Megadeltas and Climate Change

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The Intergovernmental Panel on Climate Change (IPCC 2007a) ranks heavily populated coastal deltas among the world’s most vulnerable natural systems to the effects of climate change. The IPCC refers to large (>10⁴ km²) coastal deltas as “megadeltas”, which they also classify as “hotspots of societal vulnerability” (IPCC 2007a, p. 327). These large deltaic systems, which are the focus of this article, provide important ecological services to society. In addition to serving as a land base for many of the world’s most densely populated cities, deltaic wetlands and the estuaries they fringe are among the most biologically productive systems in the world. Their high fertility and biological productivity account for a large percentage of world fisheries landings and many have been drained, deforested, or impounded for agriculture and aquaculture. Even in the absence of a changing climate, most megadeltas are deteriorating as a result of human activities that have affected their natural flood pulses and sedimentary processes (Day et al. 1997). Climate change has the potential to amplify the decline of deltaic systems through several mechanisms, but the most important drivers are sea level rise, increased storm intensity, and changes in rainfall and runoff to the coast.

A coastal delta is a landform at the mouth of a river that builds up sediments that are transported to the coast by water and deposited as the river current slows when it meets the sea. In their natural state, deltaic plains are broad, relatively flat expanses of near sea-level wetlands interlaced with channels and natural levee ridges. The formation and maintenance of deltas is inextricably linked with changes in sea level. All modern deltas of the world appear to be less than 10,000 years old (Meade 1996) and most began to form between 8,500 and 6,500 years ago, when sea level rise since the last glacial maximum (about 18,000 years ago) had decelerated to a pace that allowed deltas to accrete vertically and prograde seaward (Stanley and Warne 1994, Coleman et al. 1998). The thick fluvial deposits that comprise most deltaic systems are naturally prone to compaction under their own weight, but if sediment supplies are sufficient they can build and maintain their surfaces as sea level rises. Sediments deposited via biologic processes can be as equally important as the mineral sediments that deltas receive from rivers (Cahoon et al. 2006). Deltas are sensitive to any process that alters the balance between marine processes and the rate of sediment deposition. As long as the rate of sediment supply exceeds the rate of removal by marine forces and subsidence, a delta will tend to build seaward.

Several hundred million people currently live in deltaic plains, which are attractive to human settlement because of their extensive natural resources (water, fish, wildlife, and forests) and their position along coastlines at the entrance to major rivers, which makes them convenient for transportation and commerce. The development of cities, industry, ports, and agriculture in megadeltas has been accompanied by forced drainage of wetlands and the construction of flood control works that isolate deltaic environments from their sediment source. The drainage of organic soils and groundwater withdrawals to support human settlements have caused land surface subsidence in many deltas including the Chao Phraya in Thailand, the Ganges-Brahmaputra in Bangladesh, and the Changjiang (Yangtze) in China. Hydrologic modification (such as the construction of dams in tributary rivers) has altered the seasonal flow of fresh water and sediment to many deltas—such as the Mississippi in North America, the Indus in Pakistan, and the Nile in Egypt—thereby creating sediment deficits that contribute to subsidence and erosion of the delta...
While some deltas have received more sediment in recent decades as a result of human activity, generally the net effect of human development has been a decline in sediment supply. Agriculture and deforestation generally increase suspended sediments in rivers, though these increases may be short lived, while dams and levees decrease the volume of sediment delivered to and distributed within deltaic coasts (Meade 1996).

In a sample of 40 deltas distributed worldwide, Ericson et al. (2005) found that approximately 20% are experiencing accelerated land surface subsidence and 70% show decreased accretion rates due to a decline in fluvial sediment supply. An analysis of satellite images of fourteen megadeltas (Danube, Ganges-Brahmaputra, Indus, Mahanadi, Mangoky, McKenzie, Mississippi, Niger, Nile, Shatt el Arab, Volga, Huanghe, Yukon, and Zambezi) indicated that a total of 15,845 km² of wetlands have been irreversibly converted to open water since 1990 and that most of the wetland losses were attributed to human activity (Coleman et al., 2005). According to this analysis, if a similar trend is present in forty other world deltas, a total wetland loss would be on the order of 364,000 km² over the past 15 to 20 years.

Climate change will amplify the potential for erosion and submergence of deltaic systems, particularly those that are already stressed by human development. Sea level rise is projected to accelerate during the coming decades (IPCC 2007b), thereby inundating low-lying coastal systems that are not experiencing sufficient tectonic uplift or sediment accretion that would allow them to keep pace with the rising sea. Tropical cyclones are projected to increase in intensity, creating higher wave energy and storm surge that contribute to erosion and land loss in coastal deltas (Emanuel 2005, IPCC 2007b). During Hurricane Katrina, for example, which made landfall in coastal Louisiana in 2005, an estimated 388 km² of the Mississippi River deltaic plain was converted to open water (Barras 2006). Due to changes in precipitation and temperature, runoff is projected to decrease in many land areas of the Northern Hemisphere (Milly et al. 2005). A decline of runoff to the coast has serious implications for sediment starved deltas and the populations that inhabit them.

In the Nile delta, which covers an area of about 22,000 km², one meter of sea level rise would affect 15% of Egypt’s gross domestic product (El-Sayed 1996) and 0.5 m of sea level rise could displace over 2 million people (El-Raey 1997). Using GIS methods, Anthoff et al. (2006) mapped coastal economic activity and population density and concluded that Asian deltas are the most vulnerable to sea level rise. Their analysis indicates that 75 per cent of the world’s population affected by a 1 meter rise in sea level live on the Asian megadeltas and deltas, with a large proportion of the remainder living on deltas in Africa. The relative vulnerability of coastal delta populations globally is depicted in Figure 1.

Recognition of the high vulnerability of deltas has led to several national and international efforts aimed at providing information that will help deltaic populations anticipate and adapt to climate change. The following projects, reports, and websites are recommended as initial sources for additional information:

http://www.megadelta.ecnu.edu.cn/main/projectbackground.htm

Delta-focused projects of START, sponsored by
Figure 1. Relative vulnerability of coastal delta populations as indicated by population potentially displaced by current sea-level trends to 2050, including local effects. Extreme > 1 million people, high = around 500,000 people, and medium is > 5000 people potentially displaced (Source: IPCC 2007a, based on Ericson et al., 2005).

the Earth System Science Partnership
http://www.start.org/Program/AIACC.html

Deltas on the Move, a project sponsored by the Dutch National Research Programmes
http://ivm10.ivm.vu.nl/deltas

Physical science of climate change and coastal impact assessments of the Intergovernmental Panel on Climate Change (IPCC Fourth Assessment Report)
http://www.ipcc-wg2.org/

Delta website of the U.S. Geological Survey, National Wetlands Research Center
http://deltas.usgs.gov/

Sea level rise impact analyses of the Tyndall Center for Climate Change Research
http://www.tyndall.ac.uk/
http://www.tyndall.ac.uk/publications/working_papers/twp96.pdf

References


