Consequences of Changing Mangrove Forests in South Asia on the Provision of Global Ecosystem Goods and Services

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(Government partner: U.S. EPA)

NASA Land-Cover/Land-Use Change Program,

Grant number NNX17AI08G

LCLUC Spring Science Team Meeting, 2018

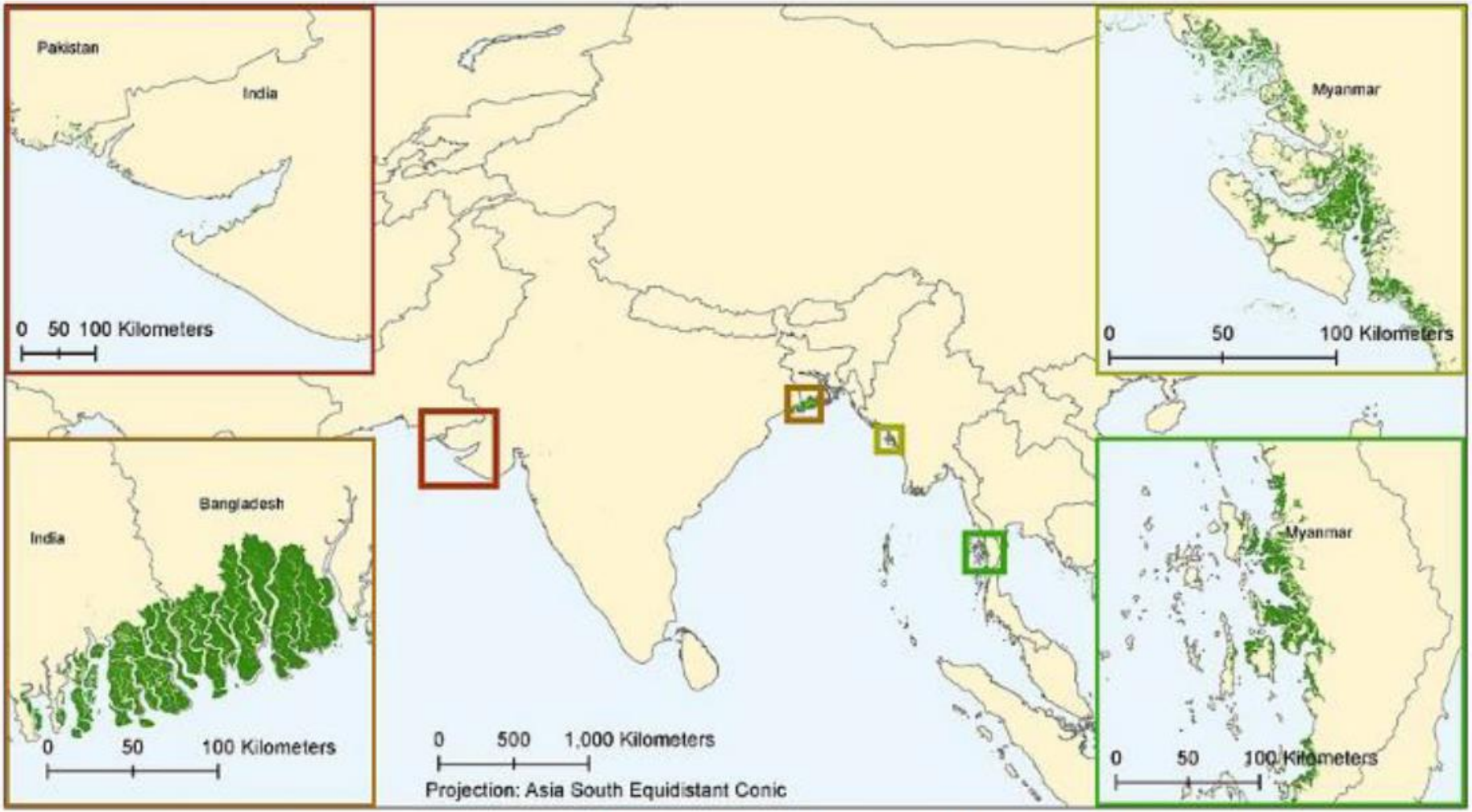


Figure 1: Approximate locations of mangrove forests in Bangladesh, India, Myanmar, Pakistan, and Sri Lanka (Giri et al. 2011b).

Objectives

1. Develop an operational methodology for **detecting and monitoring mangrove cover dynamics** in South Asia on an annual basis
2. Create a **comprehensive database of mangrove cover changes** in South Asia on an annual basis from 1985 to the present at 30 m resolution
3. Quantify the impacts of mangrove cover changes in South Asia on **carbon stock changes and species extinction risks** on an annual basis from 1985 to the present
4. Analyze of the **effectiveness of the existing protected areas system** in South Asia, and prospective cost-effective additions to it, in avoiding carbon emissions and species extinctions caused by mangrove deforestation and degradation.

Project time-line

Major activities	*Year1*	*Year2*	*Year3*
Develop and test methodology for annual mapping and monitoring	X		
Complete annual database on mangrove cover change and change analysis		X	
Estimate carbon stocks, changes in carbon stocks, and social cost of carbon	X	X	
Map species	X		
Assess biodiversity threats, areas in need of protection, species persistence		X	X
Retrospective impact evaluations of protected areas, carbon, biodiversity		X	
Prospective analyses of cost-effective protection for carbon, biodiversity			X

What to map?

- True mangrove vs mangrove associates
- Area, extent & spatial distribution
  - Expansion and contraction
- Species zonation
- Canopy closure
- Density
- Height
- Disturbance
- Mangrove health
- Biomass

Rates, patterns, causes, and consequences

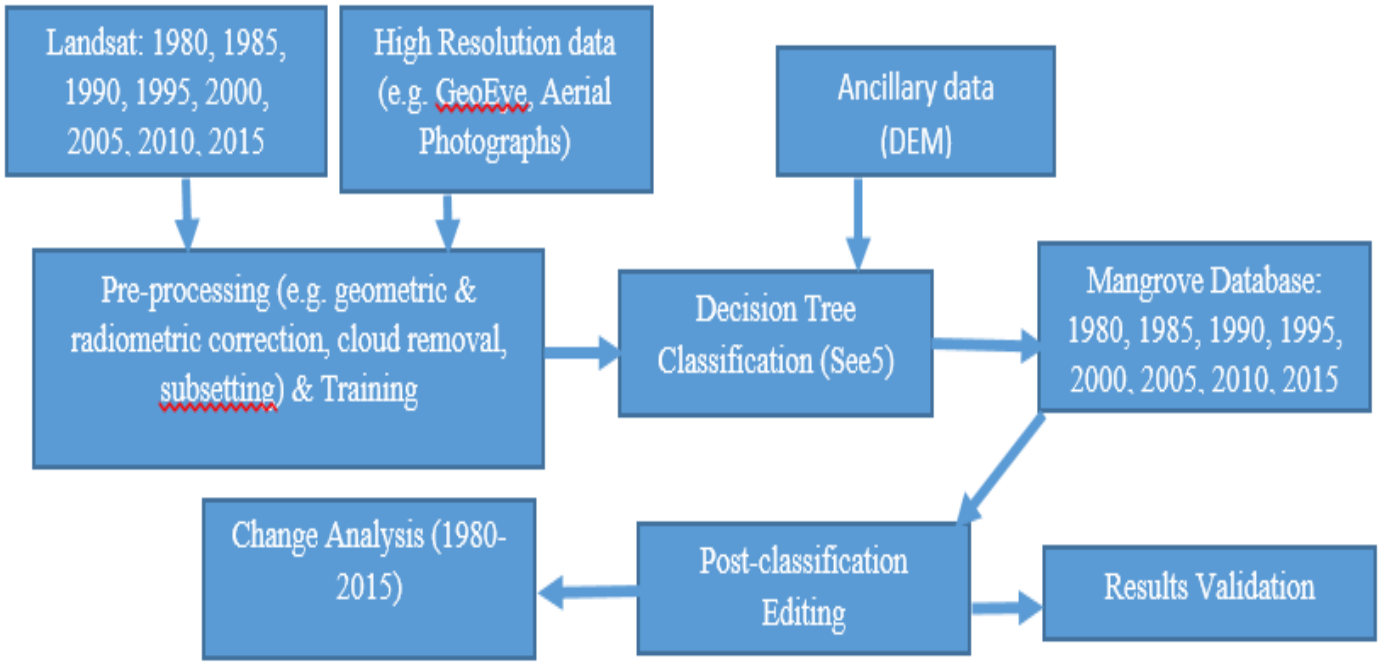
Methodology

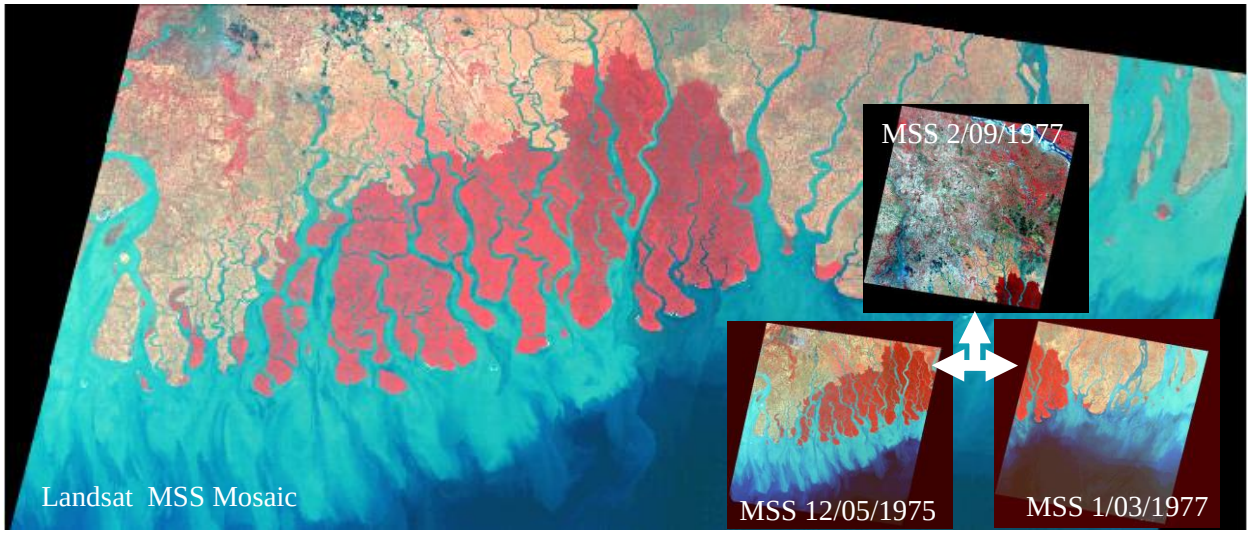
Classification – every 5 year
Annual Change Analysis

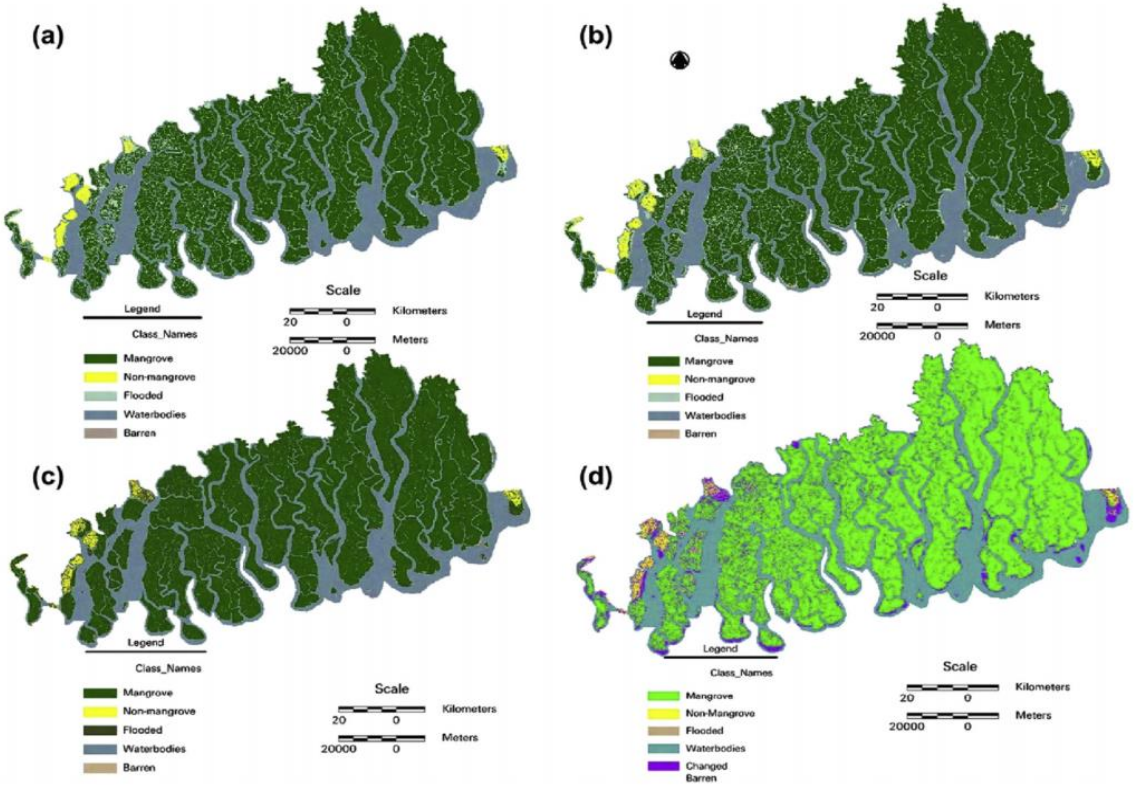
MapPy - pre-processing

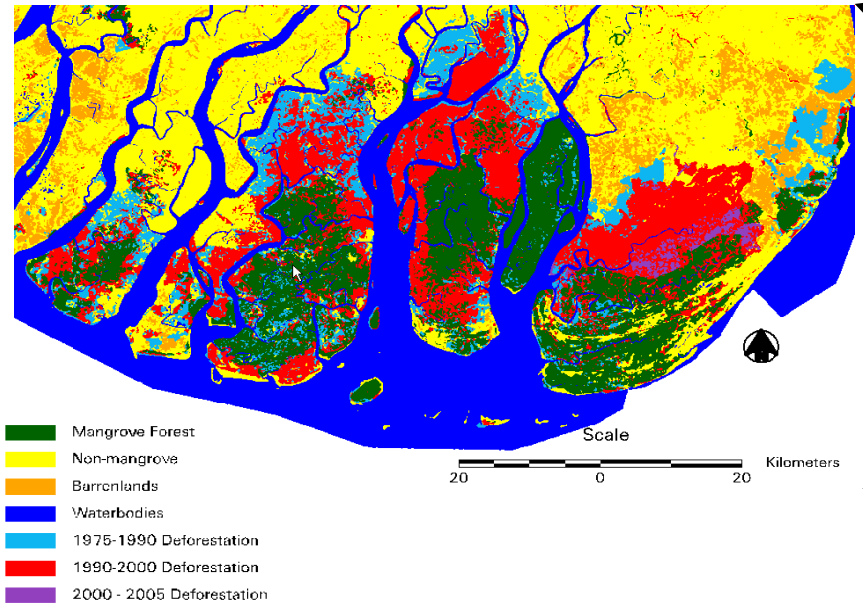
AMCTool: Automated Mangrove Classification Tool (IDL 6.3 and Envi 4.3)

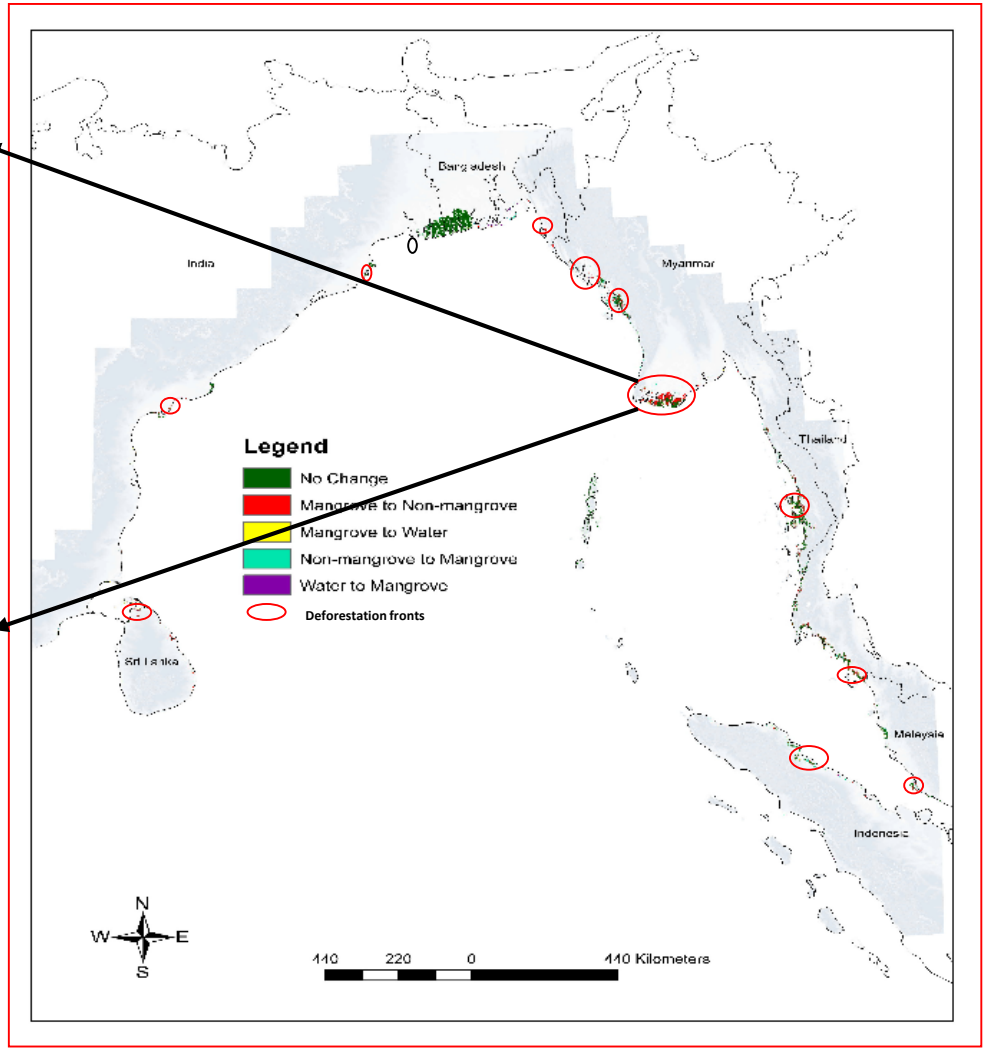
- Landsat 6 bands
- Elevation
- Indices

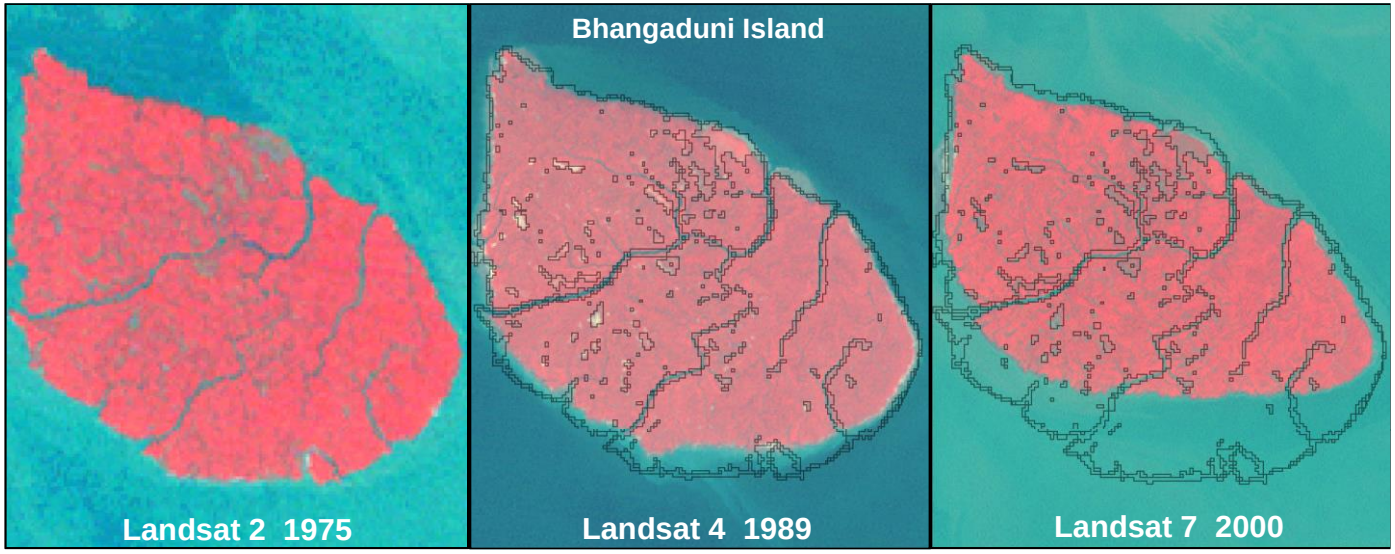



MSS 2/09/1977
Landsat MSS Mosaic
MSS 12/05/1975
MSS 1/03/1977

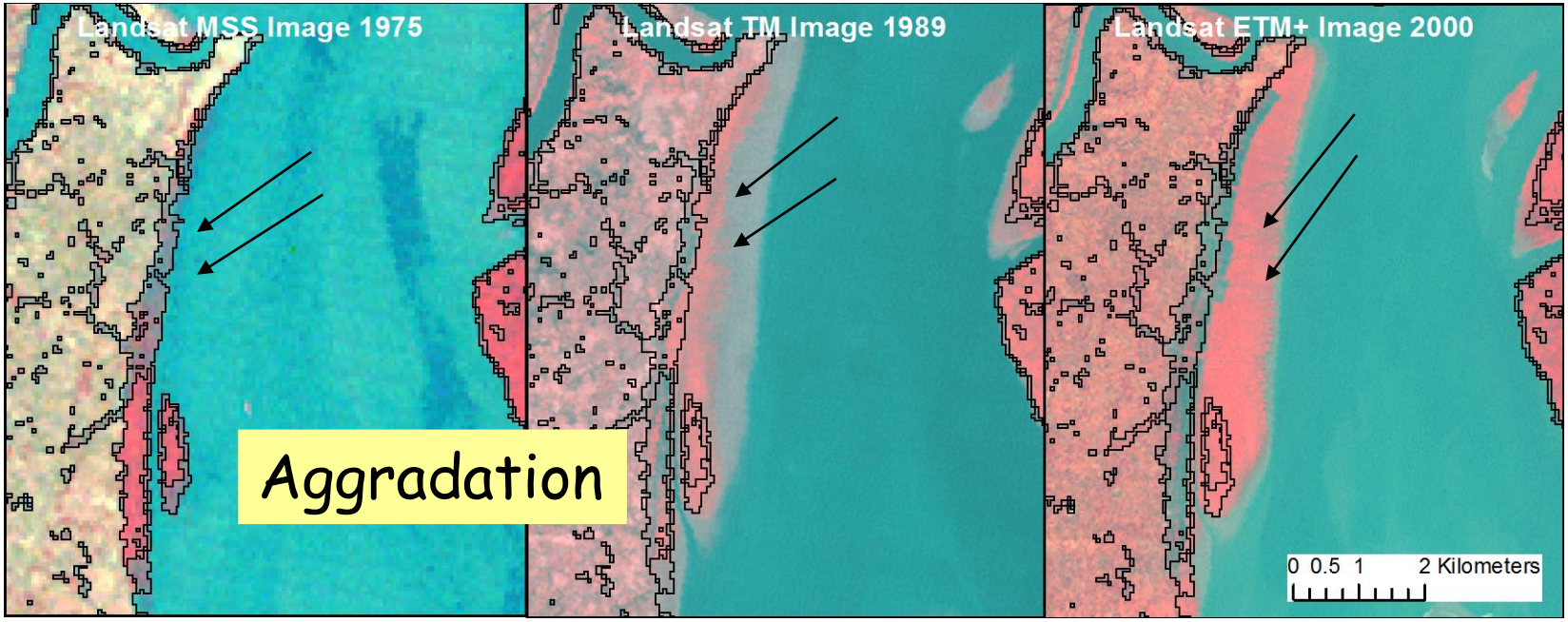

(a)
Legend
Class_Names
Mangrove
Non-mangrove
Flooded
Waterbodies
Barren
Scale
20 0 Kilometers
20000 0 Meters
(b)
Legend
Class_Names
Mangrove
Non-mangrove
Flooded
Waterbodies
Barren
Scale
20 0 Kilometers
20000 0 Meters
(c)
Legend
Class_Names
Mangrove
Non-mangrove
Flooded
Waterbodies
Barren
Scale
20 0 Kilometers
20000 0 Meters
(d)
Legend
Class_Names
Mangrove
Non-Mangrove
Flooded
Waterbodies
Changed
Barren
Scale
20 0 Kilometers
20000 0 Meters


Mangrove Forest
Non-mangrove
Barrenlands
Waterbodies
1975-1990 Deforestation
1990-2000 Deforestation
2000 - 2005 Deforestation
Scale
20
0
20
Kilometers

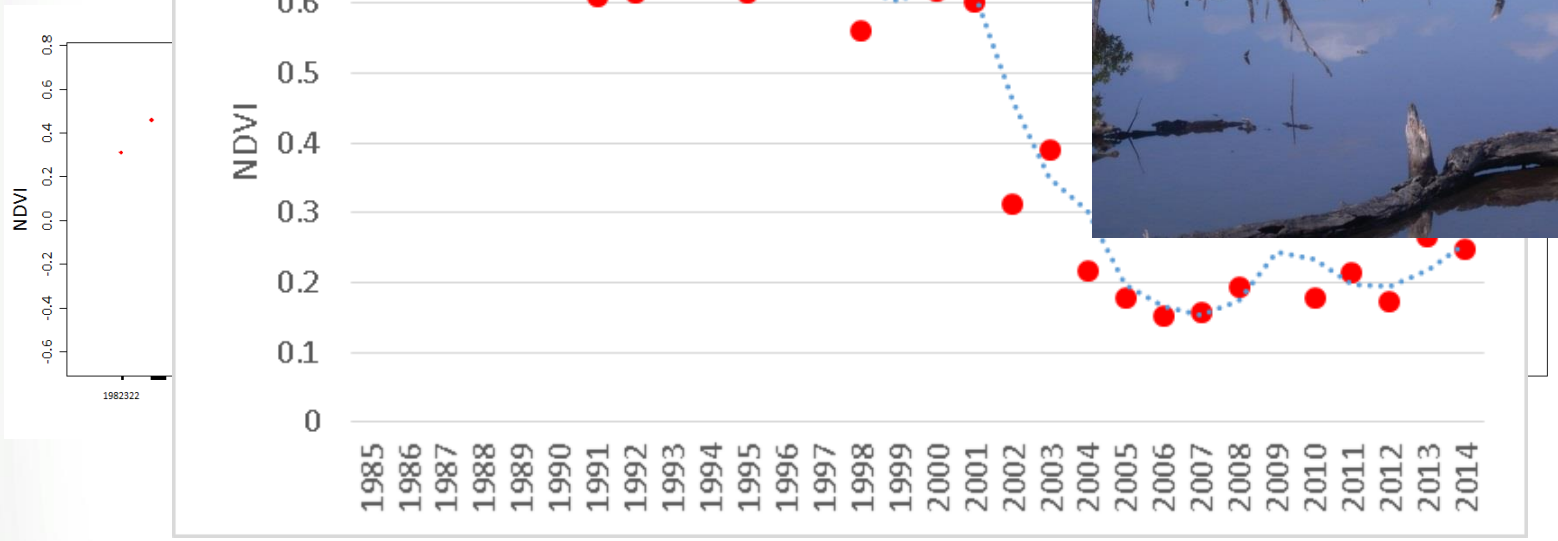

Bangladesh
India
Myanmar
Thailand
Sri Lanka
Malaysia
Indonesia
Legend
No Change
Mangrove to Non-mangrove
Mangrove to Water
Non-mangrove to Mangrove
Water to Mangrove
Deforestation fronts
N
W
E
S
440
220
0
440 Kilometers

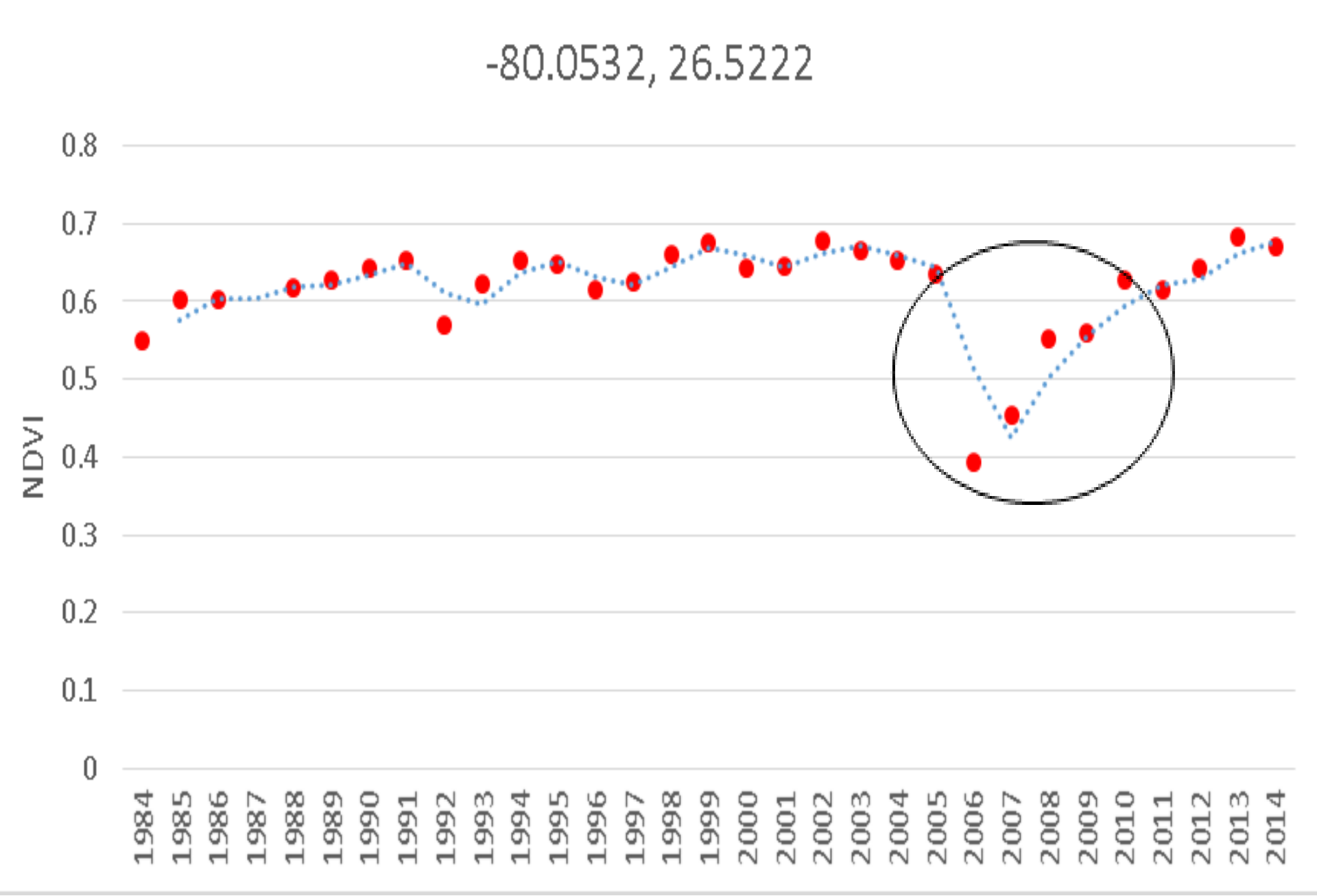

Bhangaduni Island
Landsat 2 1975
Landsat 4 1989
Landsat 7 2000

Erosion


Landsat MSS Image 1975
Landsat TM Image 1989
Landsat ETM+ Image 2000
Aggradation
0 0.5 1 2 Kilometers

NDVI differentiating Spectral difference




-80.0532, 26.5222
NDVI
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Estimation of carbon stocks

Lead researchers: Brian Silliman, Qiang He

Methodology: meta-analysis of existing studies

Carbon meta-analysis: study locations

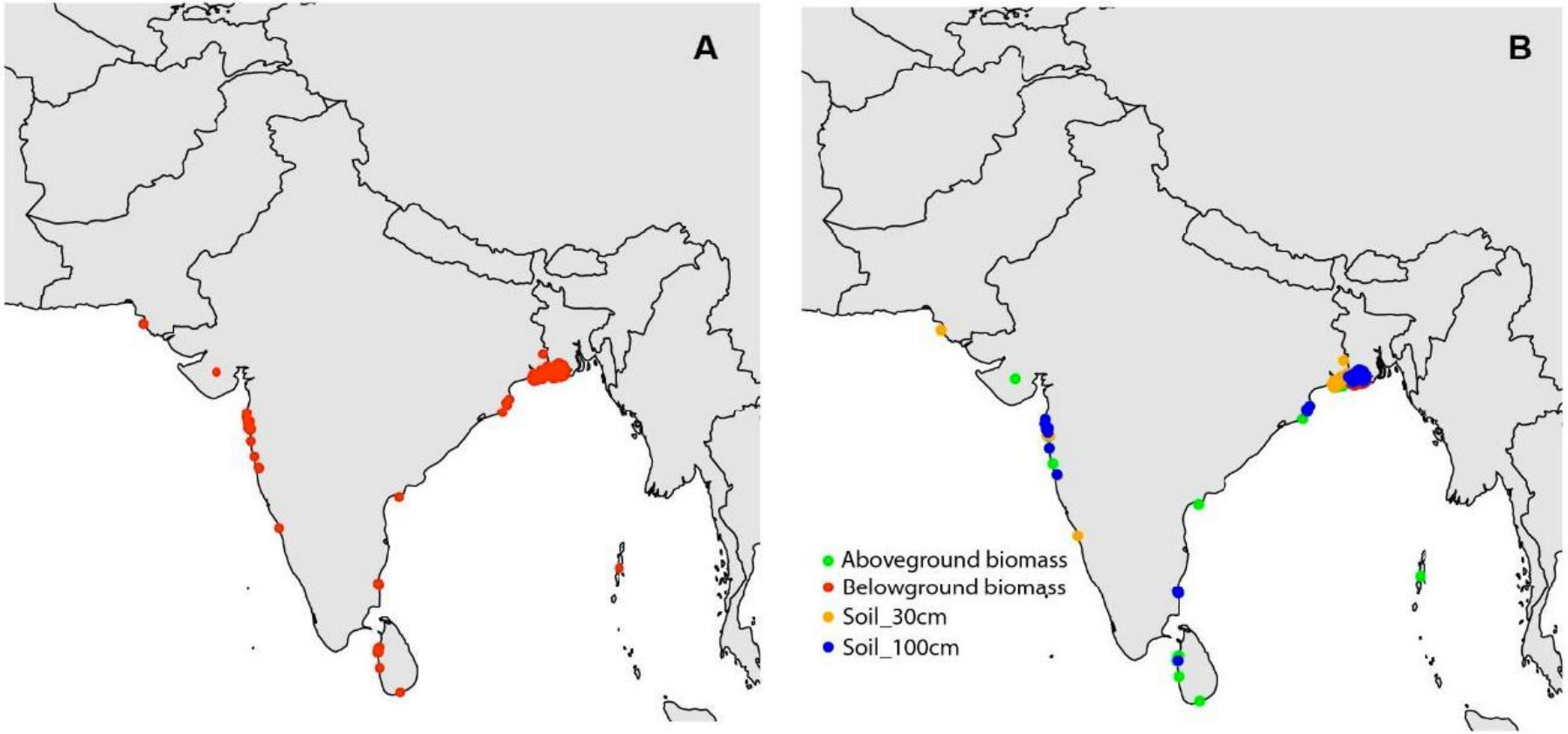
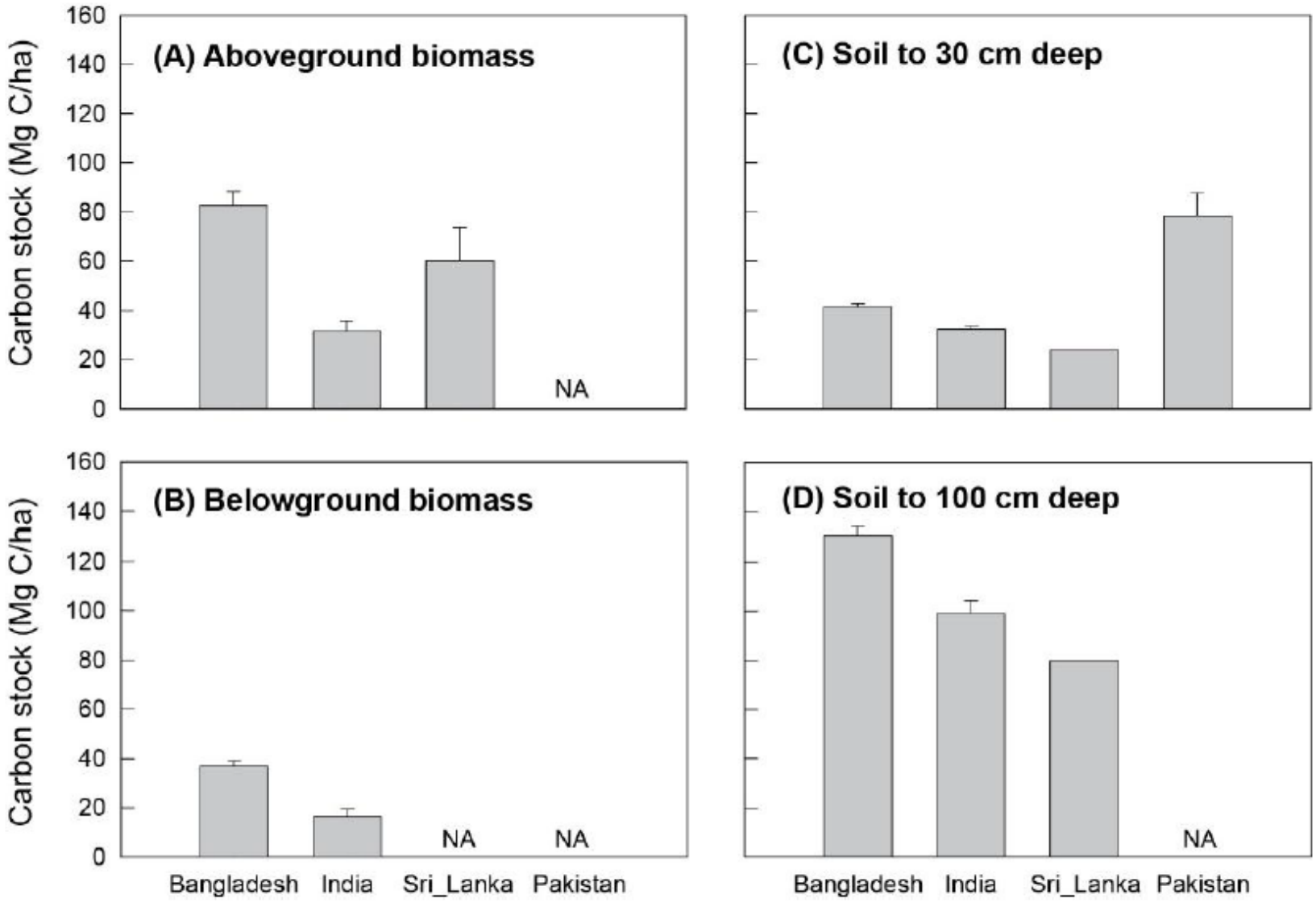
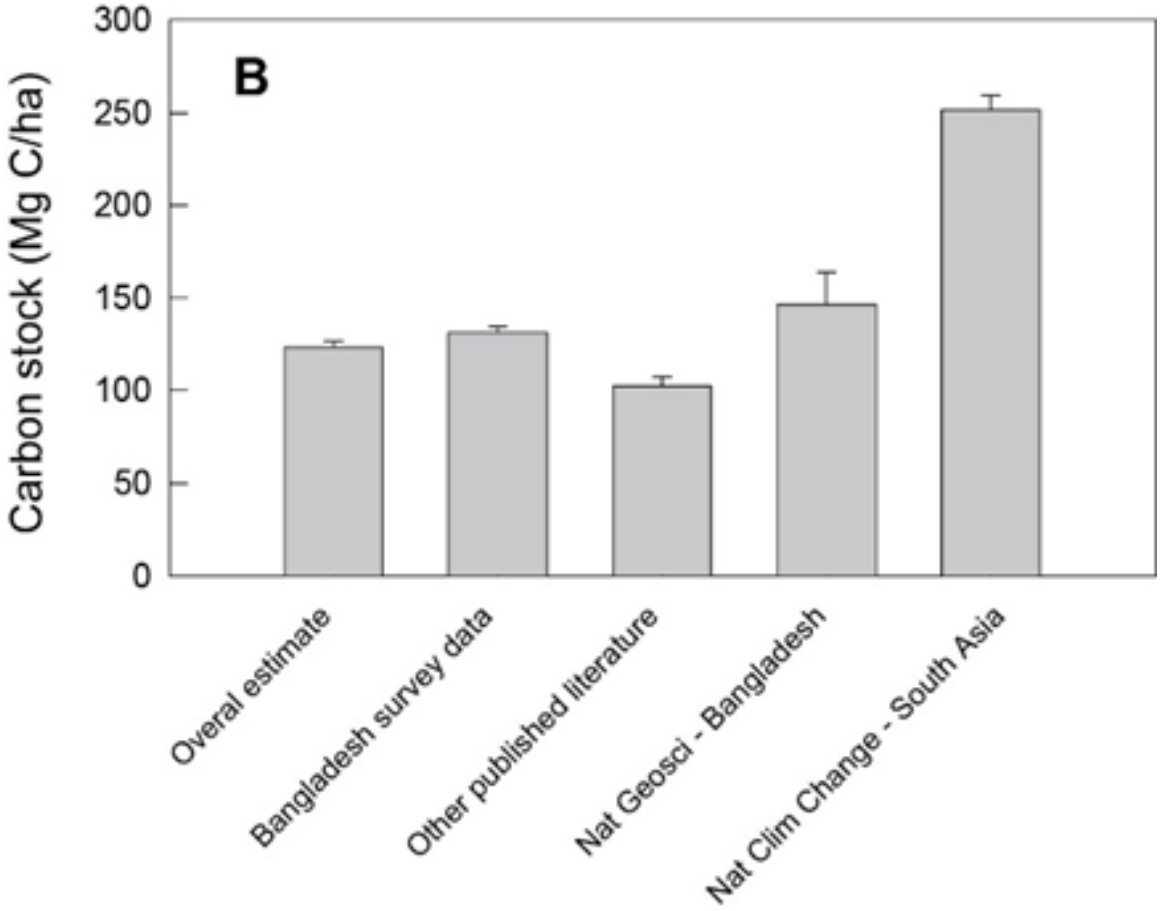


Figure 3. Map showing sites with available mangrove carbon stock data. A) all sites; B) sites for each carbon stock category.

C stocks by component and country



Estimates of soil C stock (100cm deep)



Estimation of extinction risks

Lead researchers: Stuart Pimm, Ryan Huang

Goals

1. Identify which mangrove areas have the highest numbers of species/endemic species
2. Assess how much of the original forest remains and how fragmented it is
3. Determine which mangrove areas are currently protected
4. Determine how one can expect extinction risks to change

Methodology: spatially explicit metapopulation models for selected species

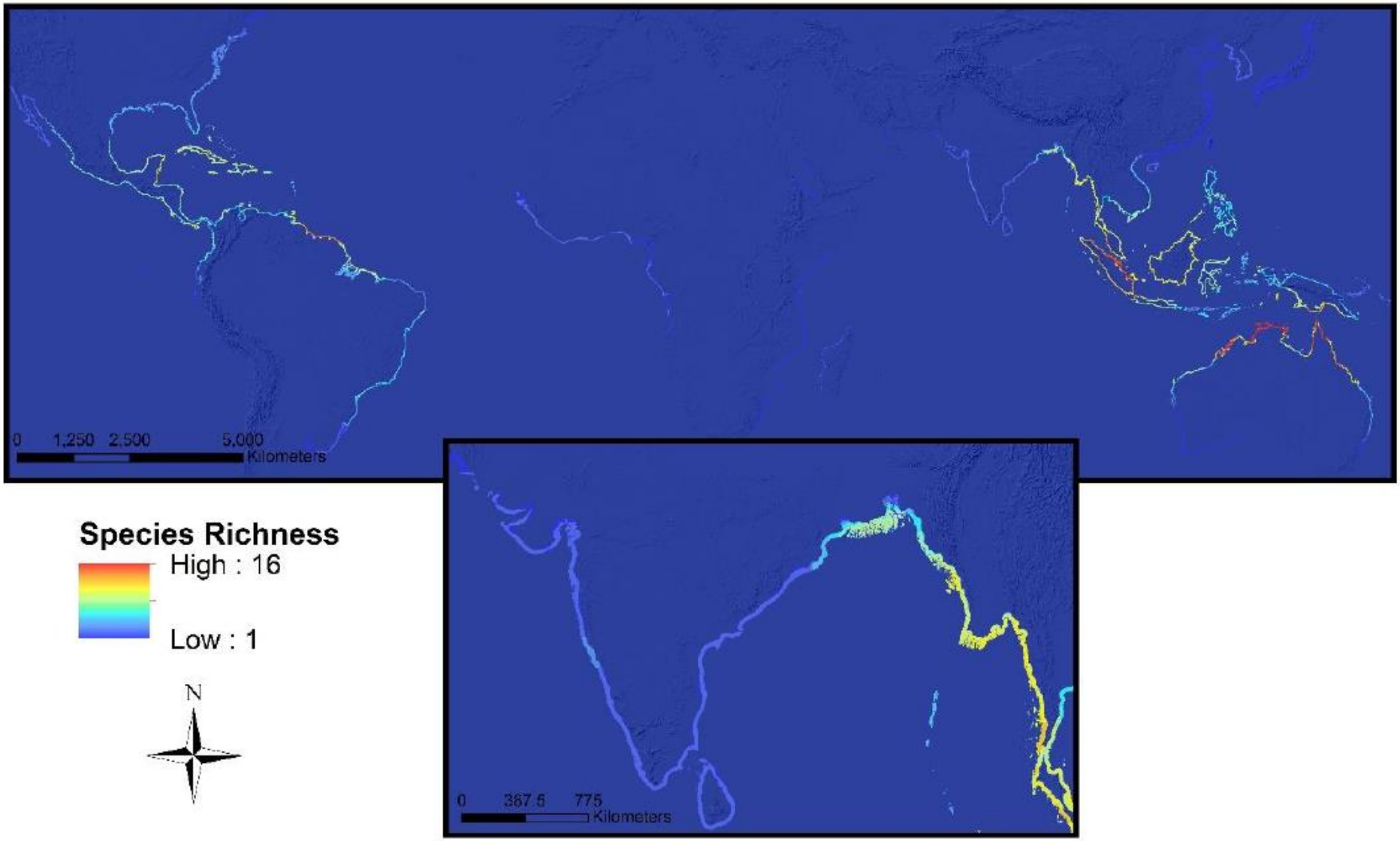


Figure 7. Global and South Asian maps of avian species that use mangroves as a major habitat.

Table 1. Calculated metapopulation capacities (λ) and metapopulation densities (Λ) for the years 2000 and 2015 as well as the percent change over the years.

Species	Metapop.	2000 λ (Λ)	2015 λ (Λ)	Δ λ (%)	Δ Λ (%)
P. megarhyncha	1	6.8E+12 (1564)	6.8E+12 (1564)	-0.048	-0.0028
P. megarhyncha	2	2.3E+11 (253)	1.8E+11 (290)	-27.867	12.826
P. megarhyncha	3	1.3E+11 (523)	1.3E+11 (525)	-0.049	0.435
P. megarhyncha	4	1.8E+12 (515)	1.7E+12 (522)	-1.357	1.350

Source: Darren Bellerby from Singapore, Singapore - Mangrove Pitta, CC BY 2.0
https://commons.wikimedia.org/w/index.php?curid=52651871

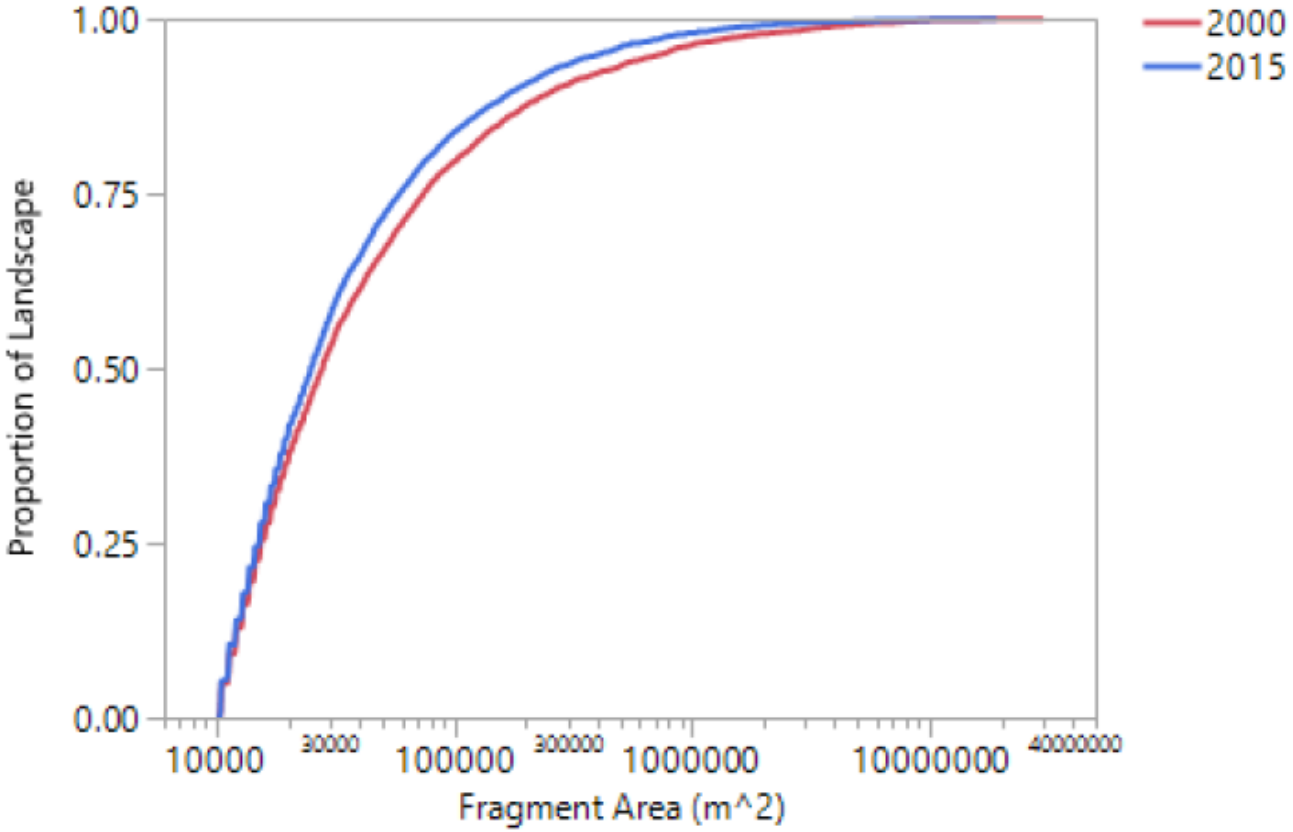


Figure 8. Cumulative distribution plot of fragment areas for the second metapopulation of *Pitta megarhyncha* for the years 2000 and 2015.

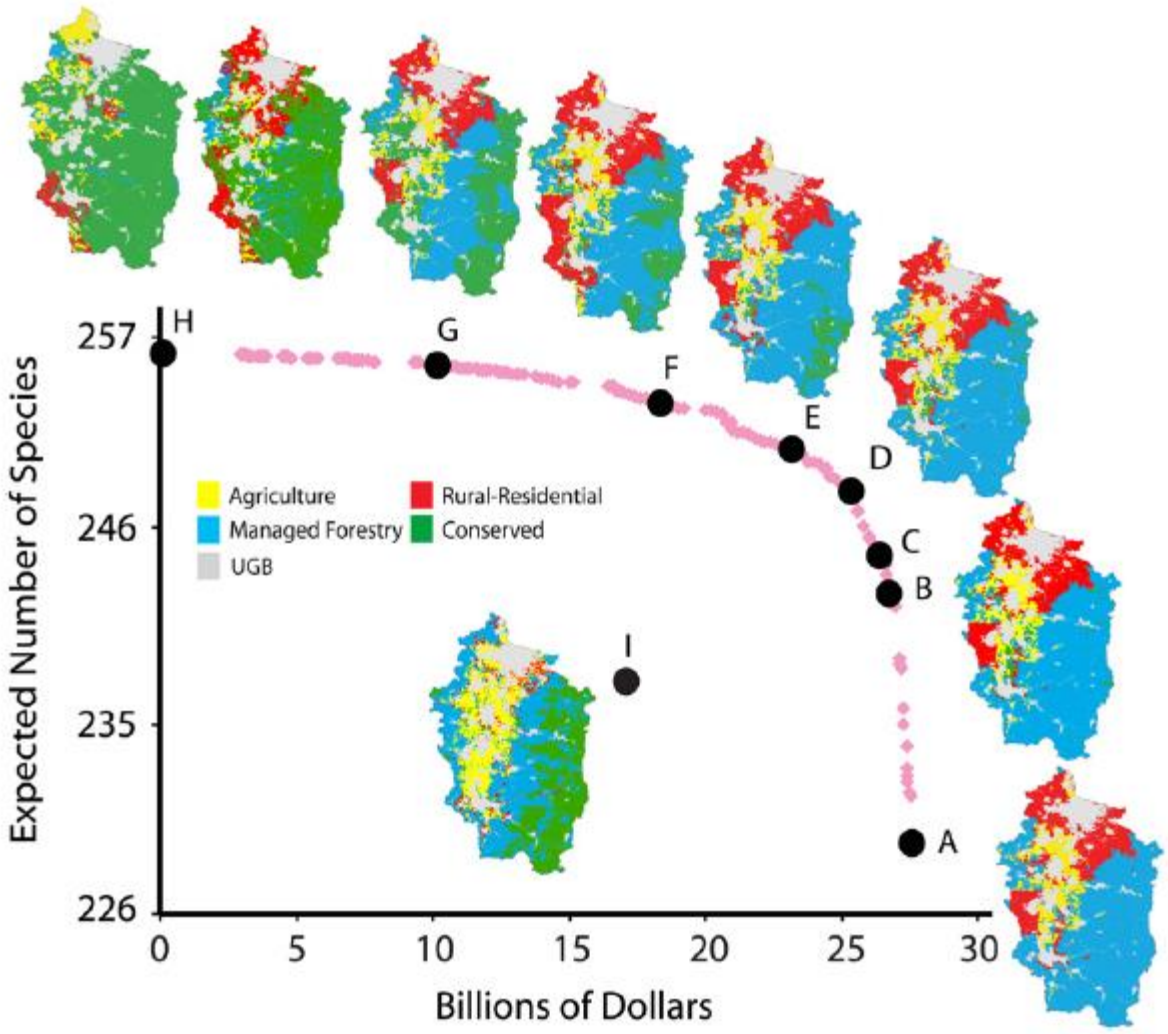
Economic analyses

Lead researchers: Jeffrey Vincent, Brian Murray, Wumeng He

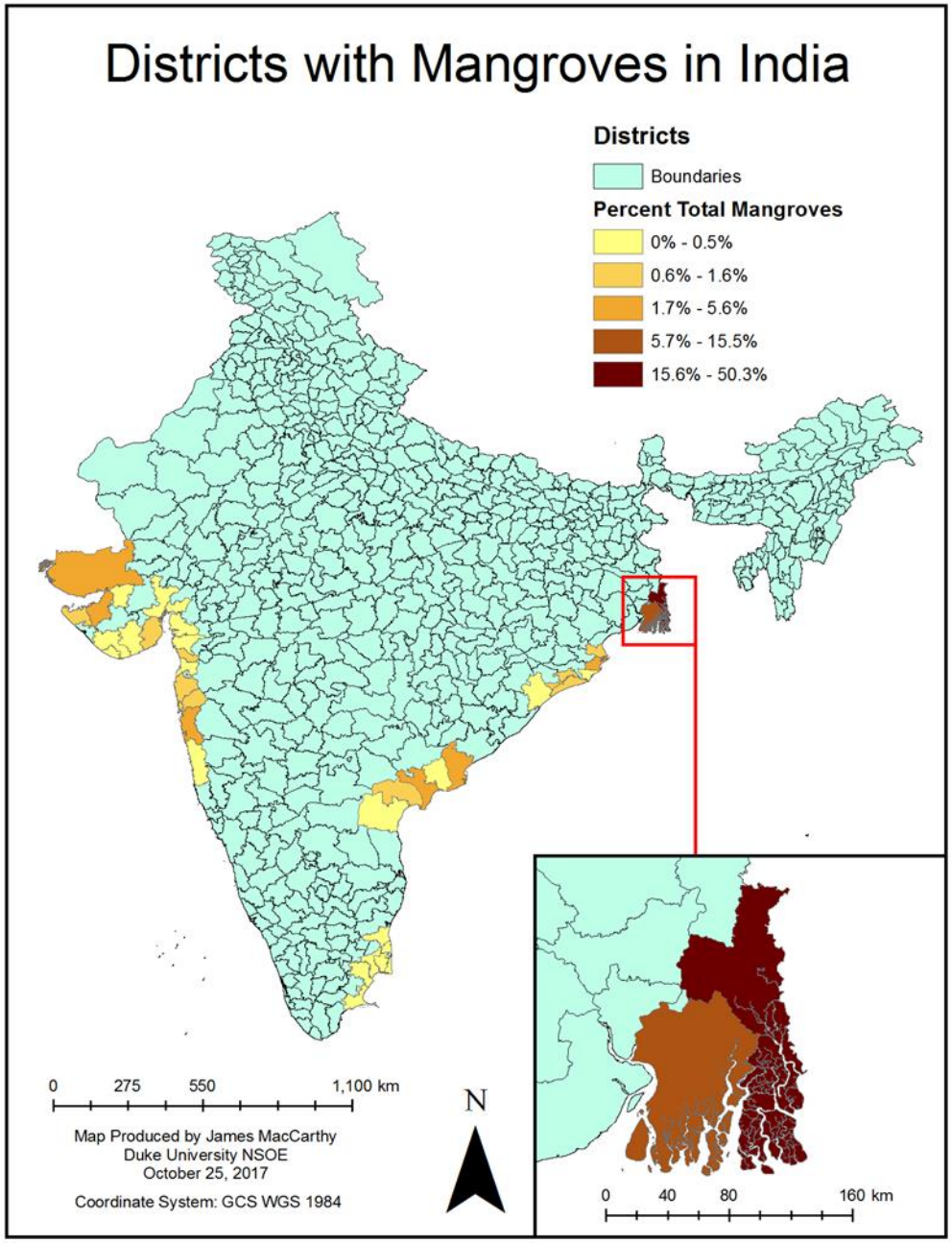
1. Cost-effective protection for carbon sequestration and biodiversity conservation
   - *Carbon stocks, extinction risks*: from previous slides
   - *Opportunity cost of protection*: household-level land values from National Sample Survey, interpolated using hedonic regressions

2. Effectiveness of existing PA system at reducing:
   - Area deforested
   - Carbon emissions
   - Species extinctions

   Methodology: difference-in-differences

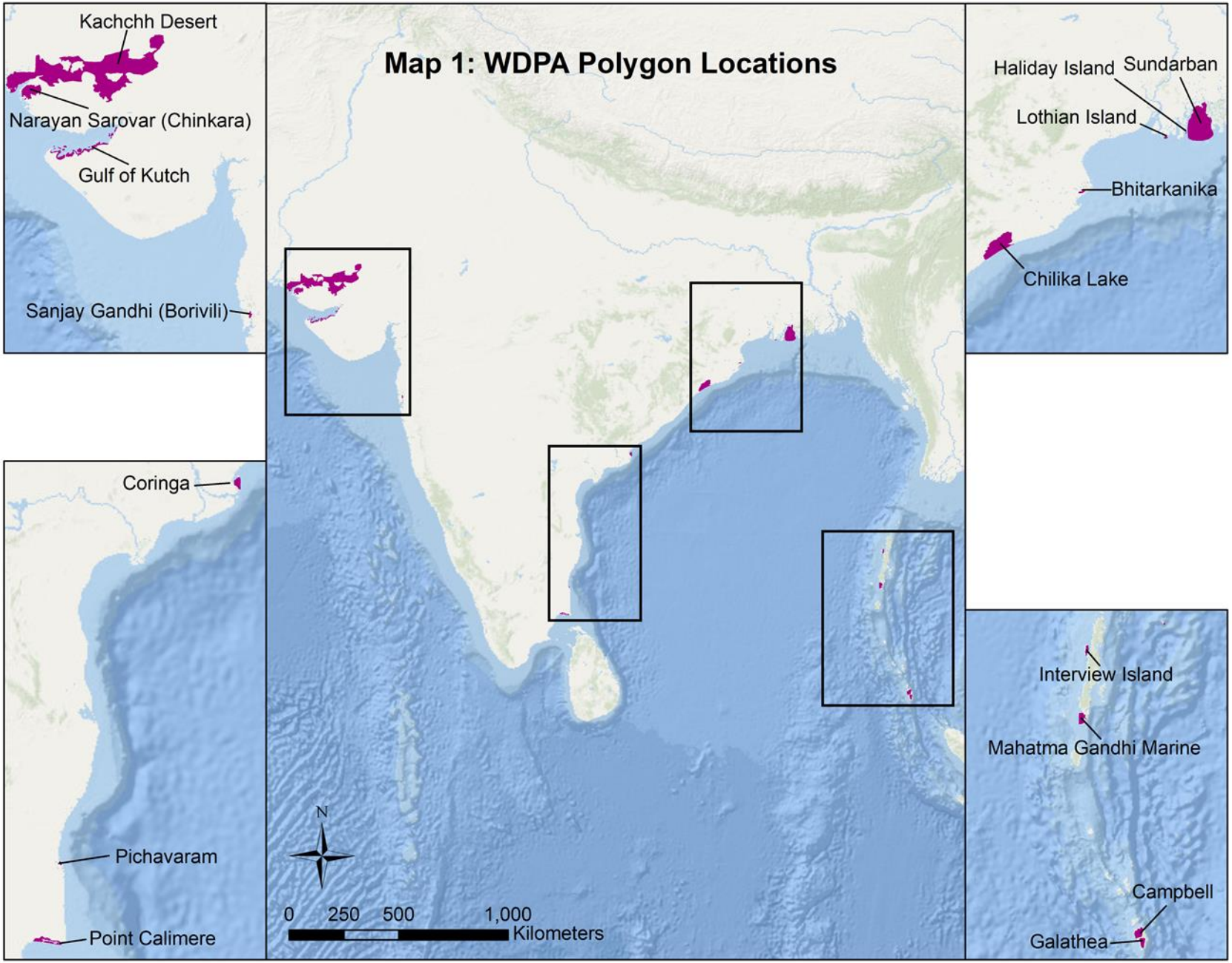


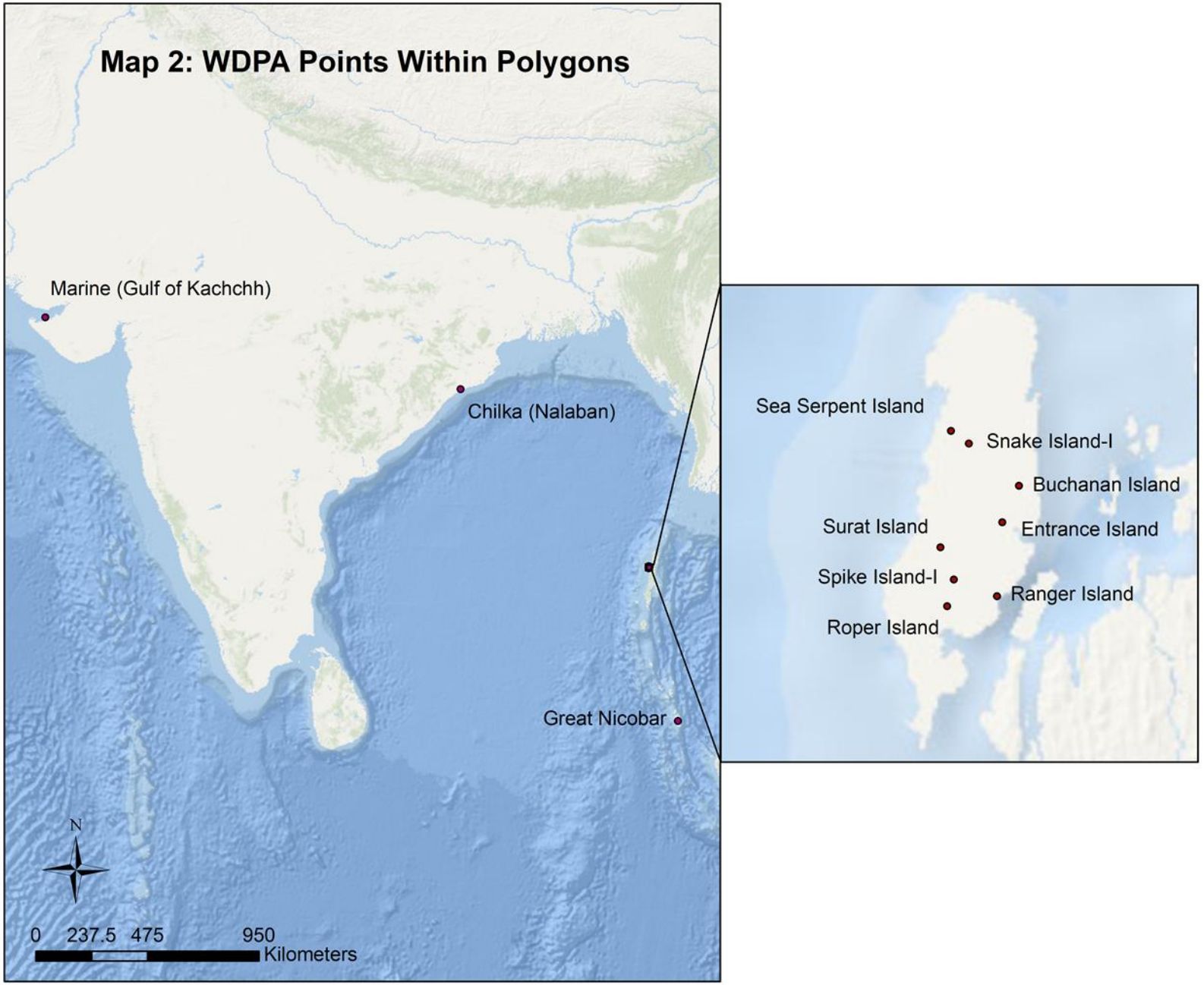
Source: Polasky et al., "Where to put things" (Biological Conservation, 2008)

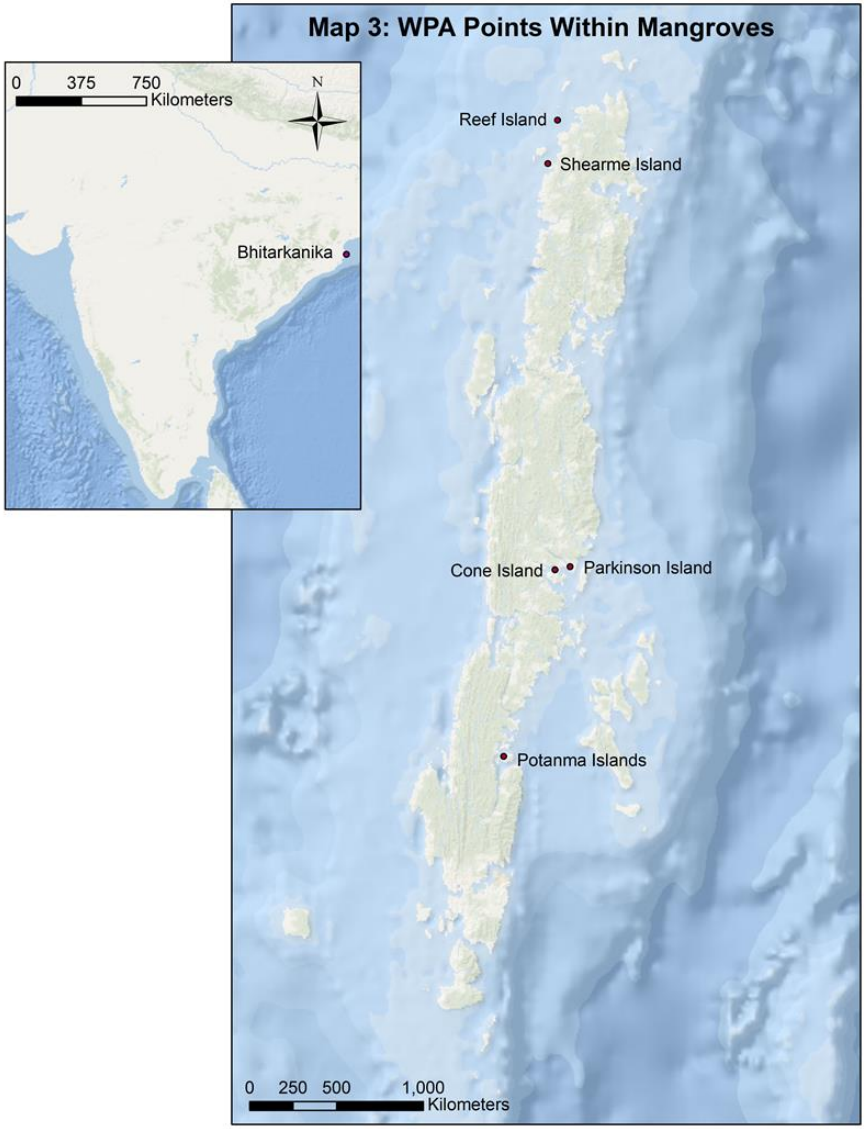

Districts with Mangroves in India
Districts
Boundaries
Percent Total Mangroves
0% - 0.5%
0.6% - 1.6%
1.7% - 5.6%
5.7% - 15.5%
15.6% - 50.3%
0
275
550
1,100 km
N
Map Produced by James MacCarthy
Duke University NSOE
October 25, 2017
Coordinate System: GCS WGS 1984
0
40
80
160 km

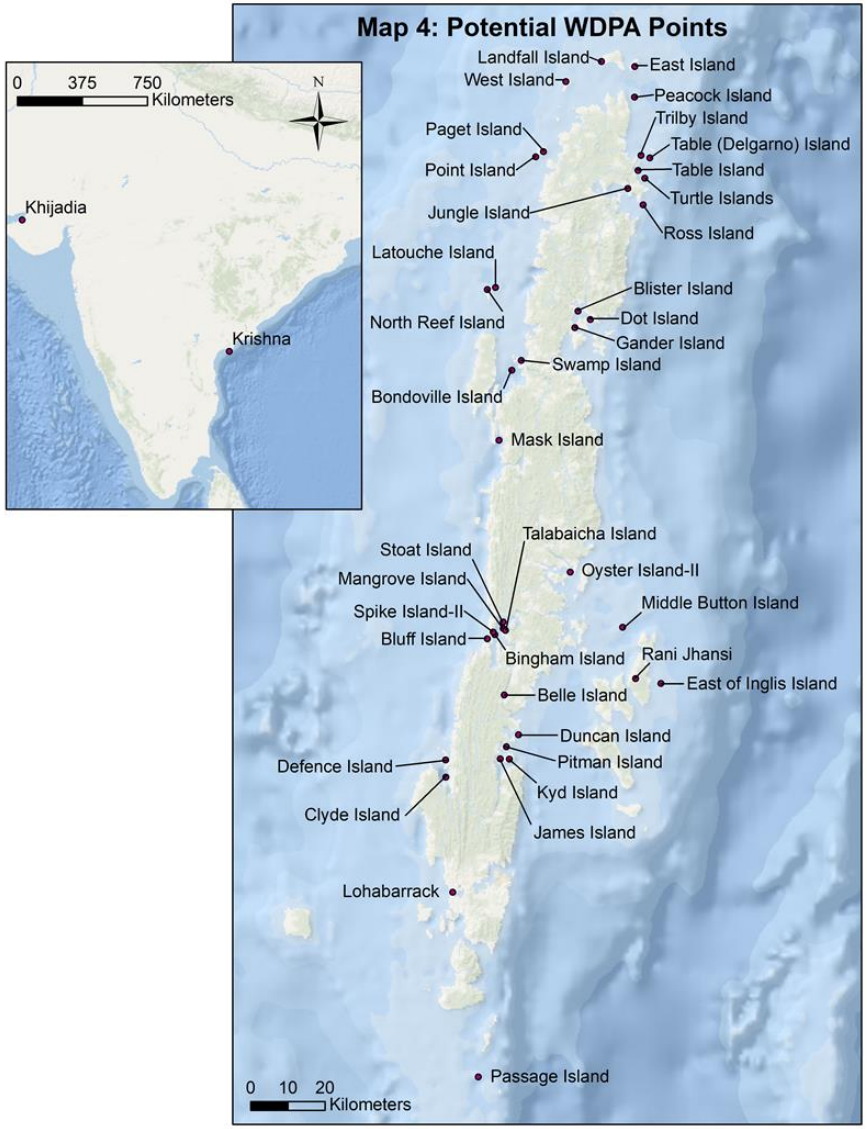
Statement 2.1: Number of villages/blocks surveyed and number of households surveyed for Schedule 18.2 Visit 1 and Visit 2: NSS 70th round, Central sample

State/UT	no. of fsu's (villages/blocks) surveyed		no. of sample households					
			Visit 1			Visit 2		
	rural	urban	rural	urban	rural+urban	rural	urban	rural+urban
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Andhra Pradesh	149	150	2070	2098	4168	2030	1971	4001
Arunachal Pradesh	47	32	560	448	1008	557	447	1004
Assam	214	68	2982	947	3929	2980	941	3921
Bihar	266	88	3671	1227	4898	3662	1210	4872
Chhattisgarh	85	56	1147	784	1931	1143	764	1907
Delhi	10	148	107	1955	2062	103	1767	1870
Goa	14	12	168	168	336	164	161	325
Gujarat	166	163	2302	2215	4517	2281	2145	4426
Haryana	78	76	1037	1047	2084	1034	1015	2049
Himachal Pradesh	88	24	1111	334	1445	1102	322	1424
Jammu & Kashmir	92	68	1242	947	2189	1239	936	2175
Jharkhand	102	68	1369	936	2305	1358	899	2257
Karnataka	170	168	2340	2344	4684	2313	2200	4513
Kerala	159	160	2167	2232	4399	2117	2140	4257
Madhya Pradesh	250	192	3428	2665	6093	3406	2587	5993
Maharashtra	330	328	4589	4536	9125	4559	4317	8876
Manipur	96	80	1328	1117	2445	1328	1116	2444
Meghalaya	68	36	930	504	1434	930	504	1434
Mizoram	47	48	604	672	1276	602	657	1259
Nagaland	44	28	616	392	1008	616	392	1008
Odisha	214	84	2954	1173	4127	2935	1129	4064
Punjab	94	92	1270	1286	2556	1262	1253	2515
Rajasthan	214	140	2933	1936	4869	2904	1843	4747
Sikkim	40	24	548	335	883	548	331	879
Tamil Nadu	246	244	3429	3413	6842	3386	3234	6620
Telangana	97	94	1344	1310	2654	1331	1235	2566
Tripura	104	72	1456	1008	2464	1453	1008	2461
Uttarakhand	39	32	523	446	969	522	442	964
Uttar Pradesh	618	356	8587	4956	13543	8505	4797	13302
West Bengal	326	300	4527	4175	8702	4508	4037	8545
A & N Islands	20	12	237	165	402	231	152	383
Chandigarh	8	16	112	222	334	104	194	298
Dadra & N. Haveli	8	8	112	112	224	111	100	211
Daman & Diu	8	8	112	112	224	111	100	211
Lakshadweep	10	8	111	112	223	107	104	211
Puducherry	8	24	112	336	448	108	321	429
all-India	**4529**	**3507**	**62135**	**48665**	**110800**	**61650**	**46771**	**108421**


Map 1: WDPA Polygon Locations
Kachchh Desert
Narayan Sarovar (Chinkara)
Gulf of Kutch
Sanjay Gandhi (Borivili)
Haliday Island
Sundarban
Lothian Island
Bhitarkanika
Chilika Lake
Coringa
Pichavaram
Point Calimere
Interview Island
Mahatma Gandhi Marine
Campbell
Galathea
N
0 250 500 1,000
Kilometers


Map 2: WDPA Points Within Polygons
Marine (Gulf of Kachchh)
Chilka (Nalaban)
Great Nicobar
Sea Serpent Island
Snake Island-I
Buchanan Island
Surat Island
Entrance Island
Spike Island-I
Ranger Island
Roper Island
N
0 237.5 475 950
Kilometers


Map 3: WPA Points Within Mangroves
0 375 750 Kilometers
N
Bhitarkanika
Reef Island
Shearme Island
Cone Island
Parkinson Island
Potanma Islands
0 250 500 1,000 Kilometers


Map 4: Potential WDPA Points
0 375 750 Kilometers
N
Khijadia
Krishna
Landfall Island
West Island
East Island
Peacock Island
Trilby Island
Paget Island
Table (Delgarno) Island
Point Island
Table Island
Turtle Islands
Jungle Island
Ross Island
Latouche Island
Blister Island
North Reef Island
Dot Island
Gander Island
Swamp Island
Bondoville Island
Mask Island
Talabaicha Island
Stoat Island
Oyster Island-II
Mangrove Island
Middle Button Island
Spike Island-II
Bluff Island
Bingham Island
Rani Jhansi
East of Inglis Island
Belle Island
Duncan Island
Pitman Island
Defence Island
Kyd Island
Clyde Island
James Island
Lohabarrack
Passage Island
0 10 20 Kilometers