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Mangrove Deforestation Hotspot Analysis - S Asia, SE Asia and Asia-Pacific

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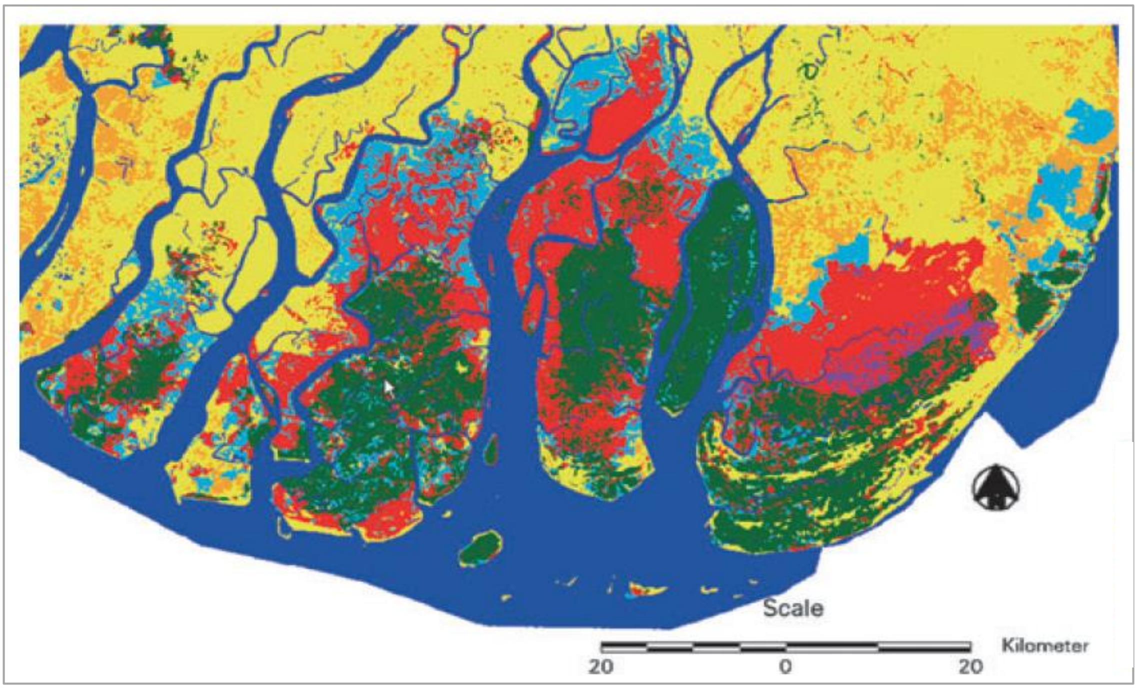

Figure 1: Spatial distribution of mangrove deforestation in Irrawaddy Delta, Myanmar during 1975–90 (blue), 1990–2000 (red) and 2000–05 (purple), and remaining mangrove shown in green (Giri *et al.*, 2008).

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1. Introduction

Mangroves are distributed in >120 countries throughout the world (FAO, 2005). These biodiverse intertidal ecosystems provide a diverse range of goods and services critical to coastal livelihoods (Giri *et al.*, 2008). A growing number of studies report that mangroves are equal to or more carbon-dense than terrestrial forests, meaning these ecosystems make important contributions to global climate change mitigation through CO_2 sequestration (Donato *et al.*, 2011). Despite their value, global mangrove distribution continues to decline due to anthropogenic activities (Webb *et al.*, 2014).

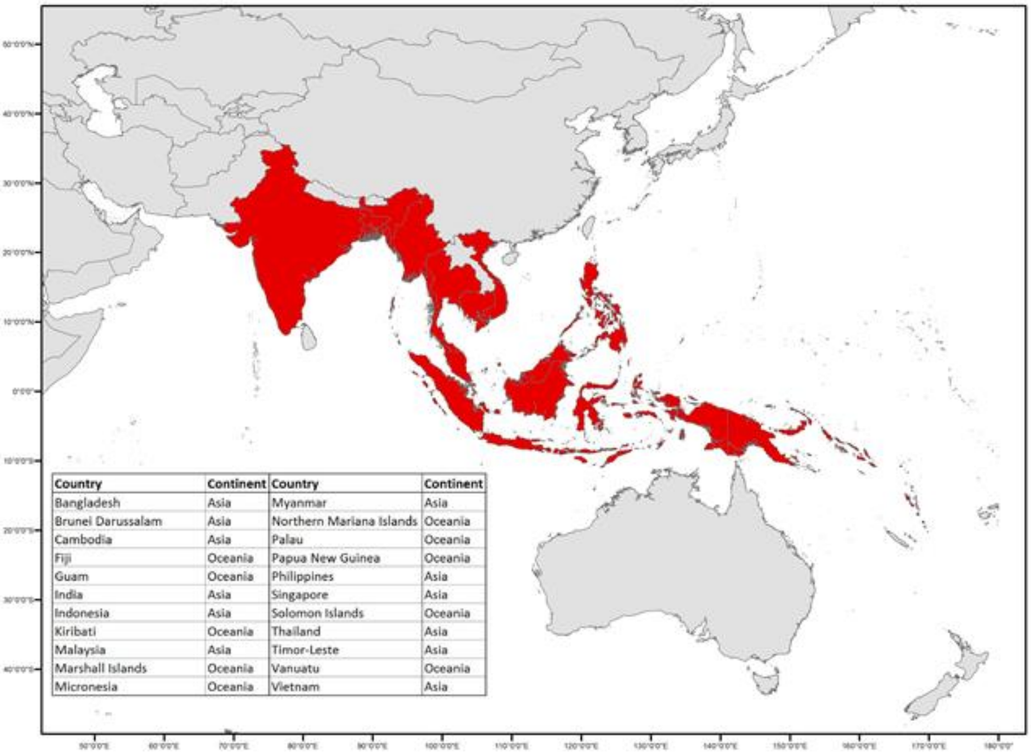
The Blue Ventures (BV) Blue Forests (BF) project aims to support and enhance coastal livelihoods and safeguard biodiversity through the restoration, conservation and managed-use of mangrove ecosystems. These efforts are further augmented through the Population Health and Environment (PHE) initiative, a holistic approach which integrates community health services with marine conservation and coastal livelihood initiatives. In addition to ongoing efforts in Madagascar, BV has secured funding to replicate BF and PHE work in two new countries. Indonesia has already been selected as one while the second is yet to be determined.

This report serves to 1) inventory, evaluate and compare geospatial datasets which provide information about the global, multi-national and/or national distribution and dynamics of mangrove ecosystems, and 2) identify a short-list of “hotspots” for mangrove loss. Deforestation, used as a proxy for conservation and restoration potential, will help the selection of a third country from this short-list wherein BV’s BF and PHE initiatives can be replicated. The focus of this report is on three sub-regions: **S Asia**, **SE Asia** and **Asia-Pacific**, collectively referred to as the region of interest.

2. Methodology

2.1 Region of interest

The region of interest (ROI) includes 20 countries (Bangladesh, Brunei Darussalam, Cambodia, Fiji, India, Indonesia, Kiribati, Malaysia, Maldives, Marshall Islands, Micronesia, Myanmar, Nauru, New Caledonia, Palau, Papua New Guinea, Philippines, Singapore, Solomon Islands, Thailand, Timor-Leste, Vanuatu, and Vietnam) and 2 territories (Guam and Northern Mariana Islands) across three major sub-regions: **S Asia**, **SE Asia** and the **Asia-Pacific** (**Figure 2**). Maldives, Nauru and New Caledonia were added due to their inclusion in referenced studies and geographic proximity. Collectively, the ROI contains approximately half of the world’s mangroves and exhibits the highest rates of loss in the world (DasGupta, 2017).



Country	Continent	Country	Continent
Bangladesh	Asia	Myanmar	Asia
Brunei Darussalam	Asia	Northern Mariana Islands	Oceania
Cambodia	Asia	Palau	Oceania
Fiji	Oceania	Papua New Guinea	Oceania
Guam	Oceania	Philippines	Asia
India	Asia	Singapore	Asia
Indonesia	Asia	Solomon Islands	Oceania
Kiribati	Oceania	Thailand	Asia
Malaysia	Asia	Timor-Leste	Asia
Marshall Islands	Oceania	Vanuatu	Oceania
Micronesia	Oceania	Vietnam	Asia

Figure 2 Region of interest.

Approximately 7% of the world's mangroves are found in **S Asia** distributed primarily in sporadic coastal pockets (Giri *et al.*, 2015). This sub-region includes the world's largest mangrove ecosystem, the Sundarbans, covering approximately 1,000,000 ha al the India-Bangladesh border (Quader *et al.*, 2017). Throughout this sub-region, loss is attributed to land-cover conversion, pollution, over-harvesting and natural drivers including cyclones, tsunamis and coastal erosion (Giri *et al.*, 2007).

SE Asia contains approximately 34% of the world's mangroves and notably contains the greatest mangrove species diversity (Spalding *et al.*, 2010; Giri *et al.*, 2011; Thomas *et al.*, 2017). In this sub-region, 30% of all mangrove loss between 2000 and 2012 is attributed to conversion for aquaculture (Valiela *et al.*, 2001; Richards & Friess, 2016). Conversion to rice agriculture has also been a major driver in certain countries, such as Myanmar, whilst in Malaysia and Indonesia loss is mostly attributed to conversion for palm oil plantations (Richards & Friess, 2016).

Mangroves in the **Asia-Pacific** are distributed across numerous Pacific islands, many of which are volcanic with mountainous terrain, limiting low-elevation intertidal areas suitable for mangrove establishment. Mangroves in this sub-region are typically found in deltas and estuaries of established river systems, the largest of which are in Papua New Guinea, Solomon Islands, New Caledonia and Fiji (Bhattarai & Giri, 2011).

2.2 Inventory, evaluation and comparison of datasets
The availability of global and multi-national mangrove datasets within the ROI was inventoried in Feb-May 2017 by conducting an exhaustive internet-based search and literature review, and through contacting experts with regional experience. Where possible, freely available datasets were obtained from online repositories. For datasets not available through repositories, authors were contacted. To this end, dialogues occurred with the following organisations: Aberystwyth University, Bangor University, International Centre for Tropical Agriculture (CIAT), Food & Agriculture Organisation (FAO), Fauna & Flora International (FFI), The INDESO Project, International Union for Conservation of Nature (IUCN), Mangroves for the Future (MFF), National University Singapore (NUS), Salisbury University, UNEP-WCMC, United States Environmental Protection Agency (EPA), Zoological Society London (ZSL). NASA, the University of North Carolina, TropWATER, and Wetland International were also contacted with no response received.

Once acquired, all available datasets were evaluated on extent of ROI represented (space) and date(s) represented (time). This identified the most up-to-date, multi-temporal datasets with coverage of all or as much as possible of the ROI. The accuracy of available datasets was further assessed qualitatively through cross-checking against high-spatial resolution satellite imagery viewable in Google Earth Pro (GEP). Datasets were typically acquired in raster format, and in a range of coordinate systems necessitating several pre-processing steps to enable qualitative accuracy assessment (i.e., QAAs) within the GEP interface. In addition, the limited processing power of GEP (regardless of computing power) required simplifying large multi-featured datasets, causing GEP to freeze indefinitely, or run with an unmanageably slow response rate. Extensive trial and error identified a reasonable maximum number of 40,000 features at which QAA could be reasonably undertaken. Each QAA was based on 100x100 km areas of interest (AOIs) divided into 10x10 km boxes. Depending on geographic coverage and initial observations of the internal variability of mangrove ecosystems, 1-2 AOIs were used per dataset. Working from NW to SE, every fourth 10x10 km box containing mangroves was selected for spot-checking, such that 25% of each AOI was systematically assessed. For each spot-check, mangrove coverage was assessed against GEP imagery as close to the dataset's date as possible. If imagery wasn't available within five years of the mangrove dataset's temporal focus, QAA was not undertaken. In some instances, part of an image was cloudy or low quality, again limiting the ability to conduct QAA. Four mangrove classes were assessed for each spot-check, based on classes described in Jones *et al.* (2016), 1) closed-canopy: tall, mature stands, >60% closed, 2) open-canopy: medium, short or stunted stands, 10-60% closed, 3) sparse/dwarf, 4) fringing/strip. Each class was assessed as either well-,under- or over-represented.

2.3 Baseline mangrove distribution; Mangrove dynamics
To contextualise dynamics, a historic mangrove distribution baseline was required for the entire ROI. Using the most suitable dataset (according to space and time, and following QAA), baselines were extracted for each country/territory. Countries/territories were geographically defined by combining geographic boundaries with corresponding exclusive economic zone (EEZ) boundaries. Country polygons were sourced from the Global Administrative Boundaries database (wwww.gadm.org) and

EEZs sourced from http://www.marineregions.org. For comparison, baselines were also extracted from reported values in all inventoried multinational studies. Mangrove dynamics were also extracted from published inventoried studies.

3. Results and Discussion

3.1 Inventory, evaluation and comparison of global and multi-national mangrove datasets; Mangrove baselines and dynamics

Four global datasets, six multi-national datasets were identified as being relevant to this investigation (**Table 1**). In addition, one national-level dataset was identified due to the unsurpassed multi-date coverage provided for the country in question (i.e., the Phillipines). Each dataset is described below, including QAA results (where applicable), baseline distributions (where available) (**Table 2**) and dynamics (as reported) (**Table 2**, **Figure 3**, **Figure 4**). This section concludes with a comparison of baseline distributions and mangrove dynamics by country.

Table 1: Inventory of global and multi-national mangrove datasets.

Data-set	Scale	Spatial coverage	Temporal coverage	Author(s)	Acquisition status
(A)	Global	Global	2000	Giri *et al.* (2011)	Downloaded
(B)	Global	Global	2000-2014	Hansen *et al.* (2013)	Downloaded
(C)	Global	Global	2000-2014	Hamilton & Casey (2016)	Downloaded
(D)	Global	Global	2010	Lucas *et al.* (2015)	Subsets acquired
(E)	Multi-national	SE Asia	2000-2012	Richards & Friess (2016)	Pending delivery
(F)	Multi-national	Tsunami-affected regions - SE Asia	1975-2005	Giri *et al.* (2008)	Acquired from author
(G)	Multi-national	S Asia	2000-2012	Giri *et al.* (2015)	Pending delivery
(H)	Multi-national	Pacific	2000	Bhattarai & Giri (2011)	Pending delivery
(I)	Multi-national	S and SE Asia	2000	Stibig *et al.* (2007)	Pending delivery
(J)	Multi-national	Vietnam, Cambodia & Thailand	2014	Clark Labs (2016)	Downloaded
(K)	National	Philippines	1990, 2000, 2010	Long *et al.* (2014)	Pending delivery

(A) Global distribution of mangroves, 2000, Giri *et al.* (2011)

The most widely-used and referenced global mangrove dataset is Giri *et al.* (2011), the first comprehensive global assessment of mangrove distribution produced using satellite imagery, providing spatially explicit information at a moderate spatial resolution for all countries in the ROI circa 2000. It was produced using approximately 1000 Landsat images subset to include areas where mangroves were likely to occur. Hybrid supervised/unsupervised classification was used to generate four land-cover classes: mangrove, non-mangrove, barren lands and water. Qualitative validation employed high spatial resolution Quickbird and IKONOS imagery. The dataset described in Giri *et al.* (2011) is available from NASA's SEDAC website. Baseline mangrove distribution was extracted from both the downloaded dataset and figures reported in Giri *et al.* (2011) (**Table 2**). There is a discrepancy in mangrove area as calculated from the downloaded dataset vs. published figures, <5% in most of the ROI excepting Indonesia where downloaded data presented 13.5% less mangrove extent, and Malaysia with 9.5% less.

(B) Global Forest Change database, 2000-2015, Hansen *et al.* (2013)

As described in Hansen *et al.* (2013), the Global Forest Change (GFC) database employed Landsat satellite imagery to produce a global index of annual deforestation from 2000-2015 at a spatial resolution of 30 m, showing stand-replacement disturbance or complete removal of canopy-cover. There are a number of limitations with the GFC dataset. Firstly, forest includes all forests, making no distinction between terrestrial and mangrove. Richards and Friess (2016) further cite the inclusion of plantations or semi-natural forests as a limitation. Secondly, forest is defined using a threshold of >5 m wherein lower-stature mangroves are under-represented. Testing the GFC over Ambaro-Ambanja Bays (AAB) in NW Madagascar confirmed this limitation - the GFC displayed no mangrove deforestation, wherein multiple studies confirm loss here is extensive (Jones *et al.*, 2016a; Jones *et al.*, 2016b; Jones *et al.*, 2014).

(C) Continuous mangrove forest cover for 21st century (CGMFC-21), Hamilton & Casey (2016)
This dataset builds on Hansen *et al.* (2013) (i.e. B) to map global mangrove change from 2000-2014. Baseline global mangrove distribution was produced circa 2000 by masking GFC with Giri *et al.* (2011) (i.e., A). Areas of annual loss within this masked extent were then identified from GFC annually to produce maps of canopy-cover (m^2) resulting in continuous coverage. Areas of mangrove gain outside of the baseline area are therefore excluded. Also, pixels containing just 0.01% forest canopy cover are included as mangrove – this falls well below commonly accepted definitions of canopy-cover for forest e.g., >30 %. Initial comparisons with known areas of loss (e.g., AAB) indicate that due to the aforementioned limitations, mangrove loss is often under-represented. QAA was further conducted for 2014 for two AOIs in the ROI: North Sulawesi, Indonesia and Irrawaddy Delta, Myanmar, confirming that low-stature-mangrove forest was under-represented. Dynamics for 19 countries and one territory are presented in and were extracted from Hamilton & Casey (2016) (**Table 2**, **Figures 3**, **4**).

(D) PALSAR-derived mangrove map, Lucas *et al.* (2015)
Unpublished research using Advanced Land Observing Satellite (ALOS) Phased Array-type L-band SAR (PALSAR) data, undertaken by Global Mangrove Watch (GMW) (Lucas, pers.comm., 2017), has generated an initial global mangrove extent map for year 2010. This is a test-dataset which has not yet undergone validation. Once finalised, GMW will generate global maps of mangrove extent for 1996, 2007, 2008, 2009, 2010, 2015 and 2016, and annually thereafter. At present, only nation-wide mangrove area in Bangladesh has been derived from the data, showing strong alignment to Giri *et al.* (2008, 2011, 2015) (i.e., A,F,G). The final maps are expected to be released in autumn 2017 through the World Resources Institute (WRI), with a corresponding paper assessing mangrove change for all countries. Lucas provided nation-wide example products for Madagascar and Bangladesh, and sub-national example products for the Irrawaddy Delta, Myanmar and Sulawesi, Indonesia. Lucas has requested that BV assist with validation to improve accuracy classification accuracy. QAA was conducted to test the accuracy of the example products. Two AOIs were selected in Bangladesh and one in Indonesia. Generally, intact, closed-canopy mangrove was mapped accurately, however there were some instances of both under- and over-representation. In addition, consistent over-representation across all mangrove classes was observed in both Noakhali District, Bangladesh and North Sulawesi, Indonesia.

(E) Mangrove deforestation in SE Asia, Richards & Friess (2016)
Building on the methodology adopted by Hamilton & Casey (2016) (i.e., C), this study assessed the rates and drivers of mangrove deforestation across ten countries in **SE Asia**: Brunei-Darussalam, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam from 2000-2012. Similar limitations apply here as with Hamilton & Casey (2016) (i.e., C), however post-processing removed some anomalous deforestation pixels by applying a “clump function” meaning only deforested pixels adjacent to other deforested pixels forming minimum patches of 0.5 ha were retained. Dynamics for ten countries were presented in and extracted from Richards & Friess (2016) (**Table 2**, **Figures 3**, **4**).

(F) Mangrove dynamics (1975-2005) - tsunami-affected regions of Asia, Giri *et al.* (2008)
This study mapped mangrove extent in regions of **S** and **SE Asia** affected by the 2004 tsunami. Approximately 700 Landsat images were used to produce four maps for years 1975, 1990, 2000 and 2005, across parts – only tsunami-affected areas – of six countries within the ROI: Bangladesh, India, Indonesia, Malaysia, Myanmar and Thailand. Classification and validation methods are similar to those outlined in Giri *et al.* (2011) (i.e., A). Change analysis was conducted using a post-classification technique, which compared classification results from each of the four imaged years. Shortcomings with this approach as noted by Giri *et al.* (2008) include semantic differences in class definitions, positional and classification errors. Maps were acquired from the authors but analysis was hindered due to unresolved dataset issues stemming from original analysis having been conducted >12 years ago. QAA was performed for the 2005 dataset, the most contemporary year of focus. One AOI was selected for each of the six countries studied. GEP imagery was available within two years of the temporal focus in nearly all cases, except Indonesia wherein the timeliest imagery was from 2012.

Increasingly variable results were observed as mangrove cover became more open/sparse. Over-representation was identified in places, particularly where mangrove had been converted to palm oil plantations (e.g. in Malaysia), or clear-cut for agriculture (e.g. Malaysia and India). Whilst mangrove was broadly well represented in India, Bangladesh, Myanmar and Indonesia, large stands were missing from Thailand and Malaysia. Dynamics for Bangladesh and Myanmar are presented in and were extracted from Giri *et al.* (2008) (**Table 2**, **Figures 3**, **4**).

(G) Distribution and dynamics of mangrove forests of S Asia, Giri *et al.* (2015)
This study employed Landsat to assess mangrove cover change from 2000-2012 in Bangladesh, India, Pakistan and Sri Lanka. Three case studies were also assessed in greater spatial and thematic detail: Indus Delta (Pakistan), Goa (India) and Sundarbans (India and Sri Lanka). The Classification and Regression Tree (CART) algorithm was employed, with results validated using existing mangrove distribution datasets, and using high resolution imagery from QuickBird and IKONOS. Post-classification change analysis identified mangrove dynamics and attributed change to natural or anthropogenic causes. Shortcomings are as described in Giri *et al.* (2008) (i.e., F). The data has not yet been provided, however, dynamics for Bangladesh and India are presented in and were extracted from Giri *et al.* (2015) (**Table 2**, **Figures 3**, **4**).

(H) Mangrove Assessment in the Pacific, Bhattarai & Giri (2011)
This study used Landsat data to produce a baseline map of mangrove extent across the Pacific circa 2000 including: American Samoa, Fiji, French Polynesia, Guam, Hawaii, Kiribati, Marshall Islands, Micronesia, Nauru, New Caledonia, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna Islands. Classification and validation methods are similar to those outlined in Giri *et al.* (2011) (i.e., A) and Giri et al. (2015) (i.e., F). The data has not yet been provided, however, distributions for nine countries and three territories are presented in and were extracted from Bhattari & Giri (2011) (**Table 2**).

(I) Land-cover map for South and Southeast Asia, Stibig *et al.* (2007)
This study used imagery from the SPOT-VEGETATION (VGT) Earth observing system to map land cover classes for **S** and **SE Asia** circa 2000. 26 land cover classes were identified using unsupervised maximum likelihood classification, including “mangrove forest”. Class assignment was validated using Landsat imagery, field knowledge and existing land-cover maps. The data has not yet been provided.

(J) Baseline mapping of aquaculture and coastal habitats, Clark Labs (2016)
Clark Maps produced a single-date, baseline inventory of pond aquaculture and coastal habitats for Thailand, Cambodia and Vietnam using Landsat data circa 2013-2015. Supervised classification techniques were used to generate 30 classes, one of which was “mangrove”. With a pan-sharpened spatial resolution of 15 m, this dataset offers a superior resolution to the datasets presented above (most at 30 m) but is limited in its spatial and temporal coverage of the wider sub-region and ROI. Distributions for Thailand, Cambodia and Vietnam are presented in and were extracted from Clark Labs (2016) (**Table 2**).

(K) Mapping and monitoring Philippines’ mangrove forests from 1990 to 2010, Long *et al.* (2014)
The sole national-level study considered in this report, this study employed supervised classification of Landsat to produce mangrove distribution maps across the Philippines for 1990, 2000 and 2010. High resolution (IKONOS and Quickbird data were used for validation purposes. The data has not yet been provided, however, post-classification change analysis identified mangrove dynamics which are presented in and were extracted from Long *et al.* (2014) (**Table 2, Figures 3, 4**).

Whilst datasets A,D,F,G,H,I,J,K report mangrove area in binary terms i.e. mangrove or non-mangrove, datasets B,C,E represent mangrove area using a continuous mangrove cover measure, reporting % forest canopy-cover. Continuous cover measures result in a reduced calculated area. In any given pixel, a binary measure will represent the entire pixel’s area as mangrove e.g. 900 m^2 out of 900 m^2 represented as mangrove. A continuous mangrove cover measure will represent the pixel in terms of % canopy cover, which if 50% would equal 450 m^2. This equates to a 450 m^2 discrepancy in a single pixel, resulting in significant discrepancy when assessed at a national scale. The presence of sparse or degraded mangrove forest accentuates this effect. This explains the difference in areal extent: figures reported by (c - Hamilton & Casey, 2016) were on average 38% lower than those reported by (a - Giri *et al.,* 2011), for the same year of focus (2000). However another reason for this is likely to be the omission of mangroves < 5 m in height, as per GFC (Hansen *et al.*, 2013). When compared to Richards & Friess (2016), figures reported by Hamilton & Casey (2016) for the year 2012 were on average 31% lower. As well as being lower in absolute terms, rates of mangrove loss were roughly double those reported by Richards & Friess (2016) (means of 3.3% versus 1.5% respectively). Given these studies employed similar methodologies, reasons for this discrepancy require further investigation. Regardless of the methodology utilised, defining mangrove area spatially is often challenging as mangroves often co-exist with other similar coastal habitats (salt marshes, tidal freshwater forests etc.) (Spalding *et al.*, 2010). Numerous studies (e.g., Friess & Webb, 2015; Blasco *et al.*, 1998) have noted the lack of consistency in how mangroves are defined (e.g. mangrove forest only; mangrove habitat inclusive of water bodies etc.). This reiterates the need to develop robust and standardised methods for accurately quantifying mangrove distribution (Friess & Webb, 2015), and is likely to be somewhat responsible for the variability in areal estimates.

Of the 25 countries within the ROI, mangrove extent in Bangladesh, Philippines, Thailand, Vietnam, Solomon Islands, Papua New Guinea and New Caledonia has remained relatively steady, exhibiting <3% loss over the time periods studied. Loss in countries and territories with mangrove area <10,000 ha (Maldives, Micronesia, Palau, Singapore, Timor Leste and Vanuatu) was <2%, but only reported on by Richards and Friess (2016) or Hamilton & Casey (2016). Change dynamics were not available for Guam, Kiribati, Marshall Islands, Nauru, and the Northern Mariana Islands.

Of all countries in the ROI, **Myanmar** exhibited the greatest rate of loss in mangrove extent. Giri *et al.* (2008) reported a 35% drop from 1975-2005. Whilst the rate of overall deforestation in Myanmar fell markedly since 2000, mangrove loss of 5.5% from 2000-2012 (Richards & Friess, 2016) and 10.2% from 2000-2014 (Hamilton & Casey, 2016) were still identified. These rates are comparatively high post-2000 when compared to other countries in the ROI. In **India** an 8% fall was reported from 2000-2012 (Giri *et al.*, 2015), again comparatively high for the period. However this figure was heavily influenced by the Sundarbans, the largest contiguous mangrove forest in the world, of which 40% is in India. Literature indicates that the Sundarbans remained relatively stable between 1973 and 2000 with a reported loss in areal extent of approximately 1.2% (Giri *et al.*, 2007). The Indian Sundarbans represents approximately 50% of India's total mangrove extent, thus it can be assumed that mangrove loss in India's other mangrove habitats was significantly higher than the nationwide loss of 8% as reported by Giri *et al.* (2015). This is backed up by Thomas *et al*. (2017), who categorise Western India as a "hotspot of mangrove change… which should be prioritised for future monitoring" by using multi-temporal radar mosaics as indicators of change. Studies including the **Philippines** reported variable findings. Long *et al.* (2014) reported a 10.5% loss in areal extent from 1990-2010, with mangrove reported as present or absent. Studies using continuous mangrove cover as a measure reported very little loss, 0.5% from 2000-2012 (Richard & Friess, 2016) and 1.49% from 2000-2014 (Hamilton & Casey, 2016). Long *et al.* (2014) generated comprehensive nation-wide maps for 1990, 2000 and 2010 and identified a 6% loss from 2000-2010, thereby contradicting studies measuring loss using continuous mangrove cover. Indonesia has by far the greatest areal extent of mangroves. Although the rate of loss in Indonesia was not as high as in Myanmar or India, in absolute terms it totalled nearly 100,000 ha from 2000-2014 (Hamilton & Casey, 2016) - equal to approximately twice the mangrove area in Cambodia. The rate of loss in Malaysia and Cambodia was not as pronounced as in Myanmar or India, but notable nonetheless. In Malaysia, loss was reported at 2.83% from 2000-2012 (Richards and Friess, 2016) and 5.58% between 2000 and 2014 (Hamilton & Casey, 2016). In Cambodia, loss was reported at 2.28% from 2000- 2012 (Richards and Friess, 2016) and 5.42% from 2000-2014 (Hamilton & Casey, 2016).

Of the three sub-regions in the ROI, **SE Asia** is the primary mangrove loss hotspot, findings which are further backed up by a recent study (i.e., Thomas *et al.* (2017)) which employed methods similar to Lucas et al. (2015) to identify mangrove change hotspots between 1996-2010. When considering individual countries across the datasets inventoried and assessed, **Myanmar**, **India** and the **Philippines** stand out as being mangrove loss hotspots. Myanmar experienced 35% loss between 1975 and 2005 (Giri *et al.*, 2008), eclipsing rates of loss seen anywhere else within the ROI. India saw a 7.6% loss from 2000- 2012, again above the average across the ROI. The loss is lopsidedly occurring in other parts of India given of the relatively well-preserved Indian Sundarbans (Giri *et al.*, 2008). The Philippines experienced 10.5% loss from 1990-2010 with relatively consistent rates across the two decades (Long *et al.*, 2014).

Secondary hotspot nations are considered to be **Malaysia**, **Cambodia** and **Indonesia**. After Myanmar, these were the next three countries with the greatest rates of mangrove loss as reported by Richards & Friess (2016), with 2.83%, 2.28% and 1.72% lost respectively between 2000 and 2012.

Hamilton & Casey (2016) reported a similar pattern, albeit with higher rates of loss: Malaysia lost 5.58%, Cambodia lost 5.42% and Indonesia lost 3.86%.

4. Next steps

This report has identified **Myanmar**, **India** and the **Philippines** as a short-list of countries exhibiting high rates of mangrove loss within the ROI. Next steps include acquiring and collating all available national and sub-national datasets for short-listed countries, conducting QAAs and detailed deforestation analysis (DA) using best available datasets. Final deliverables include an inventory and depository of all datasets, loss – persistence – gain maps and quantified dynamics (including an online version using the Carto platform), and a final report. These efforts will collectively help target a third country for replicating BF and PHE initiatives.

Table 2. Mangrove extent (ha) baseline and dynamics by country/territory.

Study	Giri *et al.* (2008)	Long *et al.* (2014)	Giri *et al.* (2011)	Giri *et al.* (2011)	Giri *et al.* (2015)	Bhattarai & Giri (2011)	Richards & Friess (2016)	Hamilton & Casey (2016)	Giri *et al.* (2008)	Long *et al.* (2014)	Lucas *et al.* (2017)	Giri *et al.* (2015)	Richards & Friess (2016)	Hamilton & Casey (2016)	Clark Labs (2016)
Year of focus	**1975**	**1990**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2005**	**2010**	**2010**	**2012**	**2012**	**2014**	**2014**
Method used	**Binary**	**Binary**	**Binary**	**Binary**	**Binary**	**Binary**	**Continuous**	**Continuous**	**Binary**	**Binary**	**Binary**	**Binary**	**Continuous**	**Continuous**	**Binary**
Extracted from	**Paper**	**Paper**	**Paper**	**Data**	**Paper**	**Paper**	**Paper**	**Supporting info**	**Paper**	**Paper**	**Data**	**Paper**	**Paper**	**Supporting info**	**Data**
Bangladesh	448,073		436,570	443,818	421,091			177,390	438,764		434,290	411,487		177,267	
Brunei				11,370			11,054	10,423					11,013	10,327	
Cambodia				47,347			47,563	33,839					46,477	32,004	34,255
Fiji				75,969		52,503		40,170						40,077	
Guam				31		34.2									
India			368,276	382,802	371,431			82,506				343,065		79,140	
Indonesia			3,112,989	2,693,538			2,788,683	2,407,313					2,740,658	2,314,277	
Kiribati						17.9									
Malaysia			505,386	553,541			557,805	496,868					541,996	469,150	
Maldives				79				30						30	
Marshall Islands				0.3		2.3									
Micronesia				9,803		9,901		695						692	
Myanmar	851,452		494,584	505,695			502,466	279,260	551,361				474,696	250,825	
Nauru				3		3.6									
New Caledonia				24,574		25,099		9,862						9,787	
N Mariana Isl				27		28.1									
Palau				5,612		5,666		4,806						4,787	
Pap N Guinea			480,121	481,807		480,121		418,992						416,904	
Philippines		268,996	263,137	257,977			257,575	209,105		240,824			256,279	205,975	
Singapore				581			583	167					583	167	
Solomon Islands				46,183		47,100		39,492						39,260	
Thailand				247,671			245,179	193,345					241,835	187,562	257,372
Timor Leste				1,014			1,066	857					1064	844	
Vanuatu				1,354		1,378		1,009						1,009	
Vietnam				211,823			215,154	71,640					214,626	70,641	146,477

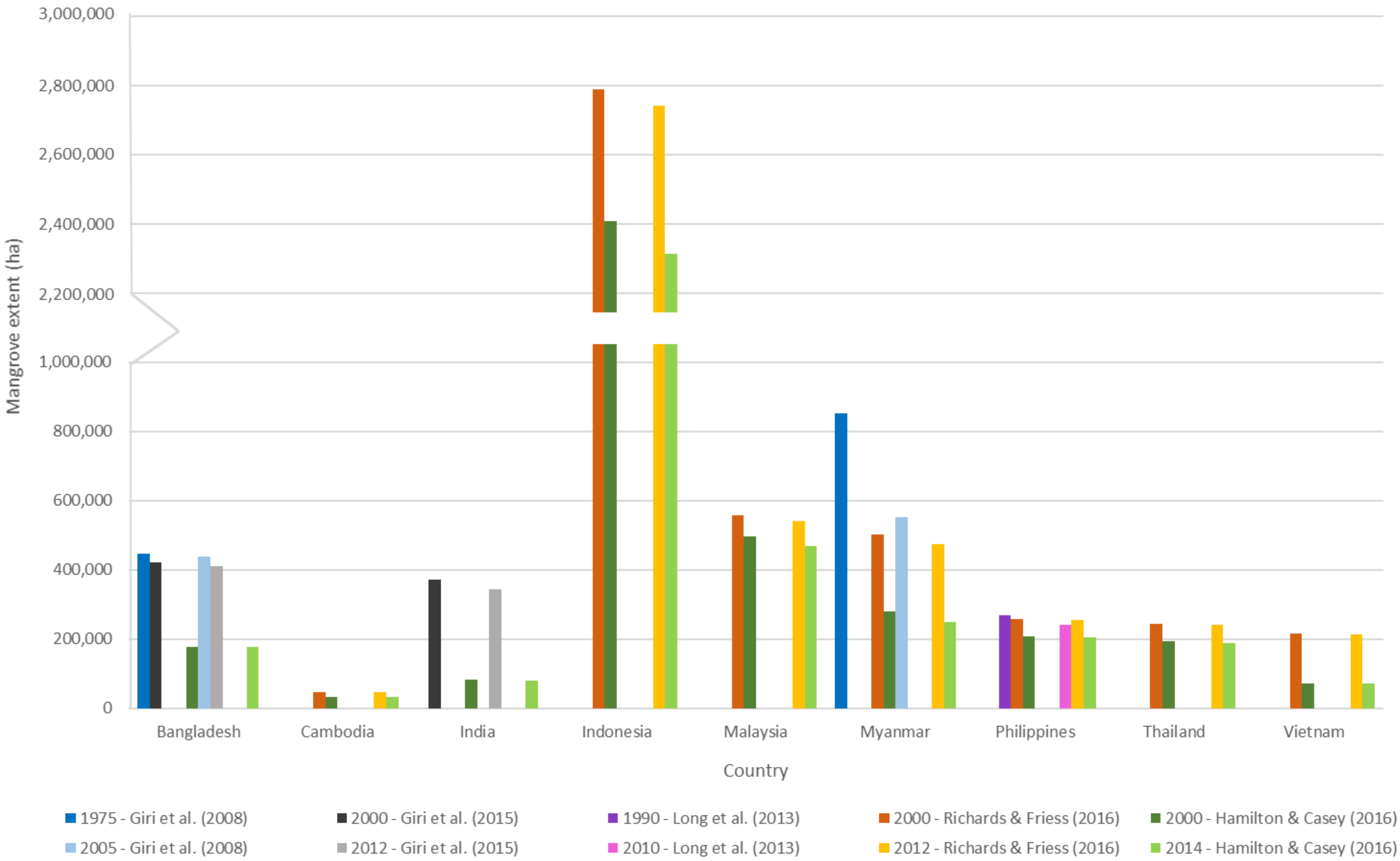


Figure 3. Mangrove extent dynamics by country and study.

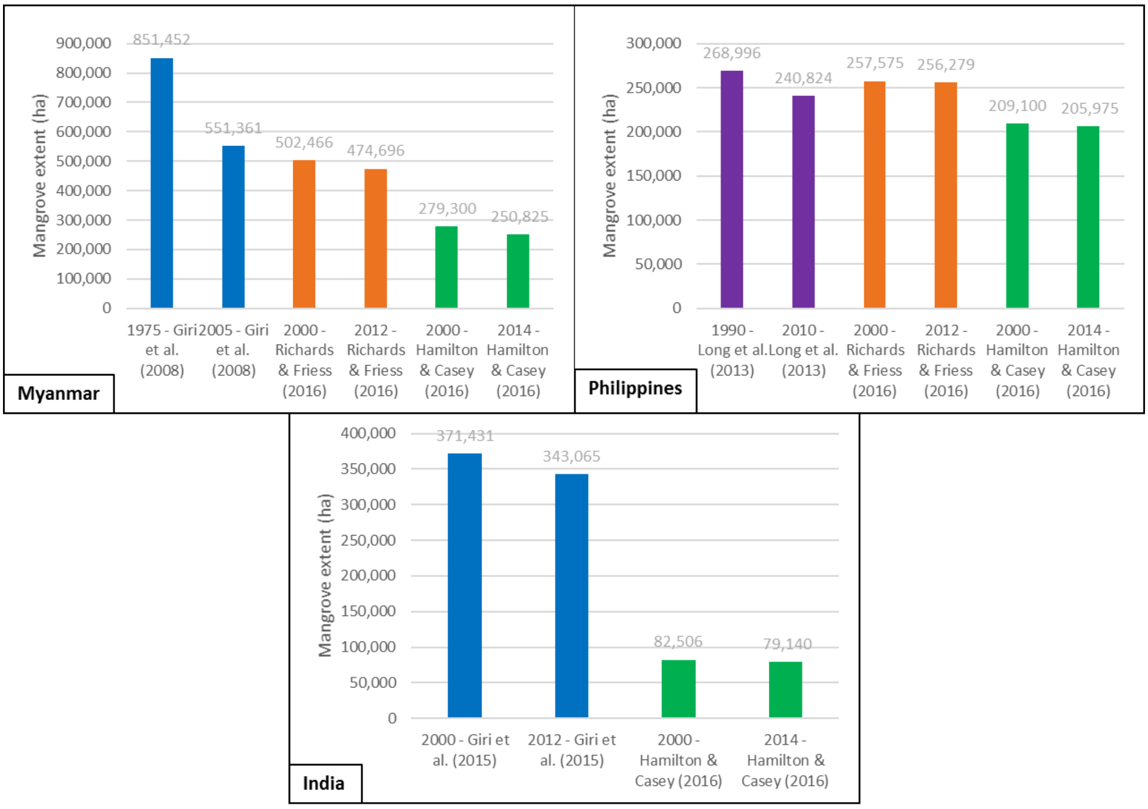


Figure 4. Change dynamics for Myanmar, Philippines and India.

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