Institution: Aberystwyth University

Unit of Assessment: 14: Geography and Environmental Studies

Title of case study: Global Mangrove Watch: Informing Public Policy for the Conservation and Protection of Mangrove Forests

Period when the underpinning research was undertaken: 2011-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Pete Bunting	Senior Lecturer; Reader	1 September 2012- present
Professor Richard Lucas	Personal Chair; Sêr Cymru Chair	1 May 2008- 31 December 2013; 1 January 2018- present

Period when the claimed impact occurred: 2015-2020

Is this case study continued from a case study submitted in 2014? Y/**N**

1. Summary of the impact (indicative maximum 100 words)

Mangroves are a critical ecosystem, under significant pressure, providing a host of ecosystem services with an estimated value of US$25 trillion annually. Aberystwyth University (AU)'s Earth Observation and Ecosystem Dynamics (EOED) Research Group led the scientific development of and technical implementation for mapping and monitoring mangrove forests globally through the Global Mangrove Watch (GMW). These GMW datasets form the reference mangrove extent for the UN Environment Programme (UNEP), tracking progress towards Sustainable Development Goal (SDG) 6.6.1, which aims to halt degradation and destruction of water-related ecosystems. The GMW mangrove extent maps have also been used by NGOs and governments to monitor mangrove extent, in turn informing mangrove restoration and protection.

2. Underpinning research (indicative maximum 500 words)

Since 2014, AU's Earth Observation and Ecosystem Dynamics (EOED) Research Group has focused on quantifying, understanding, and addressing local to global environmental change through Earth Observation (EO). This research has led to the Global Mangrove Watch (GMW) datasets, which focus on providing standardised and consistent global mapping of mangrove extent and change for multiple epochs to address a major global data and knowledge gap.

Mangroves are a highly dynamic biome where extensive changes occur over short temporal baselines [3.2; 3.5] due to anthropogenic disturbance (e.g., aquaculture ponds); natural events (e.g., storms) and processes (e.g., erosion and deposition); and climate change (e.g., dieback). Mangroves are critical for local communities across their range, as they provide essential ecosystem services such as coastal protection, harvestable wood, tourism, fisheries, and carbon sequestration. As an illustration, it has been estimated that there are 4,100,000 fishermen directly dependent on mangroves, predominately within developing countries. However, despite being needed urgently, maps depicting global changes in extent were not available.

The GMW was initially established in 2011 by Richard Lucas (AU) and Ake Rosenqvist (soloEO) as part of the Japan Aerospace Exploration Agency (JAXA) Kyoto and Carbon (K&C) Initiative to demonstrate the application of JAXA's L-band radar (~25 cm wavelength) in climate science, conservation, and international conventions. In response, AU academics, led by Pete Bunting [3.8; 3.9; 3.10], developed the techniques and software to produce a new global baseline of

mangrove extent for 2010 [3.3]. The challenge was primarily focused on separating mangroves from other land covers given the large variability in the contexts where mangroves are found globally, particularly following anthropogenic disturbance, but also to efficiently scaling data processing to handle the ~20 Tb of input data. The GMW has predominately relied on Synthetic Aperture Radar (SAR) data from JAXA. SAR allows cloud-free monitoring but has less discrimination of mangroves from other vegetated land covers than optical (visible to shortwave infrared wavelengths) data. Therefore, AU also generated a 2010 composite of 15,000 optical Landsat images to enhance the global mangrove baseline mapping.

To support the generation of mangrove change layers from the 2010 baseline, AU subsequently developed a new map-to-image change approach [3.4], which allowed processing at large spatial scales and automated processing chains. Using this approach, mangrove changes from the 2010 baseline were identified using the JAXA L-band SAR data, as these were also demonstrated as ideal for detecting changes in mangrove extent; lost, gained or stable [3.4, 3.5, 3.6]. For 1996, data from the Japanese Earth Resources Satellite (JERS-1) was used, mapping a mangrove extent of 142,005 km^2 ± 1,280. For between 2007 to 2009 and 2015 to 2018, data from JAXA's ALOS PALSAR and ALOS-2 PALSAR-2 were used respectively, with 135,927 km^2 ± 1,276 of mangrove extent mapped for 2016. From 1996 to 2016, globally, mangrove forests were lost at a rate of -0.22% per year (Figure 1). However, work at AU has also shown that since 2010, annual rates of mangrove forest loss had reduced from -0.23% between 1996 and 2010 to -0.09% between 2010 and 2016.

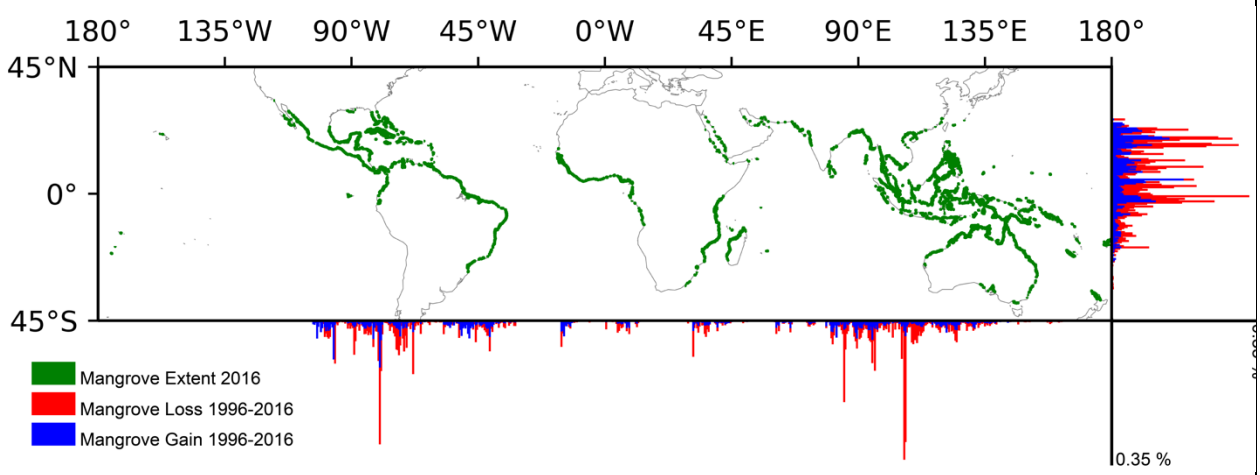

Figure 1. Global distribution of mangrove gains and losses from the GMW datasets, 1996 to 2016.

In addition to the GMW historical annual change maps of mangrove forest extent, the importance of identifying mangrove loss in near-real-time has also been highlighted [3.1]. To realise near-real-time GMW alerts, AU developed a new software system [3.7; 3.9; 3.11] that automates the download and analysis of the satellite imagery. Before this development, no software was freely available in the public domain to support such automated analysis. The change alerts are generated using Landsat 8 and Sentinel-2 optical imagery through Normalised Difference Vegetation Index (NDVI) thresholding, with a scoring system used to confirm changes across multiple observations. The alerts have been generated for the African continent since 1 January 2020 and are released monthly via the Global Mangrove Watch web portal, developed by Wetlands International and released to the general public on 27 July 2020. The research continues with on-going funding provided through donors to Wetlands International and The Nature Conservancy and will be expanding the geographic coverage of the monthly change alerts and further improving spatial detail and the generation of annual maps for other years.

3. References to the research (indicative maximum of six references)

3.1 Worthington, T. A., Andradi-Brown, D., Bhargava, R., Buelow, C., Bunting, P., Duncan, C., Fatoyinbo, T., Friess, D. A., Goldberg, L., Hilarides, L., Lagomasino, D., Landis, E., Longley-

Wood, K., Lovelock, C. E., Murray, N. J., Narayan, S., Rosenqvist, A., Sievers, M., Simard, M., Thomas, N., van Eijk, P., Zganjar, C., and Spalding, M. (2020). **Harnessing Big Data to Support the Conservation and Rehabilitation of Mangrove Forests Globally**, *One Earth* (2): 429-443. DOI: 10.1016/j.oneear.2020.04.018

3.2 Lymburner, L., Bunting, P., Lucas, R. M., Scarth, P., Alam, I., Phillips, C., Ticehurst, C., Held, A. (2020). **Mapping the multi-decadal mangrove dynamics of the Australian coastline,** *Remote Sensing of Environment,* 238. DOI: 10.1016/j.rse.2019.05.004

3.3 Bunting, P., Rosenqvist, A., Lucas, R. M., Rebelo, L., Hilarides, L., Thomas, N., Hardy, A., Itoh, T., Shimada, M., Finlayson, C. (2018). **The Global Mangrove Watch – A New 2010 Global Baseline of Mangrove Extent**, *Remote Sensing*, 10(10): 1669. DOI:10.3390/rs10101669

3.4 Thomas, N., Bunting, P., Lucas, R. M., Hardy, A., Rosenqvist, A., Fatoyinbo, T. (2018). **Mapping Mangrove Extent and Change: A Globally Applicable Approach,** *Remote Sensing*, 10(9): 1466. DOI:10.3390/rs10091466

3.5 Thomas, N., Lucas, R. M., Bunting, P., Hardy, A., Rosenqvist, A., Simard, M. (2017). **Distribution and drivers of global mangrove forest change, 1996-2010,** *PLOS ONE,*12(6). DOI: 10.1371/journal.pone.0179302

3.6 Thomas, N., Lucas, R. M., Itoh, T., Simard, M., Fatoyinbo, T., Bunting, P., Rosenqvist, A. (2015). **An approach to monitoring mangrove extents through time-series comparison of JERS-1 SAR and ALOS PALSAR data.** *Wetland Ecology Management*, 23: 3-17. DOI: 10.1007/s11273-014-9370-6

3.7 Bunting, P. (2020). **Earth Observation Data Downloader (EODataDown)**. Available: https://github.com/remotesensinginfo/eodatadown

Associated Funding

3.8 Monitoring Mangrove Extent & Services (MOMENTS): What is controlling Tipping Points? (2017-2020): Newton Fund, administered by NERC: Award: GBP455,034. PI: Pete Bunting
3.9 Mangrove Watch Africa. (2017-2019): Wetlands International and DOB Ecology: Award: GBP212,500. PI: Pete Bunting
3.10 Global Mangrove Watch Project: (2019): Wetlands International and Oak Foundation. Award: GBP15,000. PI: Pete Bunting
3.11 Mangrove Watch Africa II: (2020): Wetlands International and DOB Ecology: Award GBP49,512. PI: Richard Lucas

4. Details of the impact (indicative maximum 750 words)

The Global Mangrove Watch (GMW) has provided global 25 m resolution maps of mangrove extent, making it possible to identify changes that are significant to local communities, but doing this with global coverage and impact. Maps for three epochs, mid-1990s, 2007-2010 and 2015-2016 have been calculated, along with monthly change alerts for the Africa continent, from 1 January 2020. The GMW maps were released on 21 October 2018 at the Ramsar Congress of Parties (COP) and launched on the UN Open Data Viewer (ODV), from where they can be downloaded [5.1; 5.2], whilst also visualised on the Global Forest Watch (GFW) web portal; [5.3]. As of December 2020, the GMW data was the second most downloaded dataset on the ODV, with 7000 downloads [5.4]. 54% of which were by non-academic organisations, including governments, non-profits, and consultancies.

The GMW maps, showing changes in the extent of mangroves through time, have informed public policy and influenced decisions at many levels; internationally, through the UN SDGs [5.4], the actions of national governments, including Myanmar, Fiji, and Indonesia [5.4; 5.5], non-governmental organisations (NGOs) including the World Wildlife Fund (WWF) [5.4], Wetlands

International (WI) [5.6] and The Nature Conservancy (TNC) [5.7], and Industry, for example, through the Proteus Partnership [5.4].

The United Nations Environment Program (UNEP) adopted the GMW dataset as the historical mangrove extent baseline for reporting against SDG 6.6.1 [5.4; 5.6]. SDG 6.6.1 aims to halt the degradation and destruction of water-related ecosystems and aid the recovery of those already degraded. For this purpose, the UNEP launched the SDG661 app [5.8], which uses the 25 m GMW data, to represent mangrove ecosystems, providing nation states with accurate, high resolution, time-series data on aquatic ecosystems [5.4; 5.9].

GMW datasets have supported national governments and NGOs [5.4; 5.5; 5.6; 5.7; 5.9]. As highlighted by the UNEP Officer [5.4], many countries have limited capacity to process satellite sensor data. The GMW datasets, therefore, enabled all countries to benefit from such technologies, by providing up-to-date mapping information to inform their decision-making, which they would not have otherwise have had access to. For example, the GMW datasets were used in Fiji to assess mangrove extent changes, ecosystem services, and to sustainably manage mangrove forests [5.4; 5.5]. The GMW data also enabled the WWF to leverage '*innovative financing*' for a business-led waste management project in Fiji [5.5]. The Government of Myanmar integrated the GMW data within their Wetland Inventory, and Madagascar National Parks has used the GMW data to aid the sustainable management of their fisheries [5.4].

Within Indonesia, the country with the largest extent of mangroves, the GMW datasets were used by various government bodies, in conjunction with the WWF to inform policy including informing management of the Marine Protected Areas (MPAs) [5.5]. MPAs with large mangrove losses were subsequently prioritised for increased conservation effort. A Senior Marine Scientist at the WWF-US reports that the GMW data are '*invaluable*' enabling '*much more prominent attention*' to be bought to the plight of mangrove ecosystems [5.5].

> *The Global Mangrove Watch layers were invaluable in informing the mangrove component of this work - allowing national trends and provincial trends in mangrove extent and protection to be calculated. The availability of the Global Mangrove Watch data enabled mangroves to receive much more prominent attention in this work than would have been possible otherwise.* [5.5]

From 1 January 2020, AU provided, in collaboration with Wetlands International (WI), monthly alerts of mangrove loss across the African continent [5.6]. These alerts are being used by WI staff to monitor mangrove changes on the ground and to track their success in decreasing the spatial extent and frequency of mangrove loss [5.6]. For example, within Guinea-Bissau, the GMW monthly alerts identified mangrove loss areas that were previously unknown to WI staff. This enabled WI, through targeted field visits, to identify and understand the causes and introduce preventative actions [5.6]. AU also worked with WI to train their staff and local government agencies, in Tanzania in 2018 and Senegal in 2019, to use and validate the GMW datasets [5.6; Figure 2]. This included educating staff in the use of mobile apps and small drones to monitor and record changes in mangrove ecosystems (e.g., changes in mangrove forest extent, mudflat erosion, and canopy cover). WI field staff have subsequently used these technologies to increase the efficiency and effectiveness of their field surveys, for example when monitoring mangrove restoration sites [5.6].

Figure 2. Pete Bunting (AU) providing drone training in Senegal (July 2019)

On 27 July 2020, a new Global Mangrove Watch portal (https://www.globalmangrovewatch.org) [5.2; 5.6; 5.10] was launched by WI, TNC, AU and soloEO and made freely and openly available to all with support of the Global Mangrove Alliance [5.10]. The portal disseminates information on the state of mangroves globally, including the monthly alerts produced by AU. Mangrove extent data produced by AU is the key dataset within the portal to which all other products (e.g., above, and below ground biomass) are defined. Using the GMW data, TNC has produced a mangrove restoration potential map [5.7], which helps identify locations where mangrove restoration could be undertaken [5.6]. Being globally consistent and high spatial resolution, the GMW datasets have demonstrated local impact on individual catchments, regions and nations while also providing global impact defining the extent of mangrove ecosystems globally.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 UN Ocean Data Viewer web portal. Available at: https://data.unep-wcmc.org/datasets/45
5.2 Global Mangrove Watch online portal. Available at: www.globalmangrovewatch.org
5.3 Global Forest Watch, (GMW data 'Land Cover' > 'Mangrove Forests'). Available at: www.globalforestwatch.org/map
5.4 Email and testimonial letter, Associate Programme Officer, United Nations Environment Programme World Conservation Monitoring Centre, 18 January 2021.
5.5 Testimonial letter, Lead Scientist World Wildlife Fund (WWF) US, 13 January 2021.
5.6 Testimonial letter, Senior Technical Officer Wetlands International, 6 February 2021.
5.7 The Nature Conservancy (TNC) Report: Mangrove Restoration Potential. Available at: https://oceanwealth.org/wp-content/uploads/2019/02/MANGROVE-TNC-REPORT-FINAL.31.10.LOWSINGLES.pdf
5.8 UN SDG 6.6.1 online portal. Available at: www.sdg661.app
5.9 UN Report: SDG 6.6.1 Monitoring Methodology, March 2020. Available at: www.unwater.org/publications/step-step-methodology-monitoring-ecosystems-6-6-1/
5.10 Global Mangrove Alliance. Available at: www.mangrovealliance.org/global-mangrove-watch/