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Distribution and Dynamics of Mangrove Forests of the World (1990–2005)

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Background

Mangroves forests are distributed circum-tropically in the inter-tidal region between sea and land in the tropical and sub-tropical regions (approximately between ±300 latitude) of the world (Figure 1). The current estimate of mangrove forests of the world ranges from 110,000 to 240,000 km2, and much of what remains is in degraded condition (UNEP, 2004). About 35% of mangroves have been lost over the last two decades alone (MA, 2005), and the forests have been declining at a faster rate than inland tropical forests and coral reefs (Aizpuru, 2000). Predictions suggest that 30-40% of coastal wetlands (IPCC, 2007) and 100% of mangrove forests (Duke et al. 2007) could be lost in the next 100 years if the present rate of loss continues. Earlier global land cover initiatives failed to map mangrove areas with sufficient details because coarse spatial resolution satellite data was used (Giri et al. 2007).

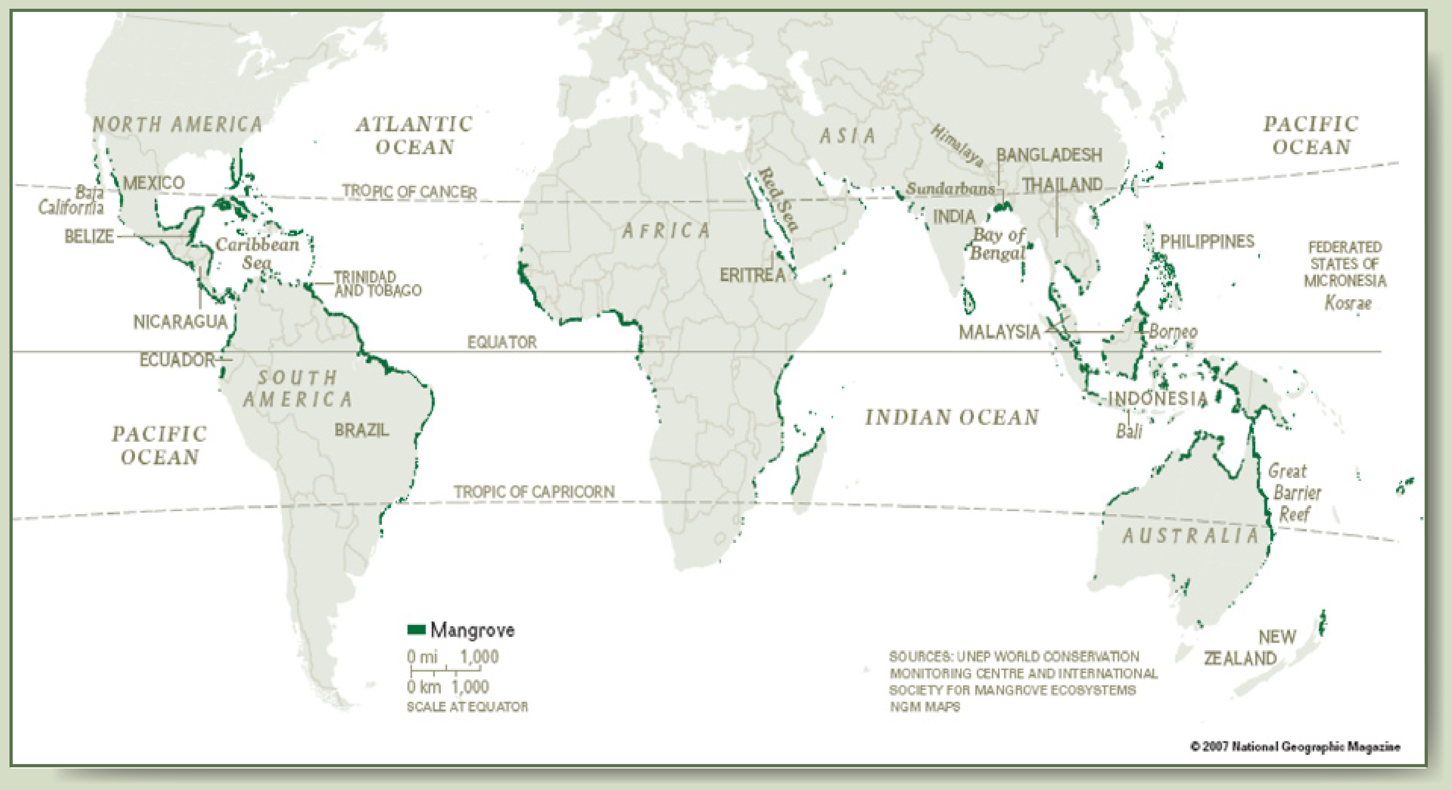

Figure 1. Approximate location of mangrove forests of the world (mangrove areas in green).

Research Objectives

Our research is organized around three scientific research questions:

1. How can we use historical and current satellite data, state-of-the-art image processing, and geospatial modeling tools and methods to better characterize mangrove forest attributes and dynamics?
2. What is the present status of mangrove forests of the world and how have the extent and characteristics of mangrove forests changed in the last 15 years?
3. What are the causes and environmental and socioeconomic consequences of mangrove deforestation?

Methods

We interpreted time-series Global Land Survey (GLS) Landsat data using a hybrid supervised and unsupervised classification approach. Landsat data were geometrically corrected to an accuracy of plus-or-minus one-half pixel, an accuracy necessary for change analysis. Each image was normalized for solar irradiance by converting digital number values to the top-of-the atmosphere reflectance. We used a post-classification change detection approach. Results were validated with the help of local experts and/or high resolution satellite data such as QuickBird and IKONOS. Detailed classification approach is shown in Figure 2.

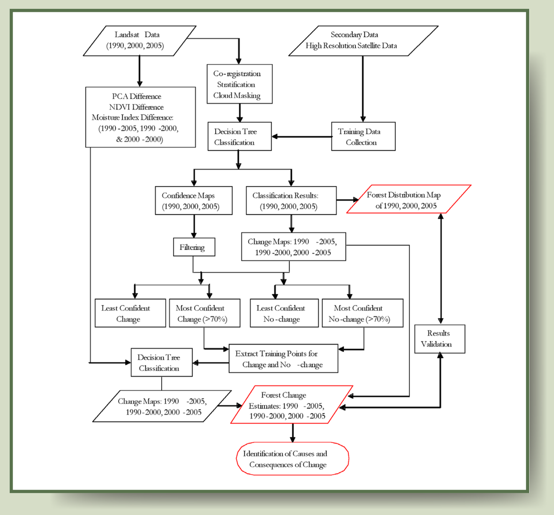

Figure 2. An overview of the proposed methodology (main outputs are highlighted in red).

Results and Conclusions

We present results obtained from the tsunami-impacted regions of Asia, Sunderbans, and Madagascar.

Mangrove Forest Distributions and Dynamics (1975–2005) in the Tsunami-Impacted Regions of Asia (Giri and others, 2008)

Our results in the tsunami-impacted regions of Asia suggested that the region lost 12% mangrove forests from 1975 to 2005, to a present extent of ~1,670,000 ha (Figure 3). Deforestation rates and causes varied both spatially and temporally. The annual rate of deforestation was highest in Myanmar (~1%) and lowest in Sri Lanka (0.1%). In contrast, mangrove forests in India and Bangladesh remained unchanged or gained slightly. In terms of temporal variation, net deforestation peaked at 137,000 ha during 1990-2000, increasing from 97,000 ha during 1975-1990, and declining to 14,000 ha during 2000-2005. The major causes of deforestation were agricultural expansion (81%), aquaculture (12%), and urban development (2%) (Figure 4, 5, & 6). The results of our study can be used to better understand the role of mangrove forests in saving lives and property from natural disasters, and to identify possible areas for conservation, restoration, and rehabilitation (Figure 6).

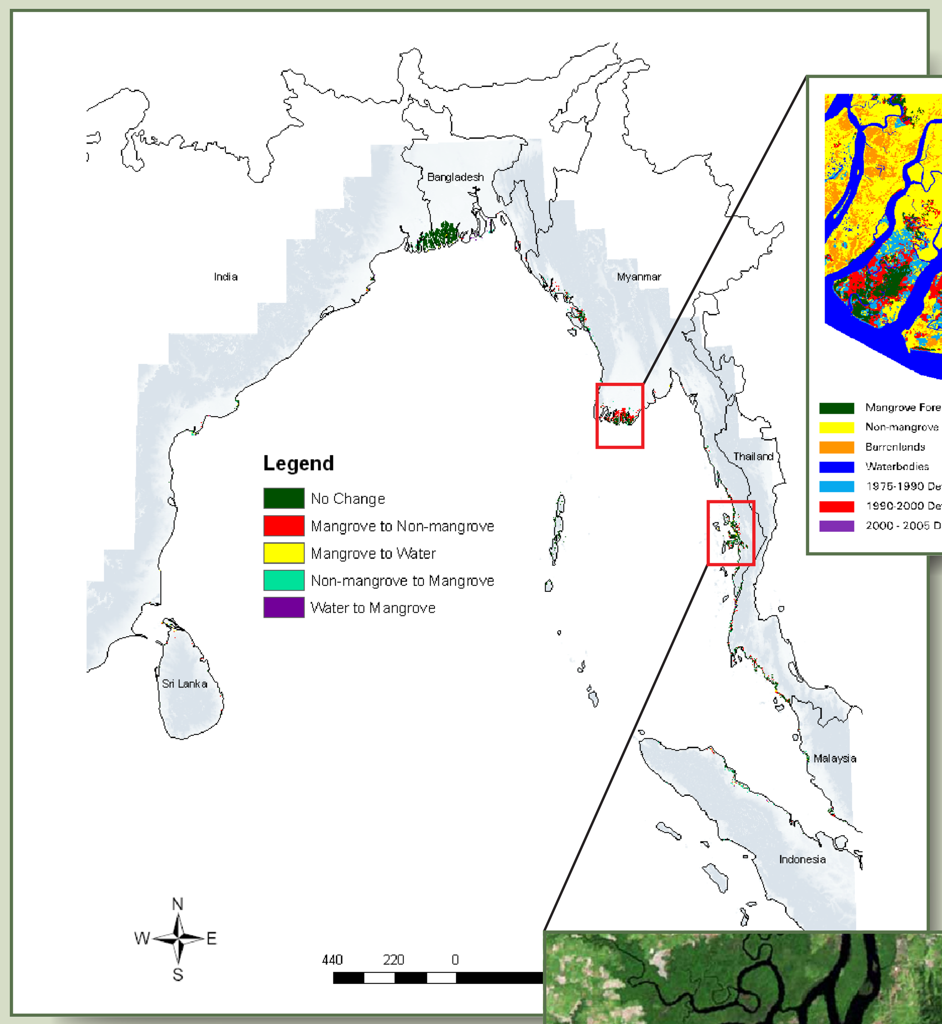

Figure 3. Mangrove forest distribution map of the tsunami-impacted regions of Asia for the year 2005.

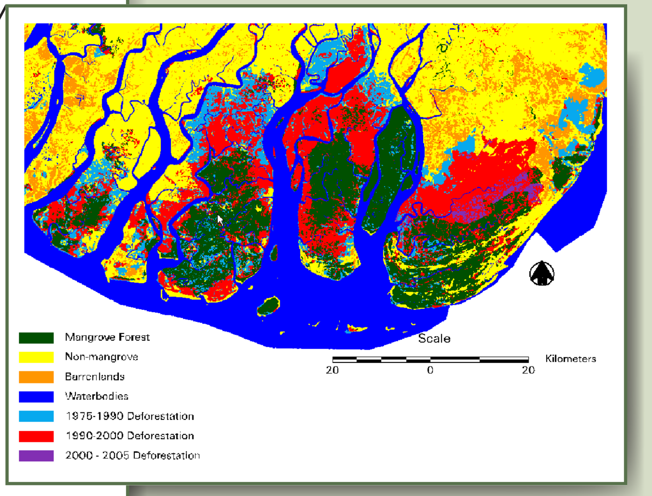

Figure 4. Mangrove forest deforestation from 1975-1990, 1999-2000, and 2000-2005.

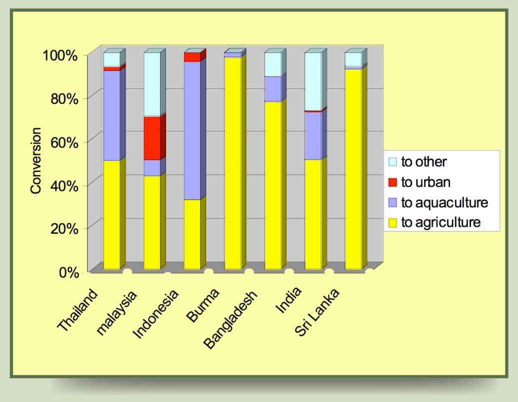

Figure 5. Major causes of mangrove deforestation in the tsunami-impacted regions of Asia.

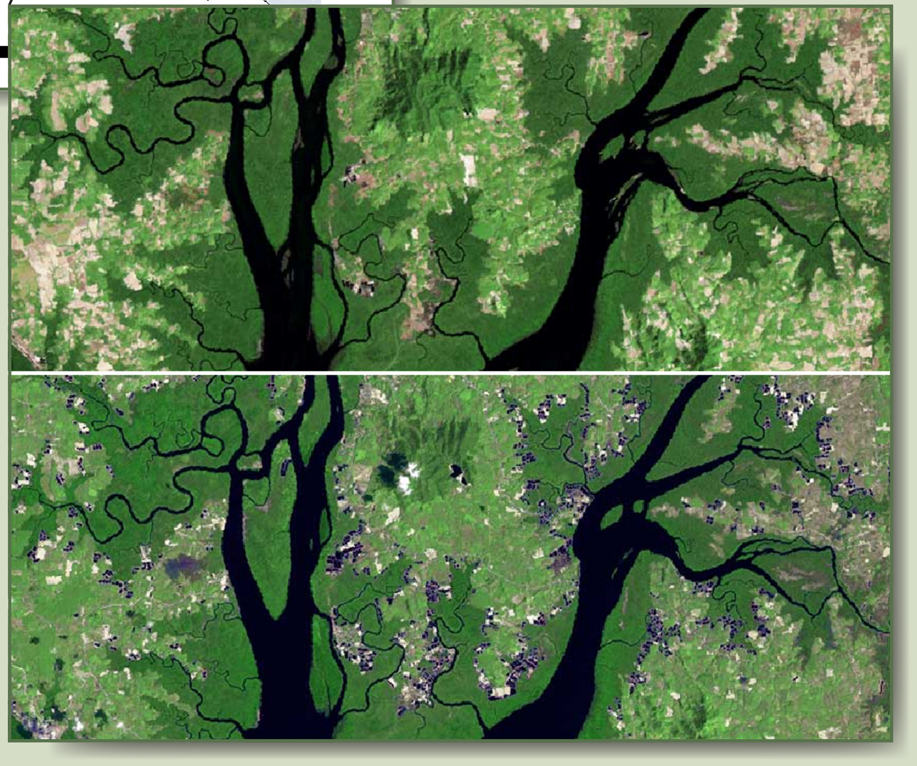

Figure 6. Growth of shrimp ponds in and around mangrove forests in southern Thailand from 1990 to 2000.

Monitoring Mangrove Forest Dynamics of the Sunderbans in Bangladesh and India using Multitemporal Satellite Data from 1973 to 2000 (Giri and others, 2007)

Our spatio-temporal analysis shows that despite having the highest population density in the world in its periphery, areal extent of the mangrove forest of the Sunderbans has not changed significantly in the last ~25 years (Figure 7). However, the forest is constantly changing due to erosion, aggradation, deforestatoin and mangrove rehabilitation programs (Figure 8). The net forest area was increased by 1.4% from the 1970s to 1990 and was decreased by 2.5% from 1990 to 2000. This is an excellent example of the co-existence of humans with terrestrial and aquatic plant and animal life.

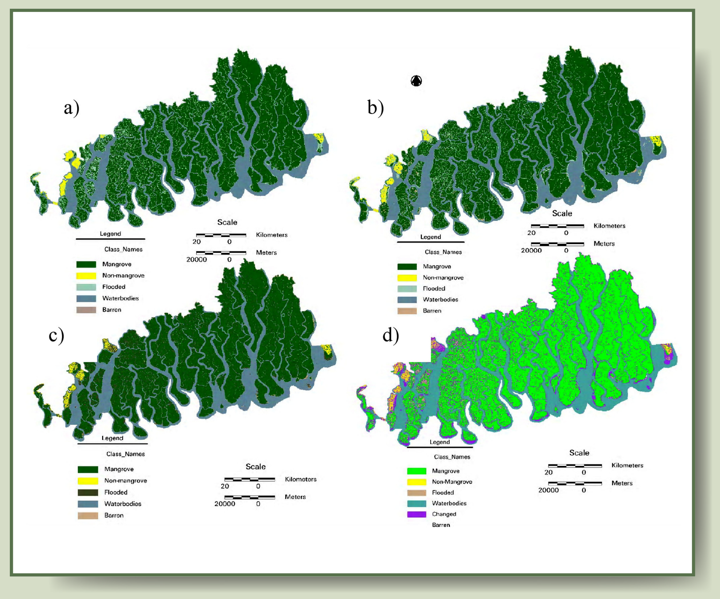

Figure 7. Mangrove forest cover distribution map of the Sunderbans in the 1970s (a), 1990s (b), and 2000s (c); and a change map from the 1970s–2000s (d).

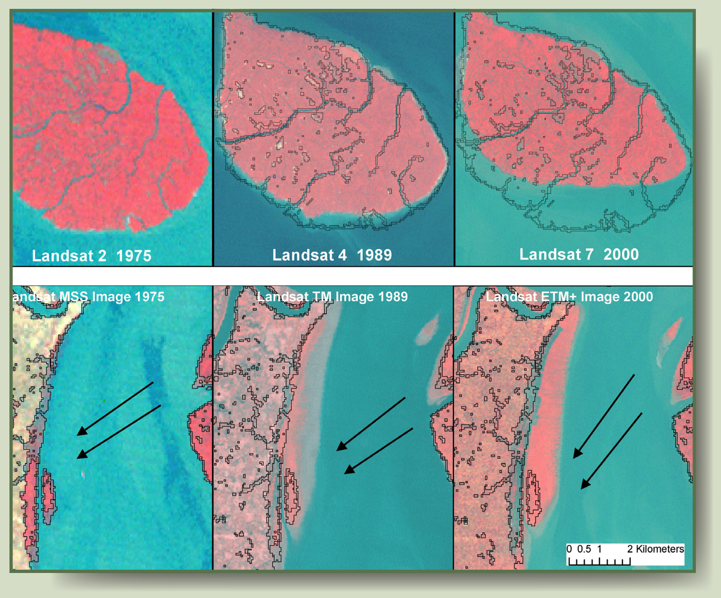

Figure 8. Mangrove forest cover changes caused by erosion (top) and aggradation (bottom) in the Sunderbans.

Mangrove Forest Distributions and Dynamics in Madagascar (1975–2005) (Giri and Muhlhausen, 2008)

Mangrove forests of Madagascar are declining, albeit at a much slower rate than the global average. Our results showed that Madagascar lost 7% of mangrove forests from 1975 to 2005 (Figure 9), to a present extent of ~2,797 km2. Deforestation rates and causes varied both spatially and temporally. The forests increased by 5.6% (212 km2) from 1975 to 1990, decreased by 14.3% (455 km2) from 1990 to 2000, and decreased by 2.6% (73 km2) from 2000 to 2005. Similarly, major changes occurred in Bombekota Bay, Mahajamba Bay, the coast of Ambanja, the Tsiribihina River, and Cap St Vincent. The main factors responsible for mangrove deforestation include conversion to agriculture (35%), logging (16%), conversion to aquaculture (3%), and urban development (1%). We also compared our results with earlier estimates (Figure 10).

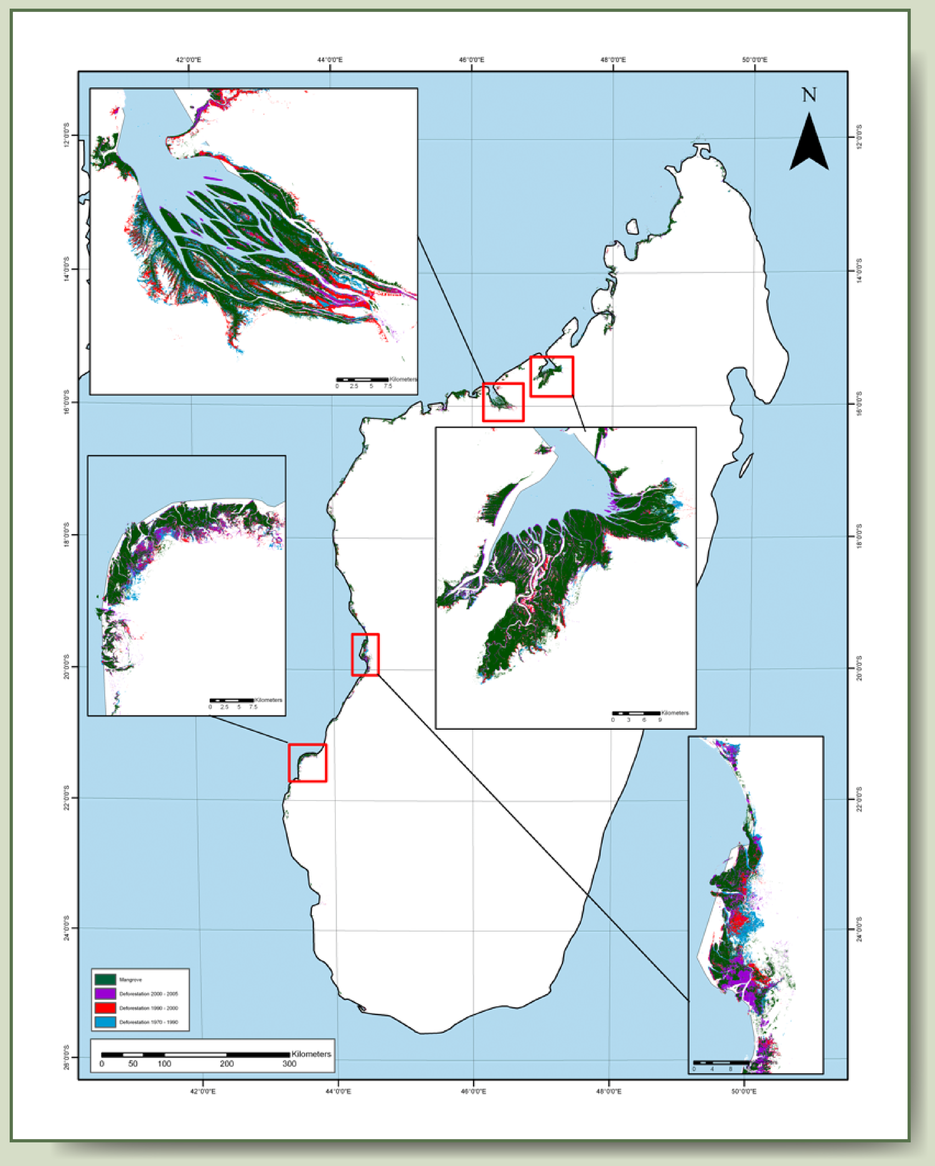

Figure 9. Mangrove forest cover change map of Madagascar (1975-2005).

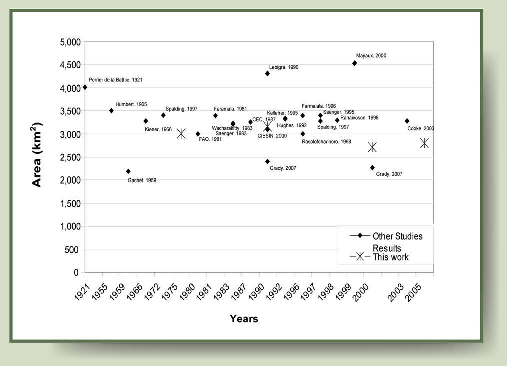

Figure 10. Comparison of aerial estimates of Madagascar obtained from this study and published statistics.

Outreach

Outreach activities were performed to promote research results form this study (Figures. 11–13).

Figure 11. Data and results from our study appeared in "Image of the day" in Earth Observatory (http://www.redorbit.com/images/images-of-the-day/img/13152/matang_mangrove_forest/index.html).

Figure 12. Research highlighted in the "Bio Bulletin" of the American Museum of Natural History and 22 affiliate museums in the United States (http://www.amnh.org/sciencebulletins/).

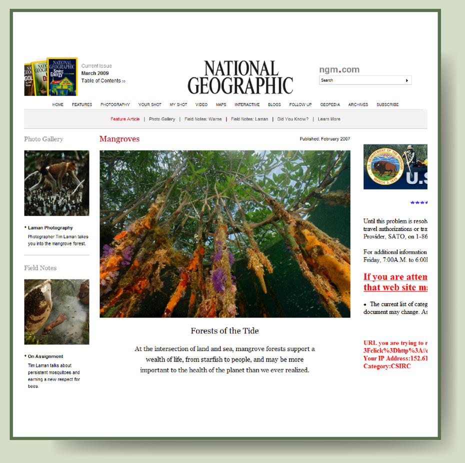

Figure 13. Our work appeared in an article entitled "Forests of the Tide" in the February 2007 issue of National Geographic (http://ngm.nationalgeographic.com/2007/02/mangroves/warne-text).

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References

Aizpuru, M., Achard, F., and Blasco, F., 2000, Global assessment of Cover Change of the Mangrove forest using Satellite imagery at medium to high resolution, in EEC research project n° 15017-1999-05 FIED ISP FR, Joint Research Center, Ispra.
Duke N.C., Meynecke, J.-O., Dittmann, S., Ellison, A.M., Anger, A., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I., and Dahdouh Guebas, F., 2007, A World Without Mangroves? Science, v. 317, no. 5834, p. 41–42.
Giri, C.P., and Muhlhausen, J., 2008, Mangrove forest distributions and dynamics in Madagascar (1975-2005): Sensors, v. 8, no. 4, p. 2104–2117. (Also available online at http://www.mdpiorg/sensors/paperss8042104.pdf.)
Giri, C.P., Zhu, Z., Tieszen, L.L., Singh, A., Gillette, S., and Kelmelis, J.A., 2008, Mangrove forest distributions and dynamics (1975-2005) of the tsunami-affected region of Asia: Journal of Biogeography, v. 35, no. 3, p. 519–528.
Giri, C.P., Pengra, B.W., Zhu, Z., Singh, A., and Tieszen, L.L., 2007, Monitoring mangrove forest dynamics of the Sunderbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000: Estuarine, Coastal and Shelf Science, v. 73, no. 1–2, p. 91–100.
IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds Cambridge University Press, Cambridge, United Kingdom, 1000 pp.
MA (Millennium Ecosystem Assessment), 2005, Coastal Systems, in Ecosystems and Human Well-Being: Current State and Trends: Washington, DC, Island Press, p. 513–549. (Also available online at http://www.millenniumassessment.org/documents/document.288.aspx.pdf.) (Accessed January 28, 2008.)
Spalding, M.D., Blasco, F., and Field, C.D., eds., 1997, World Mangrove Atlas: Okinawa, Japan: The International Society for Mangrove Ecosystems, 178 p.
Spiers, A.G., 1999, Review of international/continental wetland resources, in Finlayson, C.M. and Spiers, A.G., eds., Global Review of Wetland Resources and Priorities for Wetland Inventory: Wetlands International Publication 13. Canberra: Wetlands International, and Supervising Scientist, p. 63–104.
UNEP (United Nations Environment Programme), 2004, Global Environment Outlook Yearbook 2004. Nairobi, Kenya: UNEP, 96 p. (Also available online at http://www.unep.org/geo/yearbookyb2004/007.htm.)

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