# Introducing CGMFC-21 (Continuous Global Mangrove Forest Cover for the 21st Century)

Stuart E. Hamilton

*Assistant Professor, Salisbury University, Salisbury, MD 21801, USA
(e-mail: sehamilton@salisbury.edu)*

## Background

Research into mangrove forests has been inhibited by the lack of a suitable global high-resolution database. Current global mangrove products lack surveys conducted at regularly spaced intervals, surveys conducted in a systematic manner across all nations, or surveys at high enough spatiotemporal resolution. For example, the current premier global mangrove database, produced by Giri *et al.* (2011), provides global mangrove cover at the required 30 m spatial resolution but has only one temporal domain and provides only categorical data at the pixel level. That is, it is only for the year 2000 and each one arc-second pixel is coded either mangrove presence or absence and not the actual level mangrove cover. Localized versions of the required databases exist such as in Ecuador (Hamilton & Lovette, 2015) or the National Land Cover Database in the USA when mangroves are extracted, but these data are not global and compiled using differing methods. The suite of the FAO mangrove databases (FAO, 2007) are typically provided at the national level and then aggregated to the global scale but no methodology exists in the majority of these datasets and they are often not spatial beyond the national level. The mangrove atlases (Spalding *et al.*, 1997, 2010) provide an additional source of mangrove cover information but again these are not compiled into high-resolution spatio-temporal databases and often use the FAO data as their core input dataset.

The global forest cover (GFC) database by Hansen *et al.* (2013) allows for the possibility of mapping mangrove forests at the global scale, annually from 2000 to present, continuing into the future as updates to the database become available, at 30 m resolution, with a systemic global methodology, and with continuous data at the pixel level as opposed to earlier datasets that are typically categorical. Unfortunately, the GFC database does not delineate forest type so synthesis with other datasets is required to extract mangrove forests. Many potential datasets exist to achieve this including the mangrove biome data of terrestrial ecosystems of the world (TEOW) as delineated by Olson *et al.* (2001) or the year 2000 mangrove area of mangrove forests of the world (MFW) as delineated by Giri *et al*. (2011). If appropriately synthesized, MFW, GFC and TEOW have the potential to create a mangrove database that meets all of the specifications listed above.

## Introducing CGMFC-21

CGMFC-21 "provides a standardized spatial dataset that monitors mangrove deforestation globally at high spatio-temporal resolutions. These data can be used to drive the mangrove research agenda particularly as it pertains to improved monitoring of mangrove carbon stocks and the establishment of baseline local mangrove forest inventories required for payment for ecosystem service initiatives" (Hamilton & Casey 2016). CGMFC-21, released to the public under a Creative Commons Attribution 4.0 International License in 2016, provides global mangrove cover at 30 m resolution for the years 2000 to 2012 (Hamilton and Casey 2016). Data are provided for the entire global mangrove area as defined by Olson *et al.* (2001) and for the entire year 2000 global mangrove area as defined by Giri *et al.* (2011). In addition to being global and for a 13-year period, CGMFC-21 provides an actual estimate of the mangrove cover area for each 30 m pixel. That is, each pixel contains a measure of mangrove area and not merely presence or absence. We demonstrate the applicability of CGMFC-21 in four figures below.
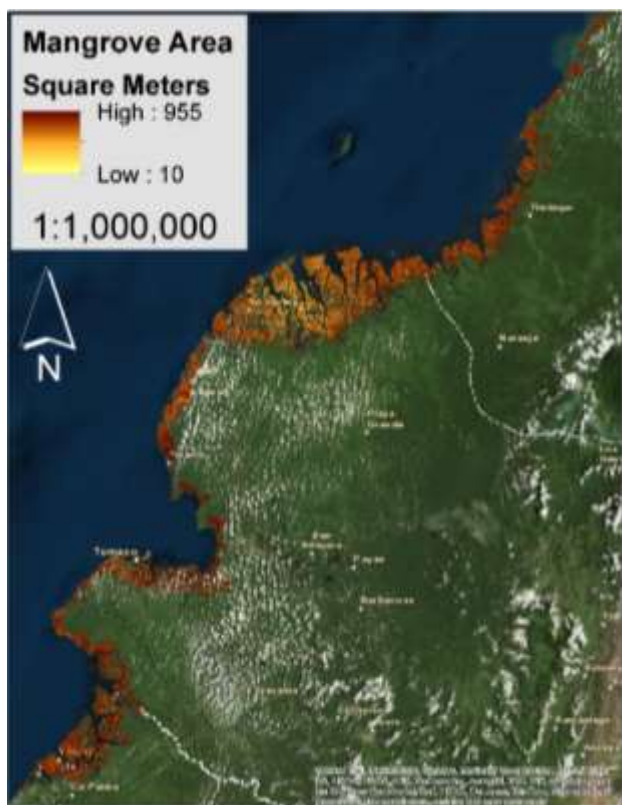
**Figure 1** represents year 2000 mangrove canopy cover along the border of Colombia and Ecuador in South America. The southern part of the region is inside Cayapas-Mataje mangrove ecological reserve and the northern portion is within the Sanquianga Natural National Park. The figure demonstrates the high granularity of CGMFC-21 along the coastal fringe mangroves of South America. This region likely contains the tallest mangroves globally (Hamilton & Lovette, 2015) as well as the historic mangrove ecosystem described by West (1956). CGMFC-21 finds that forest cover in this region is essentially stable since 2000 within the mangrove forests and the wider mangrove biome.



**Figure 2** represents year 2004 mangrove forest canopy cover in northern Madagascar along the Loza River. The denser mangrove canopy cover exists in the interior of the southern portion of the estuary. This figure demonstrates the capability of CGMFC-21 to capture riverine mangrove forest, often residing far up-river or in the interior of the estuary. Such mangrove forests as these on the Loza River have likely never been recorded as a full continuous pixel measure until the release of CGMFC-21. This demonstrates the capability of the dataset to monitor mangroves in isolated regions in which field survey or reliable official measures of mangrove cover are difficult to conduct or obtain.
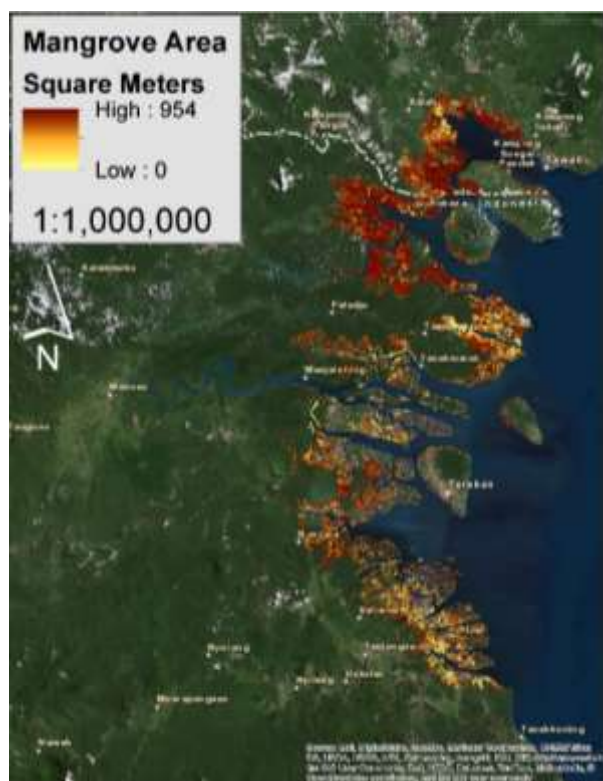
**Figure 3** represents the 2008 mangrove forest canopy cover in northeastern Kalimantan, Indonesia and in southeastern Sabah, Malaysia. Note the sparse mangrove cover near the aquaculture sites in-and-around Tarakan and to the west and southwest of Tarakan on the mainland. CGMFC-21 identifies the eastern coast of Kalimantan as one the remaining regional hotspots of mangrove deforestation since 2000. Containing a substantial portion of the world's mangrove forest, this portion of Kalimantan has lost substantial mangrove forest, most likely due to aquaculture expansion, since the year 2000. Again, CGMFC-21 demonstrates its ability to depict high resolution mangrove loss, and in addition, mangrove degradation at a high resolution over large remote geographic areas.
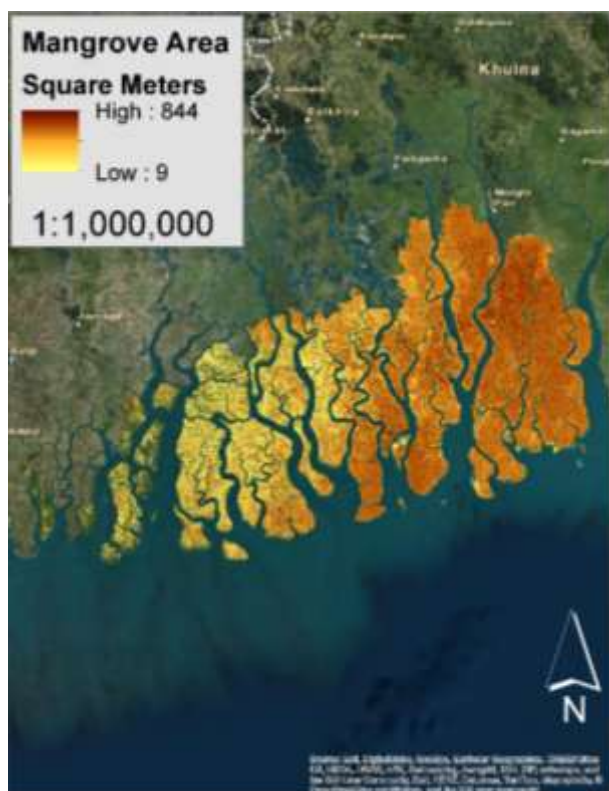


**Figure 4** represents the mangrove forest canopy cover in-and-around the Sundarbans in the year 2012. This famous image is produced in many publications but for the first time we can depict the decreasing mangrove canopy cover moving from Bangladesh into India. This change in mangrove pixel area cannot be reconciled in databases that only contain mangrove presence and absence data. CGMFC-21 confirms that the Sundarbans is the largest region of continuous mangrove cover globally but reveals that the mangrove forest in Bangladesh likely contains far more biomass per pixel than the equivalent mangrove within the Indian portion of the Sundarbans.

**Data Availability**

The full paper containing mangrove findings from 2000 to 2014 is available as an open access article at Global Ecology and Biogeography at http://onlinelibrary.wiley.com/doi/10.1111/geb.12449/abstract.

The full GIS data are available in two GIS databases and one table.

1.  The first database tracks mangrove loss globally at 30 m resolution from 2000 to 2012 for all areas with mangrove cover in 2000 and can be downloaded in GeoTIff or ESRI file geodatabase from http://bit.ly/1lMJ9zj. This is the database referred to as MFW in Hamilton & Casey (2016) and is available under a CC BY 4.0 license.

2.  The second database tracks mangrove change globally at 30 m resolution from 2000 to 2012 for all areas within the mangrove biome is available for download in GeoTIff or ESRI file geodatabase at http://bit.ly/1lMJ9zj. This is the database referred to as TEOW in Hamilton & Casey (2016) and is available under a CC BY 4.0 license.

3.  Table S1 contains full country information on global mangrove cover from 2000 to 2014 and mangrove cover change and rates of change in each county for 2000 to 2014. The table can be downloaded as a supplement from http://onlinelibrary.wiley.com/doi/10.1111/geb.12449/suppinfo under a CC BY 4.0 license.

For the full citation for all use of the above databases:

Hamilton, S.E. & Casey, D., 2016. Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecology and Biogeography* doi: 10.1111/geb.12449.

It is anticipated that these data will be updated on approximately 5-year cycles dependent on funding availability and regular updates continuing to GFC. The mangrove community is encouraged to utilize these data and provide update to information to the CGMFC-21 authors.

**References**

FAO, 2007. *The World's Mangroves 1980-2005*. FAO Forestry Paper 153, Food and Agriculture Organization of the United Nations, Rome.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., *et al*., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography* 20(1): 154-159.

Hamilton, S.E. & Casey, D., 2016. Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecology and Biogeography* doi: 10.1111/geb.12449.

Hamilton, S. E. & Lovette, J., 2015. Ecuador's mangrove forest carbon stocks: a spatiotemporal analysis of living carbon holdings and their depletion since the advent of commercial aquaculture. *PLoS ONE* 10(3): e0118880.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., *et al*., 2013. High-resolution global maps of 21st-century forest cover change. *Science* 342: 850-853.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V., Underwood, E.C., *et al*., 2001. Terrestrial ecoregions of the world: A new map of life on earth a new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience* 51(11): 933-938.

Spalding, M., Blasco, F. & Field, C., 1997. *World Mangrove Atlas*. International Society for Mangrove Ecosystems, Okinawa, Japan.

Spalding, M., Kainuma, M. & Collins, L., 2010. *World Atlas of Mangroves*. London, UK: Earthscan.

West, R.C., 1956. Mangrove swamps of the Pacific coast of Colombia. *Annals of the Association of American Geographers* 46(1): 98-121.