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Coastal degradation leaves the Caribbean in troubled waters

Recent assessments in the Caribbean indicate that suspended solids in the coastal and marine environment are already leading to severe environmental impacts in the region[a]. Key economic sectors are threatened by sedimentation and excessive runoff, and future scenarios indicate potential increases in the amounts of sediments transported from land to sea. Can something be done before local livelihoods may be irreversibly affected by these processes?

Coastal ecosystems are among the most productive yet highly threatened ecosystems in the world, and are now experiencing many rapid environmental changes[1]. Poor water quality in coastal areas can lead to rapid degradation of habitats and biodiversity which negatively impact many economic activities and livelihoods.

Rapid land-use changes and coastal development occurring in Caribbean countries can lead to increased runoff and erosion, with the problem of increased release of sediments into the marine environment. Unsustainable agricultural practices (excessive and/or inappropriate use of fertilizers, pesticides and other agrochemicals) add chemical compounds to the sediment load. This could increase the toxicity of these sediments, making them an even greater environmental threat. The latest global report on the State of the Marine Environment[2] shows that agricultural runoff, nutrient deposition and changes of sediment transport are some topics where progress is either “mixed” or “worse”.

Such trends raise serious concern regarding the health of the coastal marine environment. Predictions of estimated erosion, sediment and nutrient transport and delivery at river mouths of over 400 watersheds in the Meso-american Reef for potential land use in 2025 adapted from the Global Environment Outlook 4[3] scenarios show that increases in sediment delivery of up to 13% are possible compared with the current situation, barring a very strong commitment to sustainable development[b].

Governments of the wider Caribbean recognized the critical importance of the Caribbean Sea to economic development, and signed the *Cartagena Convention* for the Protection and Development of the Caribbean Region in 1986. Despite this regional agreement, coastal and marine ecosystems continue to be under severe threat from the impacts of sedimentation.

Fig. 1: Reefs at risk and deforestation

This map shows that in general, risk related to sedimentation is either linked with land clearing and deforestation leading to high runoff rates, or discharges from major water systems.

Why is soil ending up at sea?

Diffuse (non-point) land-based sources (LBS) of pollution reach the ocean through land runoff, precipitation, atmospheric deposition, drainage, seepage, hydrologic modification, or even from marinas and boating activities. Global estimates state that human activities have increased sediment flows in rivers, from both point and diffuse sources, by about 20%[(1)]. When the LBS Protocol for the Wider Caribbean Region was developed in 1999, agricultural runoff was considered to be the number one source of diffuse pollution and sediment was, by load, the largest pollutant entering the marine environment in the Caribbean Sea.

Forestry operations can generate significant amounts of diffuse pollution. Heavy machinery used to remove vegetation leaves soils exposed and susceptible to be washed away, especially in areas of the Caribbean where the topography is relatively steep. Soil erosion in the tropics may be up to 20 times higher on areas cleared of forests, compared to forested land[(1)]. The construction and use of roads often represents the main source of diffuse pollution from forest operations, constituting up to 90% of the total sediment loads from this sector[(c)]. The general trend is that, in most countries, forested areas have decreased during the past decades, with the highest rates of reported deforestation found in Central America[(5, 6)].

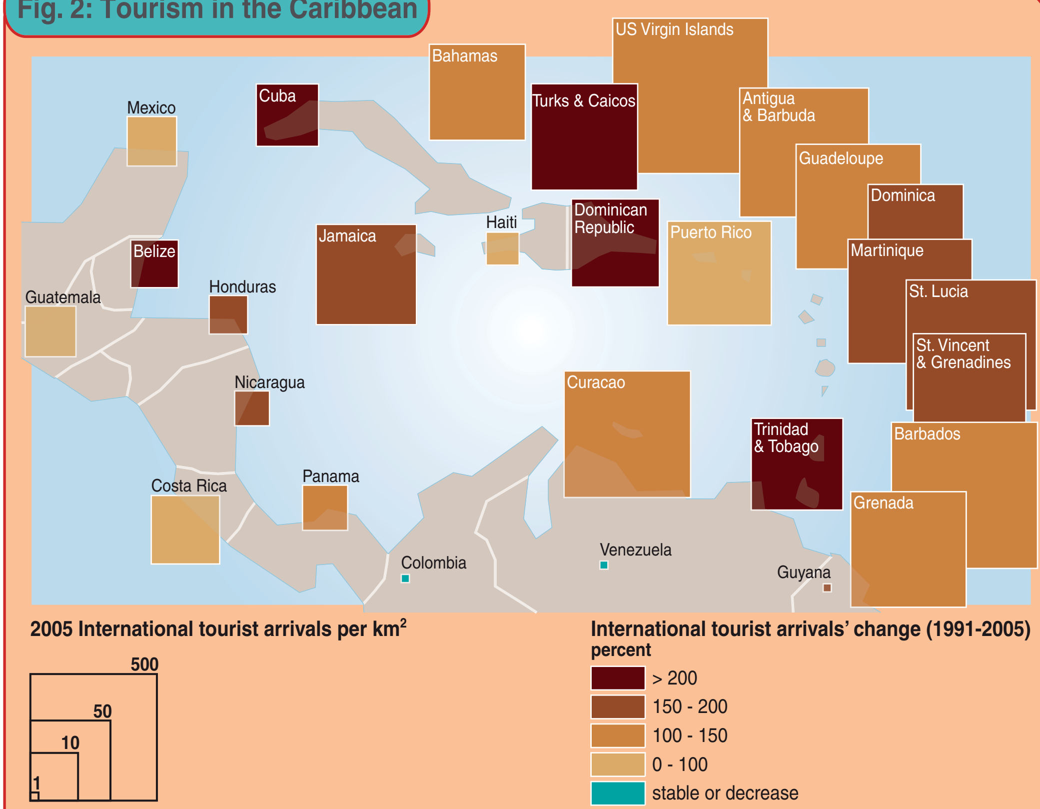
In the *agricultural sector* during the past four decades, the largest expansion of arable land in the world, both in physical land area and proportional terms, took place in Latin America and the Caribbean, and predictions for 2030 indicate that this will continue[(7)]. Poor agricultural practices expose land and disturb the soil, making it more vulnerable to erosion during rainstorms and increasing eroded sediments runoff, often combined with fertilizers and pesticides, into nearby waters and eventually to sea. Given Caribbean islands' recent geologic formation (volcanic), the soils are not as well developed as in other parts of the world, and they generally have low levels of organic matter which also contribute to the soil erosion rates[(d)]. Runoff and storage facilities are rare, apart from reservoirs built for municipal and industrial use.

Urban areas and coastal development are expanding in the region. Growing coastal populations and rising numbers of tourists (Fig. 2) are adding to the coastal pressures on the marine ecosystems. In the past 15 years, the number of tourist accommodations more than doubled, and numbers continue to increase rapidly in many countries[(c)]. At construction sites, soil exposed and not well-contained can easily end up in runoff waters and at sea, and sediments and solids constitute the largest volume of pollutant loads to receiving waters in urban areas[(c)]. Also, non-porous urban landscapes accelerate surface runoff as water cannot easily percolate into the ground, increasing pollutant loads such as sediments, oils, greases, toxic chemicals, nutrients and pesticides, heavy metals and even viruses and bacteria from failing septic systems.

Apart from the fact that sewage is a major pollutant in itself of, e.g. nutrients and pathogens, untreated sewage is also a major point-source contributor of sediments, through e.g. inadequate management of sewage sludge and septic tanks. An indicator of threats from coastal development identifies a third of the region's reefs as threatened by pressures associated with coastal development, including sewage discharge, urban runoff, construction and tourist development[(4)].

The latest report on climate change[(8)] suggests it is likely the frequency of heavy precipitation events will increase, meaning greater likelihood of erosion and sediments runoff. Furthermore, increased damage from storm surges and erosion is expected on small islands as sea-level rise and changes in sea temperature will impact coastal ecosystems such as mangroves, salt marshes and coral reefs.

Fig. 2: Tourism in the Caribbean



For all countries, data from "Caribbean Tourist Organisation"[(e)] (1991-2006), except Honduras, Nicaragua, Costa Rica, Panama, Colombia and Venezuela then Wold Bank[(f)] (1995-2005).
Countries smaller than 300km² have not had their "2005 International tourist arrival per km²" represented.
Latest tourist arrival data for Costa Rica and Turks & Caicos, 2004, for Guadeloupe and Haiti, 2001.

How are the environment and livelihoods affected?

Increased sediment loadings in coastal waters increases turbidity, reduces light levels and may even cause corals to suffocate and die rapidly. A recent watershed-based runoff analysis implemented for more than 3 000 watersheds of 35 countries discharging to the Caribbean shows that one-third of all Caribbean coral reefs are threatened by sedimentation, with 20% classified as a high threat (Fig.1).

Tourism

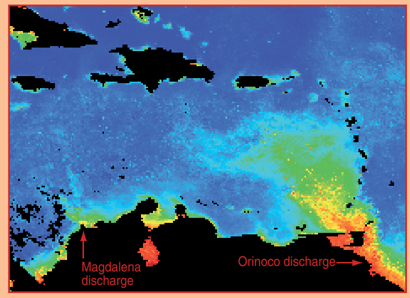
The degradation of coastal ecosystems and coral reefs may lead to important losses in revenue caused by, for example, declining numbers of visitors. Divers make up about 10% of all tourists in the Caribbean, and this group alone represents about

17% of total tourism revenue[4]. In general, divers in the Caribbean spend 60 to 80% more than other tourists, making this group high-value tourists. By 2015, revenues from dive tourism are foreseen to decline by up to 5% (loss of up to US$ 300 million per year) due to continued reef degradation[4].

Shoreline protection

It is estimated that between 70 to 90% of the energy of wind-generated waves is absorbed by coral reefs and mangroves (depending on their health status and physical and ecological characteristics)[9]. In the Caribbean, over 20% of the coastlines are protected by reefs. Data on all tropical cyclones for the period 1973-2003 show that the average frequency for any area in the Caribbean islands is one tropical cyclone every five years (0.2 per year), up to one event every second year (0.45 per year) in some areas[g]. Storm surges induced by these events can have serious environmental and socio-economic impacts. This in turn can accelerate erosion and associated habitat loss, increase salinity in estuaries and freshwater aquifers, change sediment and nutrient transport, and increase coastal flooding[6]. Coastal habitats also lose their natural pollutant-filtering capacity as the extent of mangroves, coastal wetlands and seagrasses declines[6]. Loss in seagrass habitat is mostly associated with a degradation of water quality primarily caused by high nutrient and sediment loadings (Fig.3).

Fig. 3: Satellite ocean and coastal waters monitoring



Satellite-based remote sensing can be used to monitor and study phenomena in the oceans and coastal waters. Today, data from sensors can be used to retrieve information on chlorophyll concentrations and other factors such as the turbidity (amount of suspended particles) of the water. For example, this image was acquired with the SeaWifs sensor during September 2007: the brighter the colours, the higher the concentration in chlorphyll (bright red indicates values of 10mg/m³).The Orinoco river discharge is clearly visible with its northward chlorophyll plume. The Magdalena plume is also slightly visible.

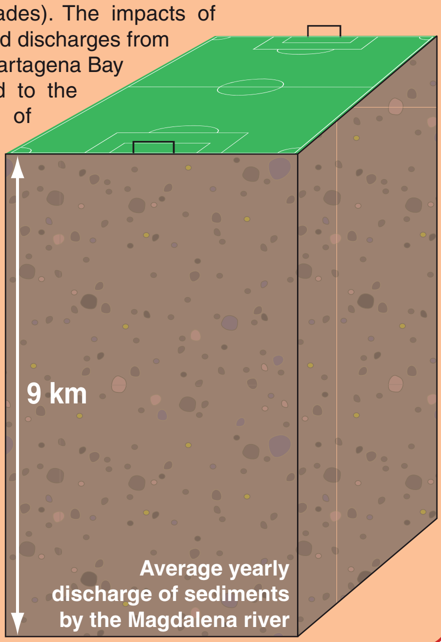
Phytoplankton, mixed with sediment and other organic matter, show up as blue-green swirls along the coastal margin of the Yucatan Peninsula (Mexico) in this MODIS image acquired on 5 February 2006. Phytoplankton blooms are often fed by surface runoff; nutrients are washed away from the land by rivers and deposited in the ocean, where they are brought to the surface by deep currents. Coral reef systems throughout the world are among the most productive ecosystems; although they comprise only a tiny fraction of the land surface, they produce large amounts of living organic material, or biomass. Sea grasses are important, too, providing habitat (food and shelter) to a variety of aquatic organisms. These regions are under stress for a variety of reasons, including erosion from coastal development, sea level rise, overfishing and tourism.

Image sources: NASA VisibleEarth[i], NASA Ocean Color Web[j]

Fig. 4: Long-term stress from the Magdalena River

The Magdalena river, in Colombia is the largest river discharging directly into the Caribbean Sea. Between 1972 and 1998, it is estimated to have delivered over 4 000 million tonnes of sediment to the Caribbean coast. The river discharges yearly an average of 96 million m³, the equivalent volume of a soccer field almost 9 kilometres high, or 320 000 dump trucks.

Multiple stressors affect the coastal ecosystems in the area, but the effect of the Magdalena River runoff has been constant and very prolonged (several decades). The impacts of heavy sediment loads and discharges from the Canal del Dique to Cartagena Bay have greatly contributed to the partial disappearance of coral formations and also to a considerable reduction in abundance of seagrass beds in the bay and neighbouring areas. High discharge periods coincide with the decline of live coral cover around the Rosario Islands (a coral reef complex that constitutes a marine protected area). Other analyses show that only 8% of the seagrass existing in the Cartagena Bay in the 1930s remained in 2001.



Data source: Restrepo 2006[10]

Fisheries

It is estimated that the fisheries sector in the Caribbean will be heavily impacted by continued coastal ecosystems' degradation. Estimates are that by 2015, coral degradation could cause the fisheries to decline by 30-45% (loss of US$ 95-140 million per year). Over 120 000 persons work full-time in the fisheries sector on Caribbean islands, and millions depends on reef fish as a vital source of protein[4].

Human health

Ciguatera fish poisoning in humans is caused by eating reef fish contaminated with a toxin known as ciguatoxin, which originates from toxic algae in coral reef areas and is passed up the food chain. Much remains unknown on why marine algae produce toxins, but activities that increase macro-algae growth such as sewage input and land runoff have been reported to increase the incidence of the disease[h].

Agriculture

Loss of valuable topsoil at rates as high as 133t/ha/yr have been recorded on unprotected lands in the Caribbean[d](Fig.4). Using an average soil density of 1.6t/m³, this amount represents approximately 83m³ of soil per hectare per year – about 10 full standard dump trucks of soil for an area the size of a football field per year. While large amounts of surface runoff are produced during the wet season, a soil-water deficit can occur during the dry season, resulting in further declines in crop yields[d]. Soil is increasingly becoming a limited resource, threathning food security and the earnings from the agricultural sector, which are important for the Caribbean countries.

(continued)

What can be done?

Individual initiatives combined with well-designed legal instruments help tackle the problem of non-point source pollution. Although exact locations of the pollution sources are not identifiable, we know that certain environments and behaviours release large volumes of sediments and pollutants. A few examples of mitigation actions related to forestry, agriculture and urban areas are:

- **Sediment fences** or laying of straw used at construction sites to filter sediments from rainwater, trap materials and slow runoff;
- **Vegetated buffers** between and around areas of high surface runoff (e.g. parking lots, roads), between farm fields and around forestry operations to absorb soil, fertilizers, pesticides or other pollutants that may reach the water;
- **Retention ponds** and constructed wetlands to capture runoff and storm water, sediments and contaminants;
- **Conservation tillage** reduces erosion by ploughing less, also helping nutrients or pesticides stay where they are applied;
- **Crop nutrient management** plans to help reduce nutrient runoff by applying fertilizers only as needed;
- **Design, management and location of roads** and skid trails in forestry to avoid situations causing heavy non-point pollution;
- **Replanting** trees after logging to reduce erosion;
- **Timing** of forestry operations to avoid activities during the rainy season, fish migration and spawning seasons.
- **Establish sewage sludge management plans** to reduce negative impacts on the environment and human health.

Fig. 4: Substituting the natural by the artificial

Recently, a tendency to build artificial reefs (e.g. using reefballs) to either replace natural reefs or create new ones has been observed. Their purpose is often to act as a physical barrier to attenuate waves, but this approach is expensive and not feasible for large areas. Furthermore, artificial reefs will never replace all ecosystem services of natural reefs. Reefballs have already been installed in 14 Caribbean Islands as well as in several Latin American countries (Reefball Foundation[k]). Much care must be taken with such projects, as coastal engineering works may disrupt natural sediment movements and in many cases even cause erosion to accelerate or bring about unforeseen problems in adjacent shorelines[5].

Reefballs as breakwater technology in Antigua

Photo: The Reefball Foundation[k]

The *Protocol concerning Land-bases Sources of Pollution* (LBS Protocol), which was developed within the framework of the *Cartagena Convention*, provides additional guidance of measures to be taken to reduce impacts of pollution on the marine environment. The Technical Annex IV deals specifically with the control of pollution from agricultural non-point sources.

Conclusion

Concerns related to diffuse pollution dramatically affect all sectors which the Caribbean region is fundamentally dependent on; *tourism*, *fisheries* and *agriculture*. The quality and quantity of drinking water resources throughout the region may also be impacted by sedimentation of upper watershed areas. Contaminated runoff and sedimentation are strongly related to human activities, and best management practices can help significantly reduce their sources and impacts.

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l Caribbean Environment Programme (CEP) www.cep.unep.org

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