequency of occurrence of the 2.9 m HWL with a factor of about 70.

Increased flooding risk – the Netherlands

The concept of flooding risk includes analyses of the frequency and consequences of hazards such as flooding, and it facilitate the identification of proper adaptive solutions. Risk is defined as follows

*Risk = (the probability of occurrence of a hazardous event) * (its resulting damage)*

This concept was used for the first time in the 1950s after the disastrous1953 storm surge in the south-western part of the Netherlands. It assisted in calculating new flood safety levels based on rational cost and benefit analyses.
Since then, the flooding risk in the Netherlands has increased due to:

1. The strongly increased damage term (increased population density and capital investment as indicated in the 3.1.2 paragraph Socio-economic pressure);

If no adaptive measures are taken, the risk will increase further due to:

2. The envisaged strong increase in the frequency of occurrence of high water levels due to accelerated sea level rise (see Figure 40).

The recognition of this increased risk has led to a re-evaluation of safety standards for the existing, protective hydraulic constructions along the rivers and sea. The strength of the protections are regularly monitored applying modern surveying tools.
Besides re-evaluating the existing coastal defence works, a paradigm shift was also proposed and executed, namely an integrated long-term approach encompassing the entire country and applying the concept of ‘Building with Nature’. This concept was used in the report by the Second Delta State Commission (2008)

and in the Dutch Delta Programme for the 21st Century, which aims to safeguard the Netherlands from flooding and to ensure a sufficient water supply throughout the 21st Century (Figure 40, see CCC Chapter I-2-5).
Examples of new, win-win solutions using the principles of ‘Building with Nature’ are the national programmes: ‘Space for the rivers’ and ‘Sand nourishment for safeguarding the coastal regions in a resilient and flexible manner.’

Recently, the Dutch government adopted a new approach for water safety standards. The new standards encompass a basic safety level at which the risk of fatalities due to flooding is no higher than 1 in 100,000 per year. A higher level of protection may apply for areas in which flooding could lead to large groups of casualties or significant losses. A higher protection level may also apply if so-called “vital functions” are present. This is the case for the major gas production area in Groningen for which a higher level is proposed, as the entire country would suffer if the supply were disrupted. Flood defences that already offer the required protection level will be properly maintained. If the standard of the flood defences needs to be raised, dike strengthening or river widening will take place (so called Layer 1 measures to prevent flooding). In specific situations Layer 2 measures can also be taken (counteracting the consequences of flooding through spatial planning). The last group of measures are the Layer 3 measures for counteracting the consequences of flooding through emergency management (Delta Programme 2015).

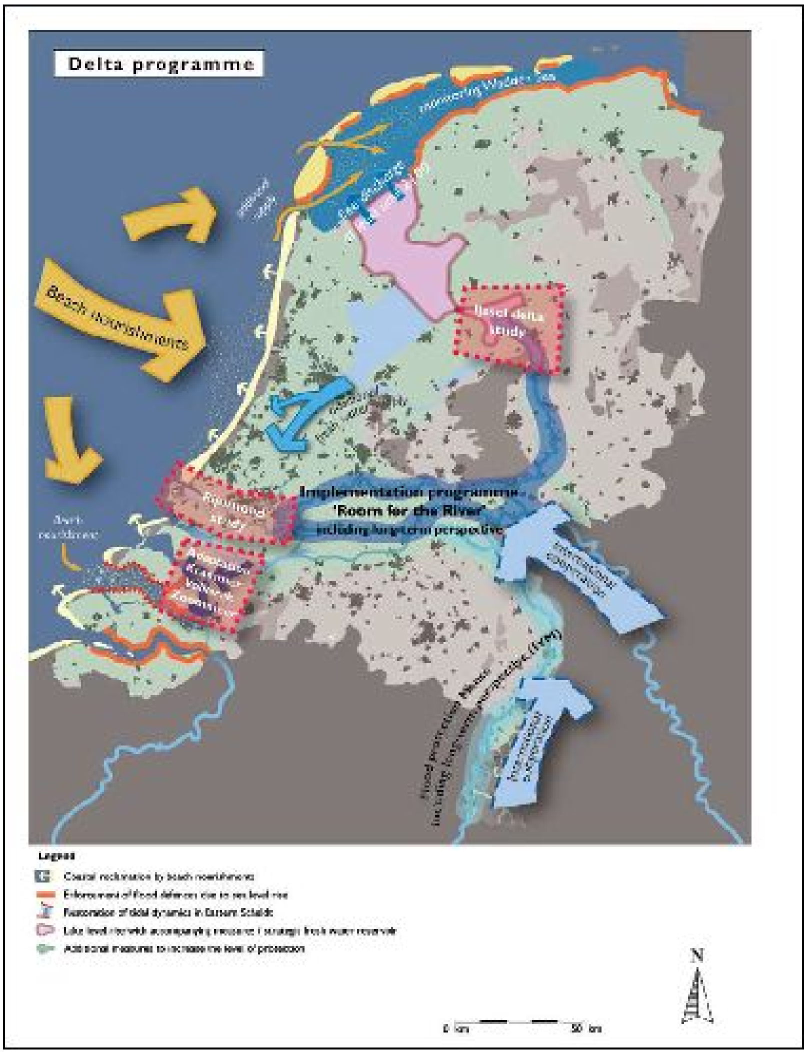

Figure 41: ***Delta Commissions vision 2100****, coherent measures to safeguard against flooding and to supply sufficient freshwater for the entire Netherlands during the 21th century (source Second Delta State Commission report, 2008)*

In this way, the Netherlands is coping with the increased risk posed by growing population density and invested capital, and it is also preparing adaptive measures to cope with future climate changes.

3.4 Increasing number of global hazards and damage

Natural hazards have increased, both in number and the extent of damage caused, during the last part of the 20th century. Reinsurance companies, like Munich Re, have recorded the numbers and damage/loss for hazardous events worldwide since the middle of the last century. These companies also their own departments dealing with climate change, are very interested in recording the risks and losses, and are developing strategies for addressing the increasing number of hazards (Munich Re 2009).

There are several categories of natural hazardous events. Meteorological and hydrological events, coping with storms and floods, are of particular interest and account for more than half of the total number of such events and the extent of damage.

The criteria for a ‘Great natural catastrophe’ are: i) number of fatalities exceeds 2,000 and/or ii) number of homeless exceeds 200,000 and/or iii) overall losses exceed 5% of that country‘s per capita GDP and/or iv) the country becomes dependent on international aid. Since 1950, 285 ‘Great natural catastrophes’ have occurred causing overall losses of 2 trillion US$ and 2 million deaths.

The numbers of such events are rapidly increasing. The damage or losses caused are increasing even more rapidly, suggesting that a growing number of people and investments are located in ever more exposed and vulnerable areas. The annual overall economic losses from extreme events have increased tenfold in half a century, and the period in which these losses double is decreasing (Figure 42).

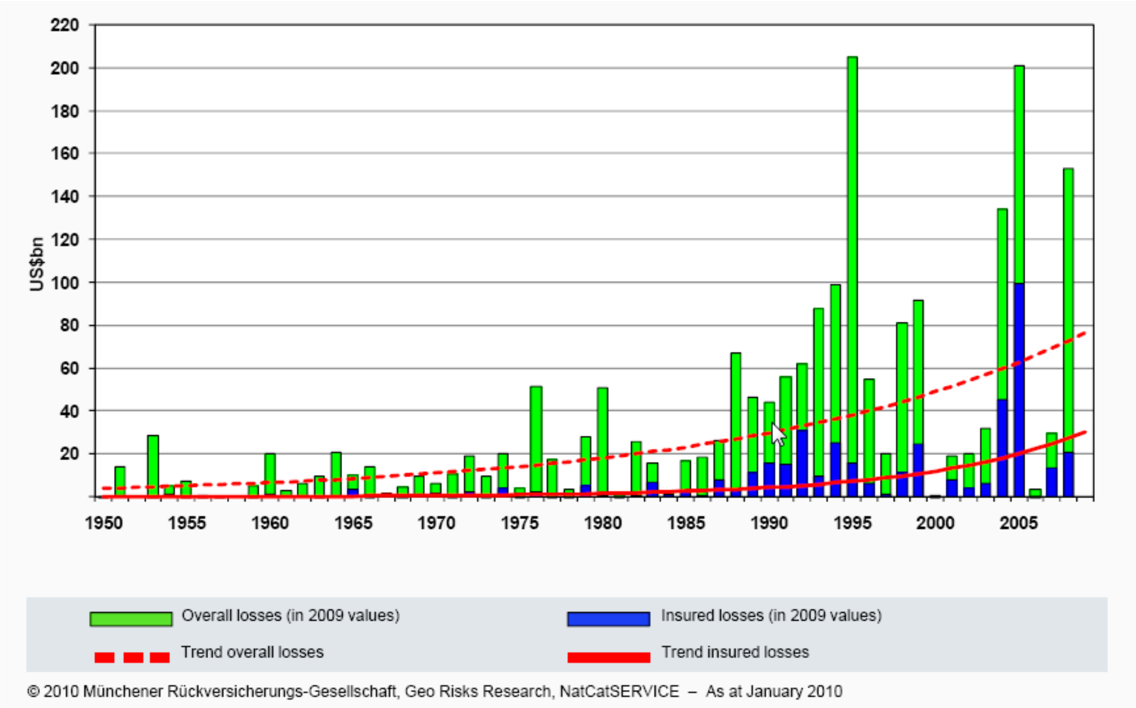

*Figure 42: **Annual losses in US $ billion due to ‘Great natural catastrophes’ worldwide** during 1950 – 2009. (Munich Re 2009)*

In summary, the drivers behind these increased numbers and damages/losses are:

- Population growth;
- Building new urban sites for settlements on locations with greater exposure to hazards, especially in coastal areas;
- Greater concentrations of population in urban and industrial centres;
- Increased rate of growth of economy, infrastructure and capital investments in the coastal zone;
- Climate change leading to a rise in catastrophic extreme weather events leading to an increase in losses (Munich Re 2009).

The anticipated strong increase in the frequency of occurrence of high water levels due to sea level rise will further increase the number of people at risk of flooding, wetland at loss, and agriculture production at loss due to related increasing salt water intrusion.

3.5 Conclusions

- Strong population growth and coastal urbanisation are intensifying the conflict of interests between the various coastal functional uses. The densely populated coastal areas are increasingly subject to degradation of living conditions for people and the natural environment.
- The strong rate of economic growth has various implications, including an increase in housing density, increased infrastructure and industrial developments, and an increase in associated capital investments in the coastal zone.
- The impacts of non-sustainable development of coastal and marine resources have been illustrated by the consequences of the intensive marine fisheries.
- The impacts of climate change, notably sea level rise and the increase in storm surges, will furthermore increase the probability of occurrence of surge heights (the frequency of high water levels), i.e. the first term of the flooding risk equation.
- Strong population growth and strong economic growth both impact the flooding risk equation by greatly increasing the damage and loss term of the risk equation.
- The combined effect of strong population growth, economic growth and climate change will greatly increase the risk of flooding, coastal erosion, and salt water intrusion. The population at risk, the coastal wetlands at loss, and the agriculture production at change and at loss will reach critical levels, notably in a number of Asian coastal nations, if no adaptive measures are taken in time.
- We are living in a very dynamic and exciting time, for example due to the amazing public availability of data sources. This means that each coastal manager of a low-lying coastal area around the world can, for example, follow the essential melting processes in Greenland and Antarctica via internet. The results of high-frequency monitoring can be downloaded from the website of the National Snow & Ice Centre, Boulder, USA: the Greenland Ice Sheet melting and for the Arctic Sea Ice melting.
- It is also important for coastal managers to monitor the sea level and to see when the first signs of the expected acceleration in the sea level rise will become clear. A helpful overview of long-term records of more than 2200 tide gauge stations records distributed around the world, is publicly available, through the website of the Permanent Service for Mean Sea Level.
- It is strongly recommend starting now with preparations of non-regret, resilient, adaptive coastal measures within an integrated long-term planning framework, in the knowledge that planning and implementation take a lot of time and that the sooner we start the more damage we can prevent.

4 Solutions

4.1 Mitigation and adaptation

Climate change, one of the most powerful agents of change, can be addressed in two main ways:

- via mitigation, i.e. by reducing the causes of climate change;
- via adaptation if mitigation is applied insufficiently or too late.

Mitigation

Mitigation aims to reduce the emission of Green Houses Gases (GHG). The sustainable production of energy for households, industry, transport, and food is one of the most prominent non-regret measures for reducing GHG emissions. It's a 'non-regret' approach because the fossil fuel reserve is in any case a finite source of energy. Several decades from now, the world's fossil fuel reserve will be depleted anyway. In other words, energy conservation measures and the rigorous application of renewable energy sources are now urgently needed on a large scale.

Planning such measures and dealing with changing social processes takes time. The earlier the measures are prepared the cheaper it will be from an economic point of view.

And, most importantly, a substantial reduction of GHG emissions must be realised in time to ensure that the increase in average temperature of our shared world does not surpass a threshold value of two degrees Celsius in this century. This means, at a minimum, that a CO_2 concentration of roughly 500 ppm CO_2 must not be exceeded. Accordingly, large-scale global mitigation is needed, as the present CO_2 concentration is 400 ppm and the present rate of increase is 2.3 ppm CO_2 per year (IPCC 2013).

The stabilisation RCP4.5 emission scenario (see CCC III-2-2.3.3) entails stringent mitigation measures, which are based on a set of global GHG emission prices and reduction by the energy and industry sectors. Such measures should be combined with measures aimed at increasing renewable energy production and CO_2 capture and storage. In this RCP4.5 scenario, the decrease in global forest cover will stabilise after 2065, and the world population will stabilise at 9 billion in 2050, slowly decreasing to 8.5 billion in 2100. The assumption hereby is that global GDP will keep on growing strongly from \$ 40 trillion to \$ 350 trillion (US\$ 2005) in 2100 (Thompson et al. 2010).

Adaptation

Adaptive measures are important for coastal countries and should be prepared now and in parallel with mitigation.

The preparation, the integrated planning of adaptive coastal measures is urgent and will become even more urgent if effective mitigation measures are taken too late.

The implementation of the planned, resilient, adaptive measures should be executed as the impacts of climate change become clearer.

In complex coastal areas, integrated coastal zone management (ICZM) is a principal response option to the three main triggers. The illustrative impacts of the three main triggers (population density, non-sustainable economic development and climate change) discussed above make it clear that the coastal zone is a complex area with many interactions. The interactions between the different components of the coastal system have different temporal and spatial dimensions. The coastal water system is a part of the overall natural system and is impacted by agents of natural change and socio-economic factors. Analyses of these system components and their interactions lead to estimates of the various impacts on the functional uses of the coastal system, which in turn impacts the agents of change in a cyclic fashion.

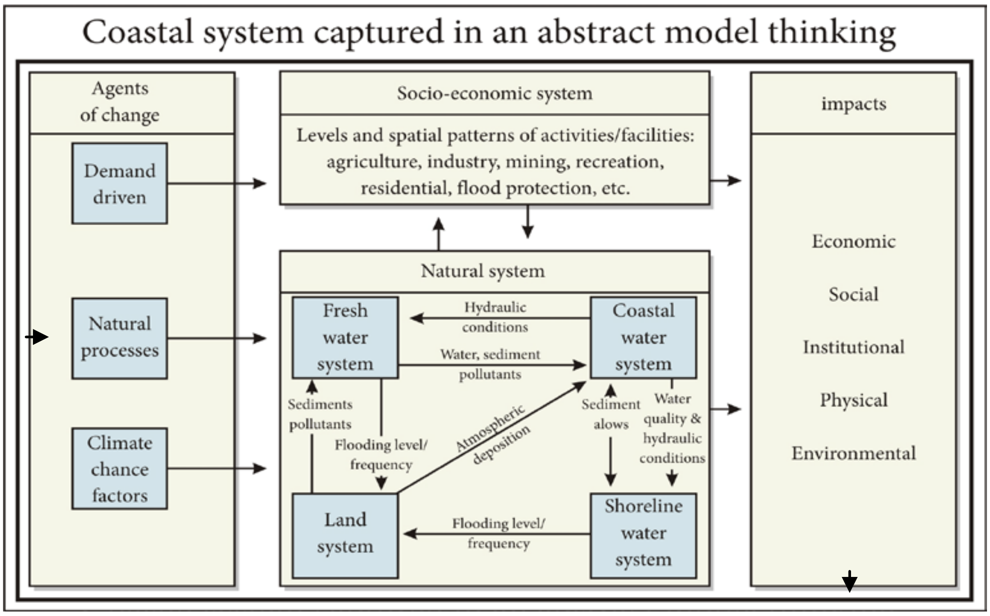

Figure 43: ***The Coastal Water system as a part of the Natural System*** *interactively affected by agents of change and socio-economic factors resulting in impacts that cyclically affect the agents of change. (source WCC'93)*

The analytical representation of the coastal water system (Figures 43 and 44) illustrates the interactive complexity, making it too complex to handle in a sector-based manner.

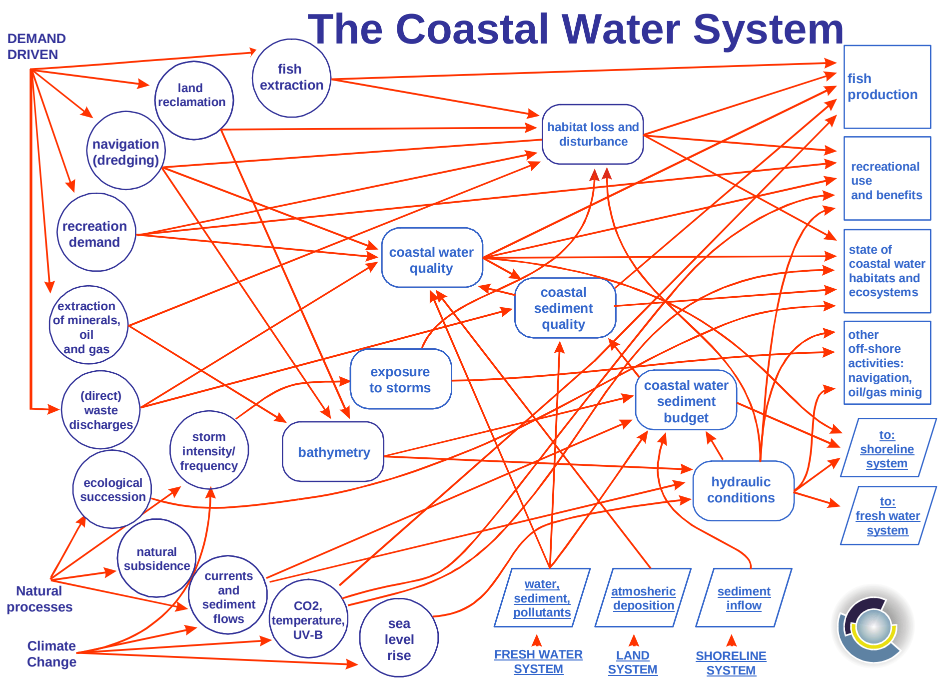

Figure 44: ***The Coastal Water System*** *is a complex system with many interactions (source: WCC'93)*

An integrated, holistic approach is required to effectively solve the interacting coastal problems. Two principle levels – the Strategic and the Operational levels – can be distinguished (Figure 45, more details in CCC Chapter III-1: 'What is ICZM').

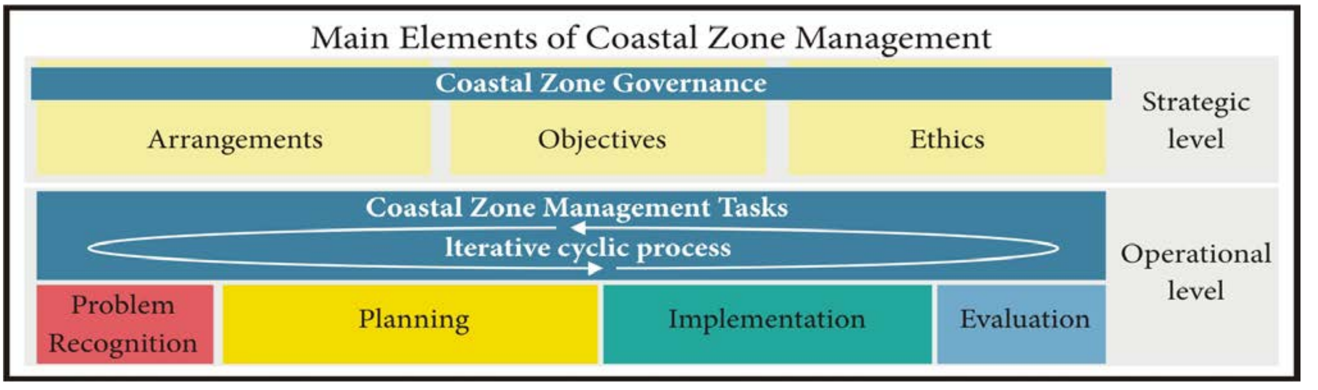

*Figure 45: **Main Elements of an Integrated Coastal Zone Management programme** (source: CZM-Centre 1996)*

A global strengthening of integrated management practices based on increasing our knowledge of coastal processes is urgently needed in order to develop the coastal system in a sustainable way.
A holistic approach towards the management of coastal resources should be the basis for integrated spatial planning aimed at ensuring the sustainable and profitable development of land & water uses for settlements, infrastructure, tourism, nature, safety, energy and fisheries.
ICZM also serves as an appropriate adaptive response option for the anticipated global climate. This was internationally recognised at the beginning of the 1990s and confirmed in 1992 by the international conventions on Climate Change (UNFCCC) and Biodiversity (UNCDB). Since then the European Commission (EC) has continued to strongly promote integrated approaches towards managing the European coastal zones as well as river basins and marine areas.
In July 2014, the European Parliament and Council have adopted the Maritime Spatial Planning Directive which provides a legislative framework for maritime spatial planning, integrated coastal maritime spatial planning and integrated coastal management (EPC, 2014). This Directive supports the integrated management and sustainable development of coastal and marine resources by means:

- increasing coordination, reducing conflicts between sectors and creating synergies;
- increasing cross-border cooperation between EU countries;
- encouraging investment by instilling clearer rules;
- protecting the environment.

The concept regarding the benefits of ICZM was firstly proposed and discussed during the 1993 World Coast Conference (WCC'93):

> The economic and environmental benefits of ICZM are greater than the costs of ICZM investments (Figure 46: 'I'). The benefits include Reduced Damage ("RD") to the environment and increased net economic production with relatively small Investments for integrated management. Note the time lag between the start of the "I" and the beginning of "RD": the small ICZM investments precede the large benefits.

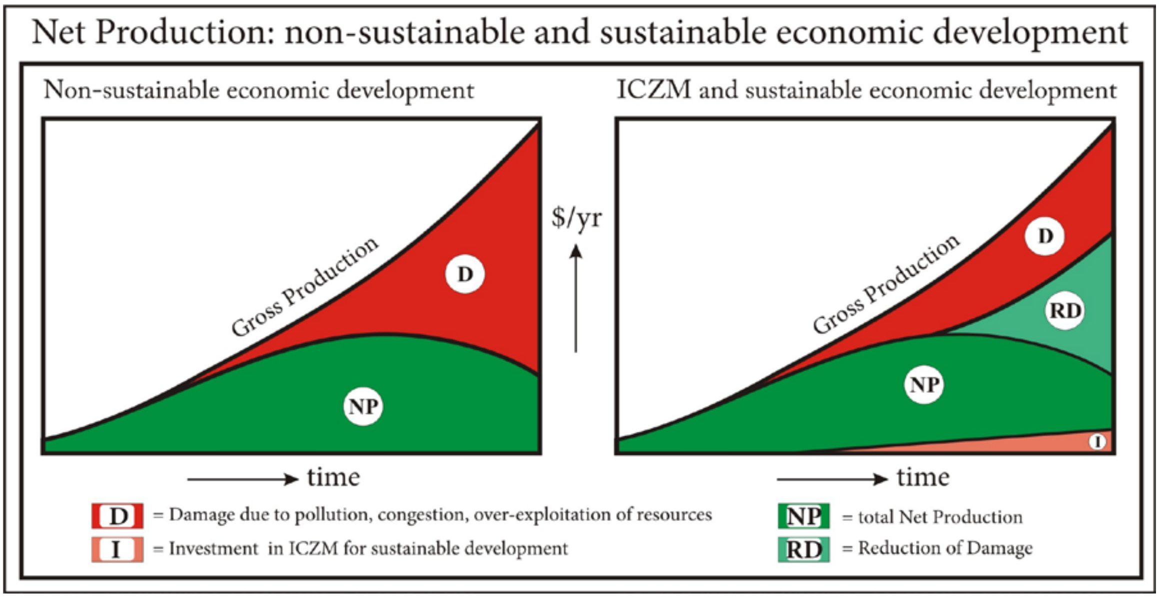

*Figure 46: **The benefits of ICZM**: small Investments (I = ICZM), Reduced Damage (RD) and increased Net Production of a coastal nation. (source: Hulsbergen & Eid, 1991; IPCC-CZMS 1992; WCC'93)*

Over the last two decades, many successful examples of major economic and environmental benefits resulting from ICZM and coastal cooperation programmes have proven the practical value of the WCC'93 concept on a national and regional scale.
These benefits, described in the CCC publication, may be the most convincing plea for an integrated approach and the sustainable implementation of non-regret, resilient adaptive measures.

ICZM, integrated spatial planning and coastal cooperation, are the sound and beneficial adaptive response options to the rapidly increasing rate of change in complex coastal and marine areas.

4.2 Eleven examples of beneficial integrated approaches and coastal cooperation

The positive results of the *EU - ICZM Demonstration programme* (EC, 2000) have been expressed in both monetary and non-monetary terms. The economic benefit versus cost ratio varied around a factor of 10. These benefits focused on habitat protection and improved infrastructure development resulting in sustainable business and tourism developments in the coastal zone. The non-monetary benefits were expressed in terms of improved decision-making, greater public awareness and lower environmental vulnerability (see CCC Chapter I-1-1 on ICZM in the EU).

The following eleven examples demonstrate the results of integrated approaches and ICZM programmes in some coastal regions and countries in Europe and Asia. These results are positive in an economic and environmental sense. These examples are very diverse in character, but the common elements are the integrated vision by the initial leader of the programme, the institutional arrangements promoting horizontal and vertical integration, the long lead time, and the creation of win-win situations and no-regret adaptive solutions.

1. *The Suzhou Creek rehabilitation project, Shanghai, China*
   The Suzhou Creek, running from Lake Tai through the heart of the megacity Shanghai to the Huangpu River in the East, was a heavily polluted waterway. The Suzhou Creek had to be transformed from an embarrassing, stinky black river (Figure 47) into a clean waterway providing positive services to the strongly expanding city of Shanghai (Figure 48).

<table>
<tr><td colspan="2" align="center">In 15 years time</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 47: The black and stinky Suzhou Creek n the early 1990s.(photo: Simon Groot)</td><td>Figure 48: Renewal of the embankment and flood wall bordering the cleaned, renovated Suzhou Creek - the base for sound urban development of the city of Shanghai. (photo: Peter Kerssens)</td></tr>
</table>

In about 15 years, much effort was spent on identifying the 3300 polluting sources, hydraulic modelling and on the subsequently cleaning up of the sources and waterways. One major factor contributing to the success of the Suzhou Creek rehabilitation project has been the adoption of new institutional arrangements and the willingness of the various relevant parties to cooperate.
The formation of the coordinating Shanghai Water Authority from the bureaus of Water Resources, parts of the Environmental Protection Bureau, and the Bureau of Urban Construction contributed considerably to the successful implementation of the rehabilitation activities in an astonishing short period of 15 years. The rapid rehabilitation was an extraordinary achievement and was made possible by strengthening cooperation within an integrated management framework (see also CCC II-2-1).

2. *Nature conservation in the Seychelles*
   The Republic of the Seychelles pays considerable attention to maintaining its vegetation on the mountain slopes, on the coastal plateau and in the coastal areas offshore. The costs of nature conservation (estimated to be in the order of a few percent of GDP) for the dense mountain forests, the coastal vegetation, and the mangrove, coral and sea-grass ecosystems are much less than the monetary and non-monetary benefits for the Seychelles. Tourists appreciate the unique nature of the coastal zone containing a high level of bio-diversity and generating up to half of the country's GDP annually. Moreover, these conservation efforts resulting in a dense coastal vegetation belt have proven to be an effective protection against tsunamis and storm surges.

*Figure 49: **A typical Seychelles shoreline** with wide beaches and an uninterrupted belt of coastal vegetation absorbing the wave energy, protecting the coastal inhabitants and attracting tourists. (photo: R.Misdorp)*

The effective wave absorption by the coastal vegetation belt has been demonstrated during the attack of the 2004 tsunami breaking waves of more than 4 m height. The subsequent damage was compared to the wave energy relatively moderate and two persons were killed. The green belt will also provide initial protection against the impacts of climate change.
The Seychelles offer a good example creating win-win situations through integrated coastal cooperation within an island community in an innovative and effective way (see CCC Chapter II-5-1).

3. *Large scale Mangrove planting in Vietnam and awareness raising*
The Vietnam Red Cross have planted : 22,000 ha of mangroves since 1994, at a cost of about one million US$, which created an integrated planned win-win situation with several benefits:
- increased safety against cyclones and flooding,
- increased fish breeding habitat & coastal fisheries,
- reduced dike maintenance;
- increased biodiversity and
- increased employment & income.

The maintenance of the sea dikes has been reduced, while the safety has been increased, due to planting of mangrove in front of the sea dikes. The reduction of the annual dike maintenance costs is several times the total investment costs of mangrove planting. The planting of mangroves embodies a pro-active approach to safe lives during cyclonic storm surges and is accompanied by considerable economic and environmental benefits (see CCC Chapters III-3-1-1 and III-3-3-7). These multi-benefit operations are good examples of 'Building with Nature' (see CCC Chapter III-3-3-1).

Figure 50: ***Mangrove planting programme*** *Vietnam; a group of Vietnam Red Cross volunteers makes a routine check on the condition and growth of the planted mangrove trees. (photo: Yoshi Shimitzu, International RC Federation, 2003)*

Dissemination of results is important to increase the awareness on coastal hazards and the preparedness of the coastal inhabitants responding to future threats. The Vietnam Vulnerability Assessment to sea level rise and socio-economic development during the 1990's made clear that low lying Vietnam is critical vulnerable to a 1m SLR/21st Century, e.g. the entire Mekong Delta will become subject to annual flooding and the people at risk will strongly increase if no adaptive coastal measure are taken (VVA-Vietnam Vulnerability Assessment). The subsequent Vietnam-Netherlands Coastal Cooperation Program-CCP & the Vietnam-Netherlands-ICZM project (VNICZM, 2000-2006) delivered valuable results not only in strengthening institutional arrangement focussing on integrated planning of adaptive coastal measures, but the common programme also contained practical activities such as monitoring of coastal

processes backed up by Remote Sensing, data base management and integrated coastal modelling have been successfully pursued (more information: CCC Chapter II-8-1).
Furthermore awareness raising among primary and secondary school children of the Thua Thien Hue province has been fruitfully achieved through children's drawing competitions with four schools, training of the teachers supported by an introductory Booklet: 'Where water and land meets' (Vahtar et al. 2003) and a comprehensive Training Manual for the teachers (Vahtar et al. 2005). Both documents are free of charge downloadable see list of References. More than 3000 printed copies of the Booklet (Figure 52), in Vietnamese language have been distributed by trained students among all the TTHue teachers. The theme of the drawing competition was "Water as a friend and foe". The drawings showed the topics important to the children: the fear for flooding, the effects of pollution and the different uses of fresh, lagoon and seawater (Figure 51).

Figure 51 One of the winning drawings, ***'Children of the world, united and holding the line'*** *preventing pollution to spread from the brown, polluted land to the healthy blue water, safeguarding the fishes. (source: CCP2002)*

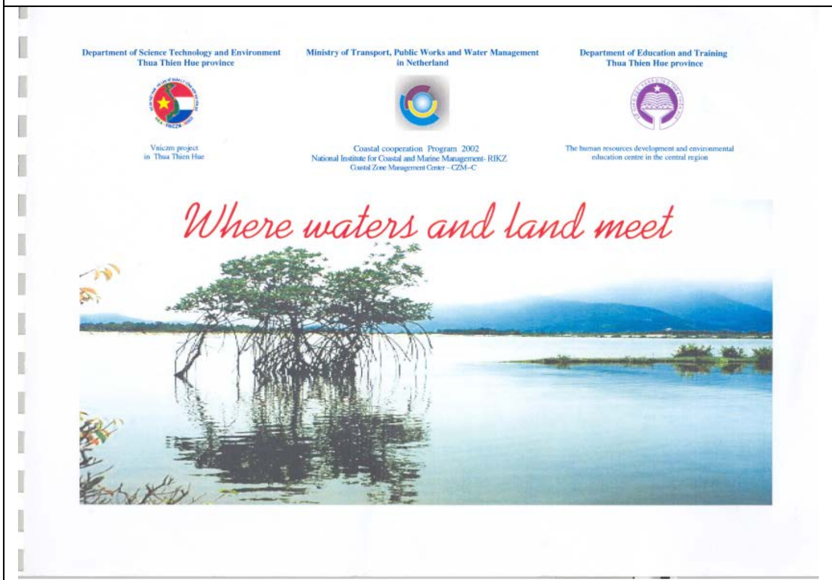

Figure 52: ***The cover page of the introductory Booklet*** *for teachers of Vietnamese schools. (source: CCP2002)*

The Booklet introduces the Training Manual and provide basic information on water as a substance, the role of water for mankind and nature and how to manage water in a holistic, sustainable way. This teaching programme has been an successful cooperation between the Ministry of Education, two TTHU Departments, students, teachers, children and their parents and the international ICZM experts. This educational and awareness programme was enthusiastically approved by the high level provincial authorities, it increased capacity building and public participation through the parents and teachers of the children. See for information: CCC Chapter II-8-3 .

Some examples of directions for sustainable fishery at strategic and operational levels are given below.

4. *Starting to solve the problem of marine litter and ghost fishing*
Coordinated cooperation between many different stakeholders is needed to address this complex marine challenge. An example of actively contributing to solve the problem of marine litter is the removal of entangling fishing nets from wrecks on the Netherlands' continental shelf. The 100th shipwreck was 'cleaned up' in the Dutch North Sea in August 2013. This milestone was reached by divers from the 'Diving for a clean North Sea' group. The divers made about 175 dives and removed about 10,000 kg of nets, weights (lead) and lures from the shipwrecks (see Ghost-fishing).
The next step is to recycle the nets into useful materials, thus creating a win-win solution! The Healthy Seas Initiative grasped the potential of fishing net recycling and is currently leading a pilot project in the North Sea region. Aquafil, the ECNC Group and Star Sock have together established 'Healthy Seas' and started the 'Journey from Waste to Wear' initiative. To date, 20 tons of discarded fishing nets have been reclaimed from the North Sea by divers, subsequently transformed into yarn, and then woven into carpets, towels, underwear, socks and even stockings (Figure 53). The aim is to replicate this pilot project in the Adriatic Sea and Mediterranean Sea, using the European coastal network of the Coastal and Marine Union-EUCC.

*Figure 53: **Healthy Sea Initiative** – YouTube*

Via a different approach, the European MARLISCO - Marine Litter in Europe's Seas – Social Awareness and Co-responsibility (2012 – 2015) project aims to facilitate social engagement in order to inspire changes in attitudes and behaviour, bringing together key stakeholders for solving the marine litter problem in four European Seas. The project undertakes activities in 15 EU countries, including national facilitated debates, a European video contest for students and other educative initiatives (see MARLISCO website www.marlisco.eu). The origin of litter is not only found in the sea but also on land, e.g. in river catchment areas.

5. *Responding to overfishing: co-management experience in Thailand*
Like many other coastal countries, Thailand has been suffering from marine overfishing during the last two decades. The Thai marine annual catch is double the estimated maximum sustainable yield (FAO, 2010). This severe form of overfishing caused negative effects on the marine fish stocks and the coastal environment on which the commercial fisheries and tourism depend. The Thai government has recognised this negative marine resource use and taken various measures. The Thai government in partnership with the EU embarked on a large–scale, five year project to improve the behaviour of all partners dealing with marine fisheries, to make them more responsible for local marine resources, and to establish rights-based fisheries.

This project has developed its approach around the five attributes of co-management: participation, partnership, capacity building, development of integrated management approaches and methods, and learning and adaptation (CHARM project 2002-2007).
By the end of 2006, a total of 479 projects in 50 of the 99 coastal Thai sub-districts had been carried out, with a total participation of 14,000 people.

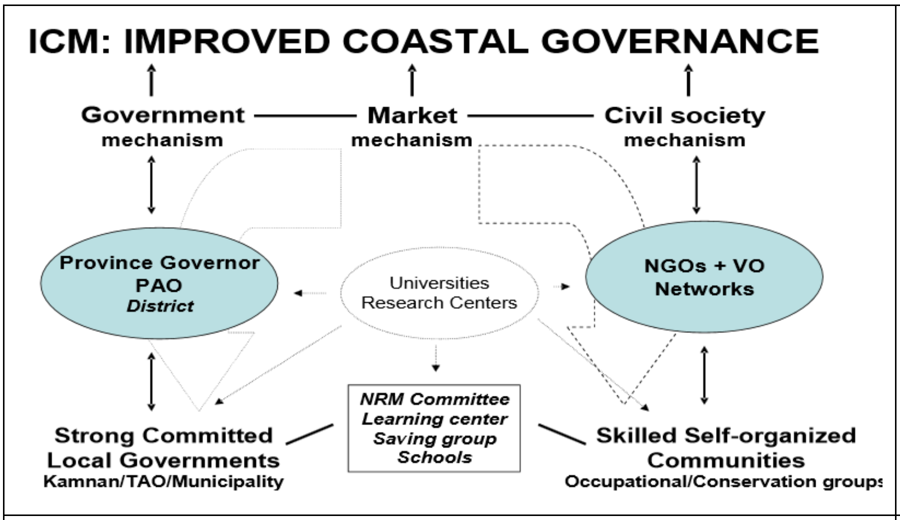

Figure 54: ***Co-management arrangement scheme****: improving coastal governance towards Integrated Coastal Management (ICM) depending on government, market and civil society. (source: CHARM, 2008)*

Figure 55: ***Learning, discussing and adapting*** *to a changing fishery culture. (photo: CHARM 2005)*

Many coastal and marine stakeholders gained new experience and learned techniques for dealing with the Monitoring, Control and Surveillance of illegal fishing and adaptation to the new situation. Co-management approaches resulted in the banning of devastating fishing and gear techniques.
The future fields of focus should be broadened to enhance community-based coastal tourism and small enterprises using the unique richness of the Thai environment in a sustainable way. More CHARM information*:* CCC II-7-2).
The positive effects of the co-management practices supplement other Thai initiatives. According to the FAO, the Thai capture of marine fish, crustaceans and molluscs decreased 35% in six years time (2004 - 2010) while the number of motorised vessels strongly decreased by 75% in the period 2002 – 2006 (FAO, 2010).

6. *Introducing artificial reefs in small coastal communities - Tamil Nadu, India*
Another example of a successful, decentralised community-based programme combating the non-sustainable use of marine resources is the Artificial Reef programme in southern Tamil Nadu. This

programme has been implemented within a framework of a Netherlands-India coastal cooperation project aiming to restore the lost fishery and to increase marine biodiversity.
More than 100 Artificial Reef (AR) modules were constructed and placed in three coastal locations northeast of the port city Tutticorin in the Gulf of Mannar (Figure 56).

The effects of the artificial reefs were regularly monitored during the Netherlands-India project from 2001 to 2006, showing that the reefs enhanced the coastal fishery stocks, encouraged coral recruitment, and helped to create new food chains. The catch per unit effort for fish and crustaceans gradually increased over time.

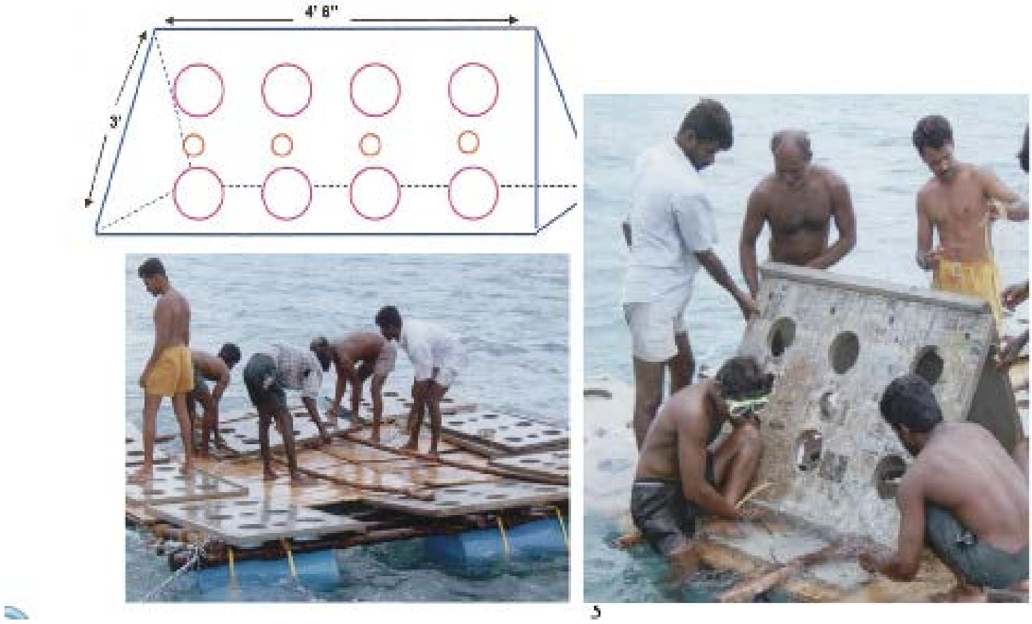

Figure 56: ***Artificial Reef module, concrete slabs, transport*** *on a raft and* ***assembling the modules*** *before deployment in three locations at water depth between 3 – 6 m. (photos: SDMRI)*

At the same time, awareness raising campaigns in the two neighbouring fishery villages informed the fishermen and their families. The traditional fishermen witnessed increased fishery yields and also became more and more enthusiastic about the associated positive effects such as increased species diversity and density in the areas around the Artificial Reef modules.
Quick, massive coral recruitment was observed on the reef modules in a period of less than five years (Figure 57). The coral ecosystem responded in a revitalised way after a preceding period of devastating fishing practices with decreasing catches and degradation of the marine environment.
Eco-tourism opportunities are clearly present in the Tutticorin coastal area. Artificial Reefs could play a major role in attracting diving tourists, which in turn help to support the livelihood of the local fishermen community.

Figure 57: ***Massive coral recruitment on the artificial reef*** *near one of the holes in the slab (upper right corner of the picture). (photo SDMRI)*

A sign of sustained beneficial cooperation is the continuation of the valuable monitoring of the artificial reefs by the Indian counterpart (the SDMRI – Suganthi Devadason Marine Research Institute, Tamil Nadu) after the Dutch assistance stopped in 2006. More information: CCC Chapter II-3-3 and SDMRI website .

7. *Thai lessons for sustainable shrimp farming*
Sustainable ICZM solutions enable shrimp farmers and supporting industries to realise a reasonable standard of living and long-term return on investment. It simultaneously minimises negative social and environmental effects. Extensive shrimp culture should be combined with other kinds of land use, such as rice production and mangrove plantations. This requires increased knowledge of coastal processes, based on a long-term process of training and cooperation between farmers, governmental institutions, NGOs, knowledge institutes and coastal stakeholders.
Sustainable Thai farm management is supported by:
   - monitoring of the coastal environment in all 22 Thai coastal provinces,
   - shrimp product certification,
   - enlarging communal ownership,
   - introducing new approaches such as mangrove bio-filtering practices for reducing the farm effluents,
   - designing Geographic Information System(GIS) planning tools for facilitating decision making and for capacity building in integrated farm management.

Adaptive measures such as rehabilitation of the barren and abandoned coastal areas is not always possible. If undertaken, it can also be expensive as illustrated by the Pak Phanang Royal project diverting river water to flush 2000 ha of polluted pond soils bordering the southern Gulf of Thailand. The more than 70 years of well documented Thai experience in shrimp farming can facilitate other coastal countries in developing sustainable aquaculture. (See for more information: CCC Chapter II-7-1):

Four Dutch examples: integrated planning and sustainable implementation of adaptive measures.
These long-term management and development programmes are regarded by the Dutch government and society as essential, resilient and no-regret responses to the changing conditions in the very low lying coastal Netherlands.

8. *The added values obtained during the sustainable Rotterdam harbour development programme (1993 – 2010) are large.* In the Rijnmond region (the greater Rotterdam area), tensions between the economy and the environment existed for many years during the 1980s, as the growing port industry and the Rijnmond urban area often had strongly conflicting interests and suffered from bad air and water quality. That is why the Rijnmond Spatial Planning and Environment Covenant was signed in 1993. Signatories to the ROM-Rijnmond covenant were the Province of Zuid-Holland, the four ministries concerned (Economic Affairs; Housing, Spatial Planning and Environment; Agriculture, Nature Management and Fisheries; Transport, Public Works and Water Management), the Rotterdam Metropolitan Region, all seventeen municipalities involved, the Port of Rotterdam, the Rotterdam Chamber of Commerce, and Deltalinqs (representing more than 700 port companies). See also ROM-Rijnmond, 2003.
The results of the 17-year Rijnmond Programme are impressive both in terms of the economic as well as environmental benefits realised. It is a good example of harmonising the Environment and Development as promoted by UNCED 1992.
The extra added economic value generated by the increased throughput of goods started to increase in 1996 and exceeded the costs of the entire programme (= 7 billion €) by a factor of three. This very positive economic result was obtained within the lifespan of the programme, after a time lag of some

years. The simultaneously improved environmental values of the ‘cleaned harbour’ area contributed to the health of the inhabitants of the harbour area and improved the nature and recreation functions (see CCC Chapter I-2-2/).

Figure 58: ***The Port of Rotterdam****, the largest harbour of Europe with an annual throughput of about 450 millions of tonnes of goods, 12,500 ha of port area (land & water, 6,000 ha industrial sites), the length of the port area: 40 km, employment: over 150,000 jobs. (Source: Google Earth: Image © 2014 Digital Globe, Image © 2014 Aerodata International Surveys Data SIO NOAA US Navy NGA GEBCO)*

9. *The Delta Programme* is one of the outcomes of The Second Delta State Commission (2008)**,** which was chaired by Prof. Cees Veerman. The impacts of Climate Change for the entire country during the 21st century with a perspective towards the 22nd century was one of the main issues this Commission analysed. It viewed a high rate of sea level rise of 1.3 m by the year 2100 as a worst case scenario and identified no-regret and resilient adaptive strategies for the entire country. The integrated planning and the sustainable implementation of the national Delta Programme will safeguard the Netherlands from flooding by the rivers and sea, and provide sufficient fresh water supply. The State Commission anchored these strategies of the Delta Programme in a special Delta Act, ratified by the parliament, including a Delta Fund for the financial reservation of one Billion (10^9) Euros annually during the 21st century. The appointed Delta Commissioner, Wim Kuiken, is responsible for the execution of this Delta Programme (see CCC Chapter I-2-5/).

Figure 59: Youtube: ***‘Working on the delta –Investing in a safe and attractive Netherlands, now and in the future’: http://www.deltacommissaris.nl/english//news/videos/workingonthedelta.aspx***

10. *Sand nourishment and the 'Sand-Motor',* are flexible measures to defend the coast in a cost effective and resilient way. Since 1990, the 350 km long Dutch coast has been supplied with 10 – 15 million m^3 sand annually dredged from the adjacent North Sea. Successful, lower-cost foreshore nourishments are based on increased knowledge of the coastal system via frequent monitoring of the coastal dynamics and measuring the coastal sediment balances during many decades (see CCC Chapter III-3-3-2).
A large volume (21.5 million m^3) of sand was supplied to one location along the coast of the Delfland in the province of Zuid-Holland, i.e. the 'Sand-Motor', in 2011. See also the You Tube of the Sand-Motor Virtual Model .
Wind, waves and residual tidal currents will gradually and naturally spread the sand northward feeding the coast there.
The thorough, multi-disciplinary monitoring and analysis of the ecological, hydraulic, morphological, biological, hydrological, geochemical and social processes of such an innovative mega pilot is providing valuable information on the economic and environmental benefits of large-scale nourishment schemes.
The NatureCoast programme is to increase the understanding and management of large-sale, 'soft', adaptive interventions and is based on the principles of "Building with Nature".
The results of the large scale, applied scientific NatureCoast programme will show whether this approach to nature-driven sand nourishment of coastal systems is successful in the Netherlands. If so, the valorised knowledge can then be employed elsewhere.

*Figure 60: **The Sand-Motor,** a large scale nourishment of 21.5 million m^3 sand, extending 1 km into the sea and more than 2.5 km wide along the shore, totally 130 ha. (photo: https://beeldbank.rws.nl, Rijkswaterstaat / Joop van Houdt, 20/03/2012);*

If the Sand- Motor fulfils our expectations, sand replenishment off the Delfland coast will not be needed for the next 20 years, while other functions such as recreation and nature will also benefit.

11. *Room for the River'* is a national Dutch programme (1995 – 2015) to give the rivers more space, where possible, aimed at improving management options for high water levels. Measures are being taken at more than 30 locations along the main rivers to provide more safety against flooding and to improve the quality of the immediate surroundings.for settlements and nature. More space for the river in the floodplain is provided by deepening the winter bed and by lateral digging to widen the summer bed, where possible accompanied by creating recreation ponds. Another example of creating win-win situations is making the released sediments commercially available for the construction industry. When needed, dikes are reinforced, but also de-poldering is employed (Figure 60). The 'Room for the River' programme is sharing knowledge with local residents, stakeholders and riverside towns, and is balancing flood protection with local development. This concept of providing space for hydraulic river processes during floods represents a paradigm shift in Dutch traditional thinking and breaks with the age-old strategy of providing protection by simply continuing to raise the level of the dikes in a continually

subsiding polder landscape with impacts of climate change awaiting. (see: Room for the River programme).

*Figure 61: **One of the 30 'Room for the River' projects:** 2000 ha of de-poldering, by removing dikes and dredging openings towards the river in the Biesbosch near the confluence of the rivers Rijn and Maas. The effect of this water rentention project: the water level during flooding will be reduced by 30 cm in the area nearby the city of Gorinchem. (photo: Rijkswaterstaat)*

The large-scale sand nourishment schemes and the 'Room for the Rivers' programmes with its flexible, resilient, no- regret, integrated approach are based on the principles of 'Building with Nature' (see CCC Chapter III 3-3-1/).

In summary, the above eleven examples of long-term, integrated, planned, and sustainably implemented programmes show that an integrated approach to complex coastal areas is feasible and can actually work. Moreover, it is also economically and environmentally beneficial to execute adaptive, resilient, no-regret measures. It is best to start the preparations for adaptation as soon as possible in order to increase the knowledge base of natural and socio-economic coastal processes, their impacts and response options decreasing future damages and fatalities.

5 General Conclusions

Three main triggers for a holistic management approach to the coastal zone have been identified. They focus on the global impacts of the exponential growth of coastal population density, the increase in non-sustainable economic development, and the concentration of atmospheric greenhouse gases. Extraordinary rates of growth of these triggers were reached during the last century and the early 2000s. It is expected that rapid population growth will continue to 2030 and possibly until 2050. The desired decrease in the rate of population growth can be achieved by equitable and sustainable economic development, combating poverty, and an increased level of education.
The effects of non-sustainable economic development of the coastal and marine resources are numerous. The devastation caused by highly intensive coastal and marine fisheries have been amply demonstrated. Effective solutions can be found in programmes which are set up within an integrated framework with innovative, win-win approaches.
The impacts of climate change such as the envisaged accelerated sea level rise, increased storminess, and changes in rainfall regimes will seriously threaten the low lying densely populated coastal zones of the world. Strong increases in the number of people threatened by flooding, coastal erosion and salt water intrusion should be addressed through the integrated planning of adaptive coastal measures as soon as possible.
The combined impacts of these three triggers on societies can be huge, especially for Asia, which is one of the most valuable and in the meantime still most vulnerable continents.
Integrated coastal zone management (ICZM), coordinated coastal cooperation and integrated spatial planning are the most appropriate instruments to anticipate and respond to long-term concerns and needs, while addressing present day challenges and opportunities. ICZM has been recognised as the non-regret, adaptive mechanism to deal with global changes.

The major economic benefits of integrated coastal cooperation together with the environmental benefits are the most convincing triggers to plan and implement an ICZM programme. Examples of beneficial win-win situations realised in various parts of the world have been provided. See for detailed information of more than 30 coastal cases:

www.coastalcooperation.net .

Integrated planning should help in the development of well balanced decisions based on knowledge of natural and socio-economic coastal processes. In general our knowledge of dynamic coastal processes needs to be increased through cooperative efforts. Investments in increasing this knowledge base have a high return on investment due to the economic benefits of informed and well balanced decision making. Investing in expanding our knowledge base is feasible in view of the large growth in economic wealth in many of the coastal countries during the last decades.
Implementing sustainable measures **NOW** will help minimise the loss of life and depletion of resources. Innovative no-regret measures dealing both with mitigation of greenhouse gas emissions and resilient, non-regret, adaptive coastal measures should be prepared now.
Even in the face of some uncertainties, a ‘do-nothing’ scenario is not acceptable; pre-cautionary principles should be applied. The preparation of measures can now be based on scenarios resulting in sets of alternative solutions. The execution of adaptive measures should take place as soon as the impacts of climate change become clearer.

It is therefore essential to prepare for adaptation now, to develop sound arrangements for coastal cooperation, and to initiate (the next cycle of) ICZM programmes directed at sustainable, resilient, no-regret coastal solutions:

Is it acute …. No,   is it urgent …Yes!

Prof. Cees Veerman

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