Land Cover/Land Use Change SARI International Regional Science Meeting in South/Southeast Asia, Chiang Mai, Thailand (17-19th July, 2017)

EVALUATING THE STATUS AND ECOSYSTEM SERVICES OF MYANMAR'S MANGROVES (2000-2014)

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Mangroves

- Mangrove forests are believed to play an important role in stabilizing shorelines and reducing the devastating impact of tsunami, hurricanes, cyclones, and other extreme weather events.

- They also provide important ecological and societal goods and services including breeding and nursing grounds for marine and pelagic species, firewood and timber to local communities, and carbon sequestration (blue carbon).

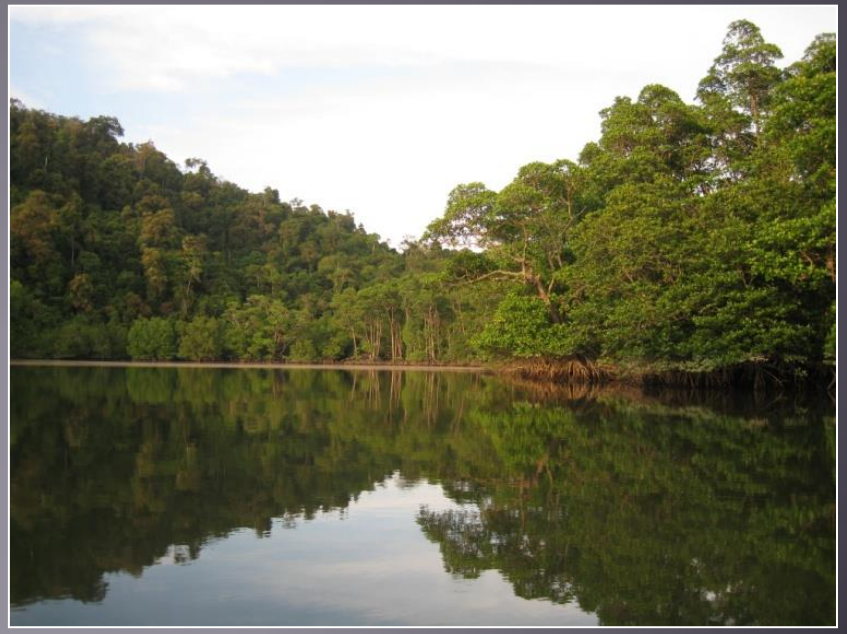
- The mangrove forests, however, are declining at an alarming rate—perhaps even more rapidly than inland tropical forests.

- Many of the remaining mangroves are degraded and under immense pressure from clear cutting encroachment, hydrological alterations, chemical spill, and climate change.

- The degradation of mangroves can no longer serve as a strong natural buffer against storm winds and waves.

According to (MONREC, 2014), Myanmar has 0.66 million ha (1.6 million acres) of mangrove forest areas. However, there are about 0.35 million ha (0.85 million acres) of other land uses encroaching in the mangrove areas.

A recent study reported that the highest rate of deforestation (4.68%) occurred in mangrove forests, with over 42% of the total mangrove forest area cleared within 10 years (Wang and Myint, 2016).



photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Objectives

(1) To assess and monitor deforestation and reforestation of mangrove forests in Myanmar using Landsat.

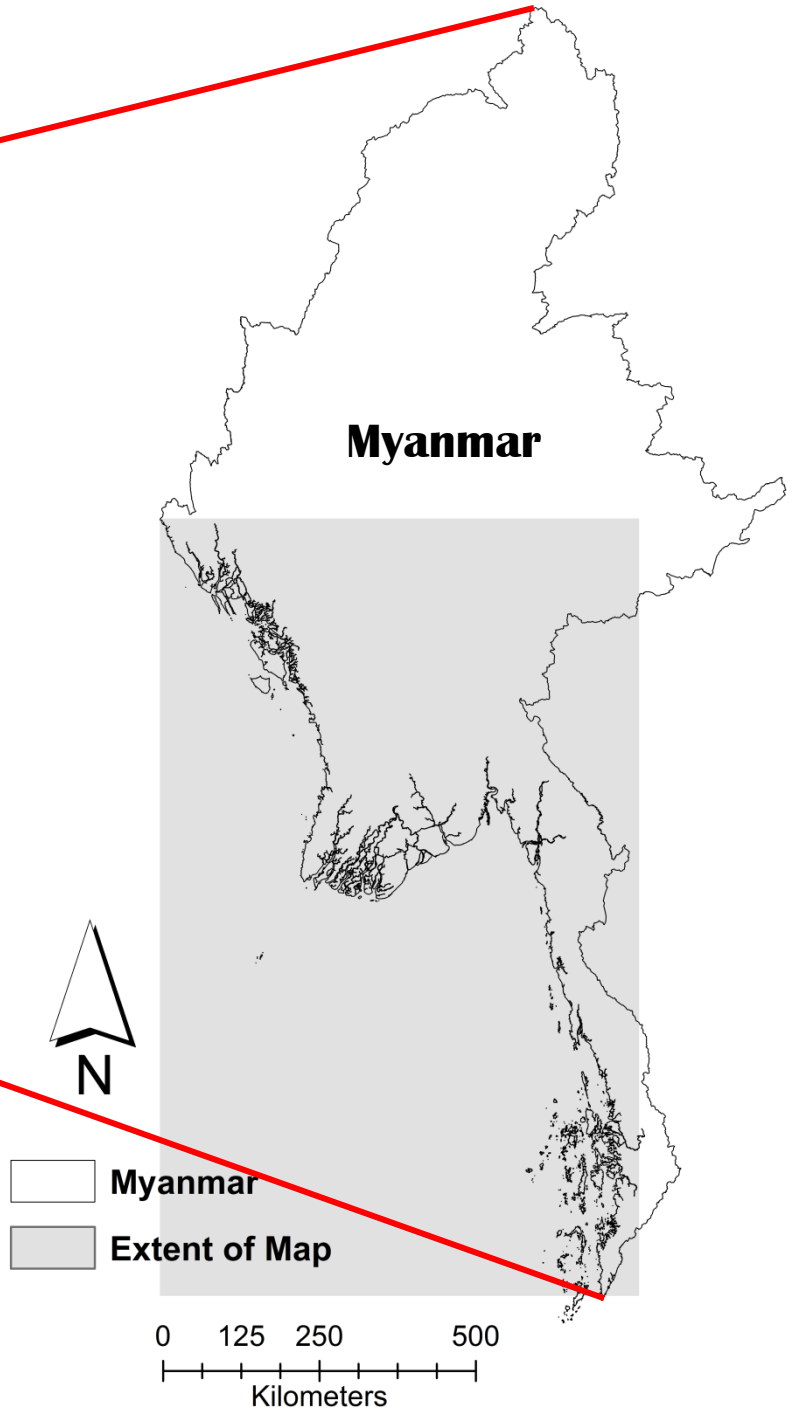
(2) To perform the valuation of ecosystem services.

(3) To analyze the spatio-temporal patterns of carbon flux, evapotranspiration, land surface temperatures, and percent tree cover using MODIS products.

(4) To examine the relations between mangrove deforestation rates and trend of the above ecosystem services.

Study Area


MYANMAR
VIETNAM
LAOS
THAILAND
CAMBODIA
South China Sea
PHILIPPINES
Philippine Sea
BRUNEI
MALAYSIA
MALAYSIA
SINGAPORE
INDONESIA
Timor-Leste


Myanmar
N
Myanmar
Extent of Map
0 125 250 500
Kilometers

photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Potential Drivers of Deforestation and Forest Degradation

(1) Charcoal burning

(2) Agriculture expansion

(3) Shrimp/fish farming activities

(4) Fuelwood production

(5) Shifting cultivation/Slash and burn

(6) Commercial timber extraction

(7) Village settlement

(8) Local household/infrastructure uses

(9) Dam construction

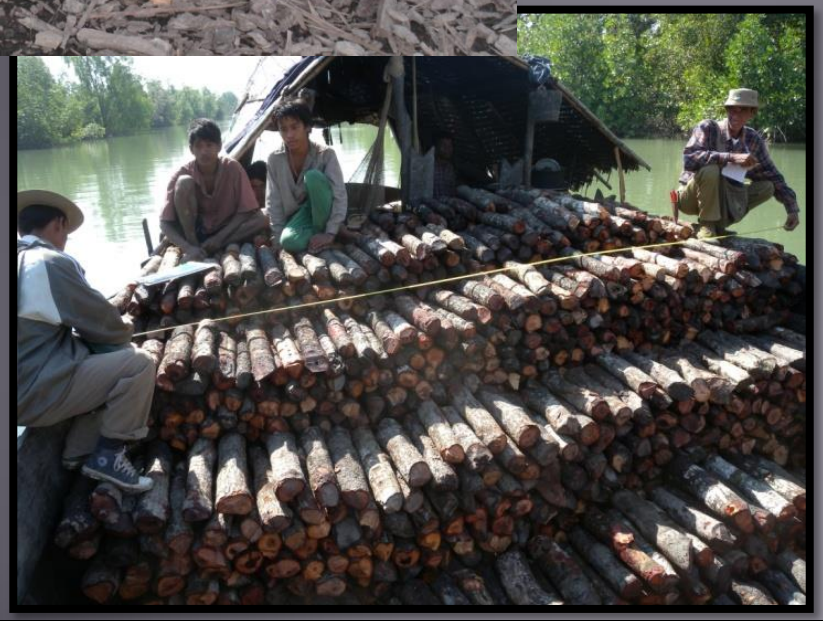
(10) Wildfire

(11) Storm events

Encroachment of agriculture land in mangroves

photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Fuel wood and Charcoal Kiln



photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Aquaculture/ Tiger Shrimp Ponds by clearing mangroves

photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Mangroves and 2004 Indian Ocean Tsunami

photos courtesy of Dr. Toe Toe Aung, Mangrove Conservation Unit, Forest Department, MONREC, Myanmar

Data and Study Area

(1) Landsat TM 5, ETM+ 7, and OLI 8 Tier1 & 2 data (19 scenes per year = 38 scenes total)

(2) MODIS Percent Tree Cover (PTC) layer (MOD44B)

(3) MODIS Net Primary Productivity or Carbon (NPP) (MOD17A3H)

(4) MODIS annual ET imagery (MOD16A3)

(5) MODIS LST 8-day composite data (MOD11A2)

Classification

- Unsupervised classifier (ISODATA) using 100 clusters per scene and merged appropriate clusters to identify mangroves.

- The original bands excluding thermal band and soil adjusted vegetation index (SAVI) were used.

- 300 validation points selected by local forest officers in 3 different key states and regions. 100 additional points selected by the Mangrove Conservation Unit, Forest Department, Ministry of Environmental Conservation and Forestry (Total 400 points).

- 400 non-mangrove points were selected inside mangroves (e.g., agriculture, open land, shrimp firm) and within ~300 m buffer around mangroves.

Spatio-Temporal Analysis

(1) A time-series trend analysis for PTC, carbon stock, ET, and LST image stacks was then performed. The 10-year pixel values from each image stack were used as the dependent variable and analyzed against the year sequence (2000-2014) using the Mann-Kendall (MK) test.

(2) Only pixels that have statistically significant changes (p-value$\leq$0.05) were retained.

(3) A slope coefficient map was generated for each image stack.

Mann-Kendall (MK) Test

The original Mann-Kendall (MK) test is a non-parametric statistical test frequently used for analysis of trend in hydrologic and climatologic data. It statistically assesses whether a monotonic increasing or decreasing trend of a variable is present over time. Unlike parametric regression analysis, the MK test does not require the trend to be linear, nor does it require normality in the observed data.

$$S = \sum_{k-1}^{n-1} \sum_{j-k+1}^{n} sgn(x_j - x_k)$$

where x_j and x_k are observations obtained at times 1, 2, …, n, respectively. *S* is positive if data collected later in time tend to be greater than those obtained earlier, and vice versa. Under the assumption of independent observations, the MK statistic can be approximated by a normal distribution when the number of observations exceeds 10, with mean and variance given by

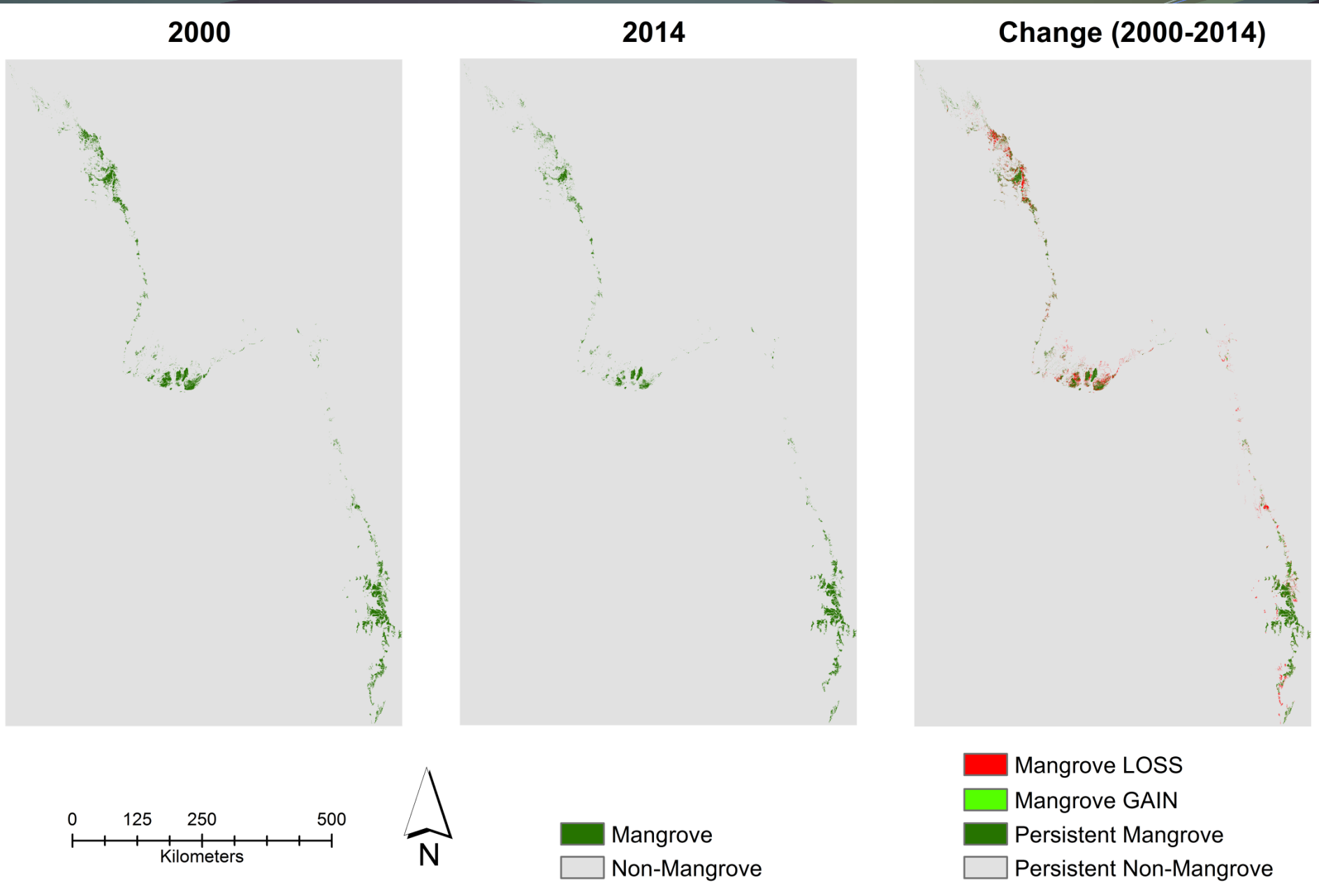
$$E(S) = 0$$

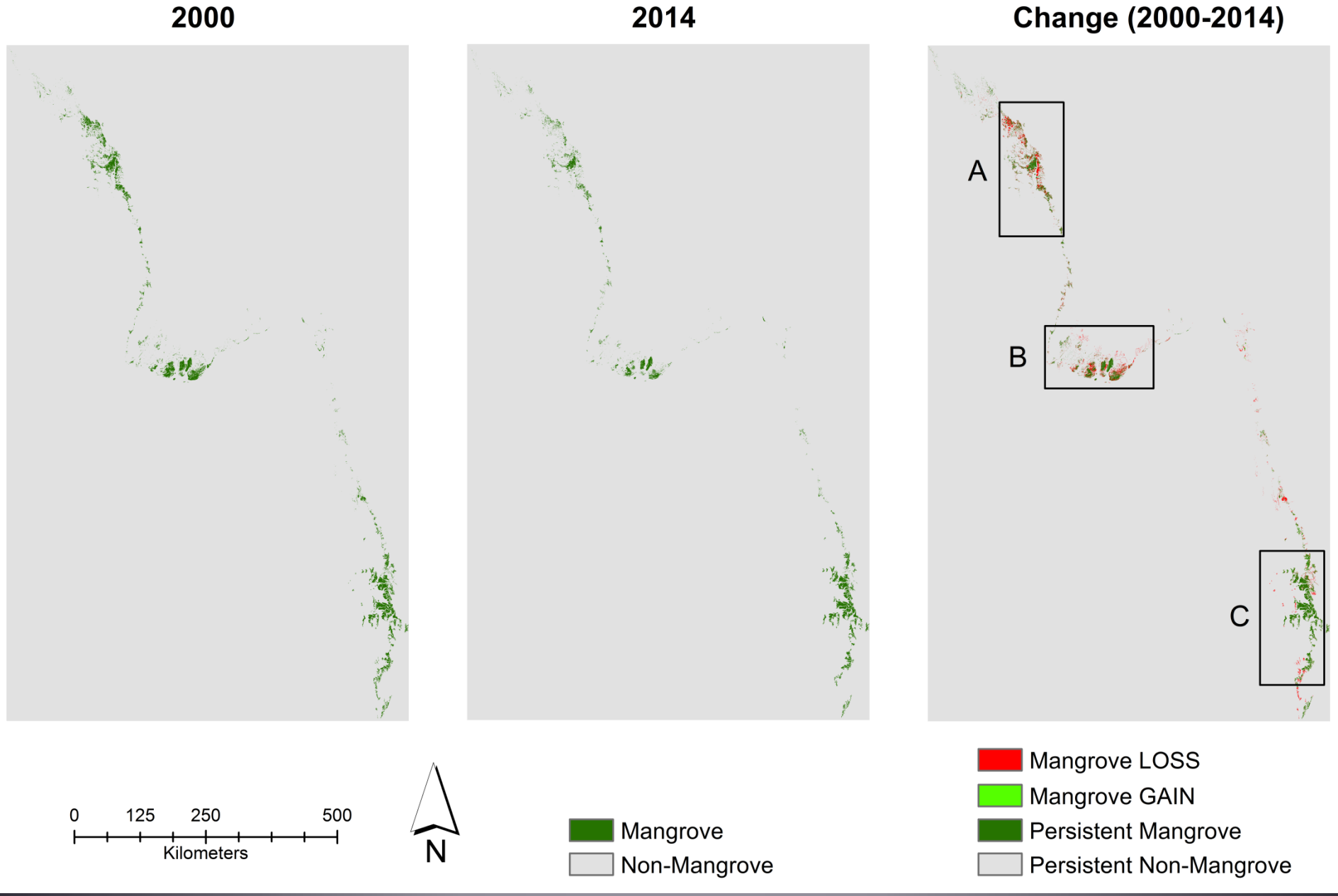
$$var(S) = n(n-1)(2n+5)/18$$

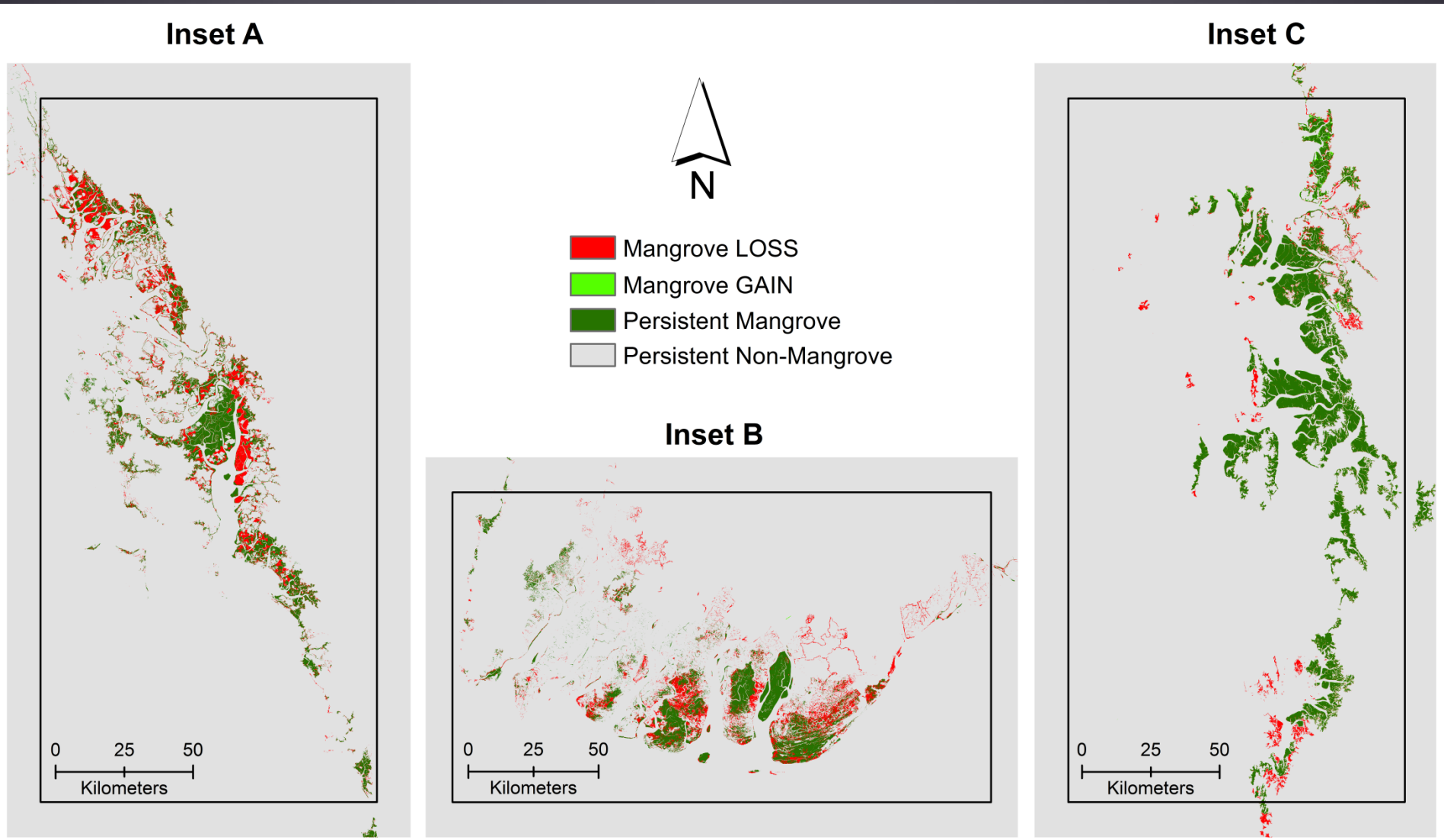
The adjusted variance of the MK statistic is

$$var_m(S) = var(S) \cdot \frac{n}{n_S^*}$$

$$\frac{n}{n_S^*} = 1 + \frac{2}{n(n-1)(n-2)} \sum_{i=1}^{n-1} (n-i)(n-i-1)(n-i-2)\rho_S(i)$$


2000
2014
Change (2000-2014)
0
125
250
500
Kilometers
N
Mangrove
Non-Mangrove
Mangrove LOSS
Mangrove GAIN
Persistent Mangrove
Persistent Non-Mangrove


2000
2014
Change (2000-2014)
A
B
C
0
125
250
500
Kilometers
N
Mangrove
Non-Mangrove
Mangrove LOSS
Mangrove GAIN
Persistent Mangrove
Persistent Non-Mangrove


Inset A
Inset B
Inset C
N
Mangrove LOSS
Mangrove GAIN
Persistent Mangrove
Persistent Non-Mangrove
0
25
50
Kilometers
0
25
50
Kilometers
0
25
50
Kilometers

Accuracy Assessment

MA: the point was labeled as mangrove in both classification process and reference data

NA: the point was labeled as non-mangrove in both classification process and reference data

NW: the point was labeled as mangrove in classification process and as non-mangrove in reference data

MW: the point was labeled as non-mangrove in classification process and as mangrove in reference data

Therefore, MA = 384, NA = 392, NW = 8, MW = 16 (Total = 800 points)

Completeness $\frac{MA}{MA+MW} = \frac{384}{400} = 96\%$

Correctness $\frac{MA}{MA+NW} = \frac{384}{384+8} = 97.95\%$

Overall Accuracy $\frac{MA+NA}{MA+NA+NW+MW} = \frac{776}{800} = 97\%$

Mangrove Forest Change Rate (Country Level)

Unit: Hectares (ha)

2000	2014		2000 Total
	Mangrove	Non-Mangrove	
Mangrove	482,034	215,680	697,714
Non-Mangrove	16,238	98,140,691	98,156,929
2014 Total	498,272	9,8356,371	

	% of 2000 Total Mangrove	% per year (2000-2014)	ha per year (2000-2014)
LOSS	30.91	2.21	15,406
GAIN	2.33	0.17	1,160

Mangrove Loss and Gain by State and Region

State/Region	Persistent Non-Mangrove Area (ha)	Persistent Mangrove Area (ha)	MANGROVE_LOSS Area (ha)	MANGROVE_GAIN Area (ha)
Ayeyarwady	3,491,631	104,781	69,518	5
Kayin	3,321,529	51	340	20
Mon	1,212,583	2,130	6,067	404
Rakhine	3,598,666	129,289	75,496	2
Tanintharyi	3,023,573	224,657	52,781	13,141
Yangon	1,066,916	1,461	1,024	0.09

Mangrove Loss and Gain by States and Regions

State/Region	2000 Mangrove	2014 Mangrove	% of 2000 Mangrove		% per year (2000-2014)		ha per year (2000-2014)	
	Area (ha)	Area (ha)	LOSS	GAIN	LOSS	GAIN	LOSS	GAIN
Ayeyarwady	174,299	104,785	39.88	0.00	2.85	0.00	4,966	0.32
Kayin	392	72	86.87	5.17	6.20	0.37	24	1.45
Mon	8,197	2,534	74.01	4.93	5.29	0.35	433	29
Rakhine	204,785	129,291	36.87	0.00	2.63	0.00	5,393	0.12
Tanintharyi	277,437	237,797	19.02	4.74	1.36	0.34	3,770	939
Yangon	2,485	1,461	41.20	0.00	2.94	0.00	73	0.01

Ecosystem Service Value (ESV) Calculations based on 'Value Transfer Method'

$$ESV_{C,S} = \sum A_m \times VC_{i..n}$$

$ESV_{C,S}$ refers to the total ecosystem service value of a Country (Myanmar) or a State/Region; A_m is the area (ha) of Mangrove in a Country or State/Region; $VC_{i..n}$ is the value of ecosystem service

Note: Ecosystem Service Value (ESV) coefficients were referred from Salem and Mercer (2012).

Recent Study using Value Transfer:

Yi et al. (2017) Impacts of Land Change on Ecosystem Services in the San Antonio River Basin, Texas, from 1984 to 2010. *Ecological Economics* 135:125–135.

Valuation of Ecosystem Services (National)

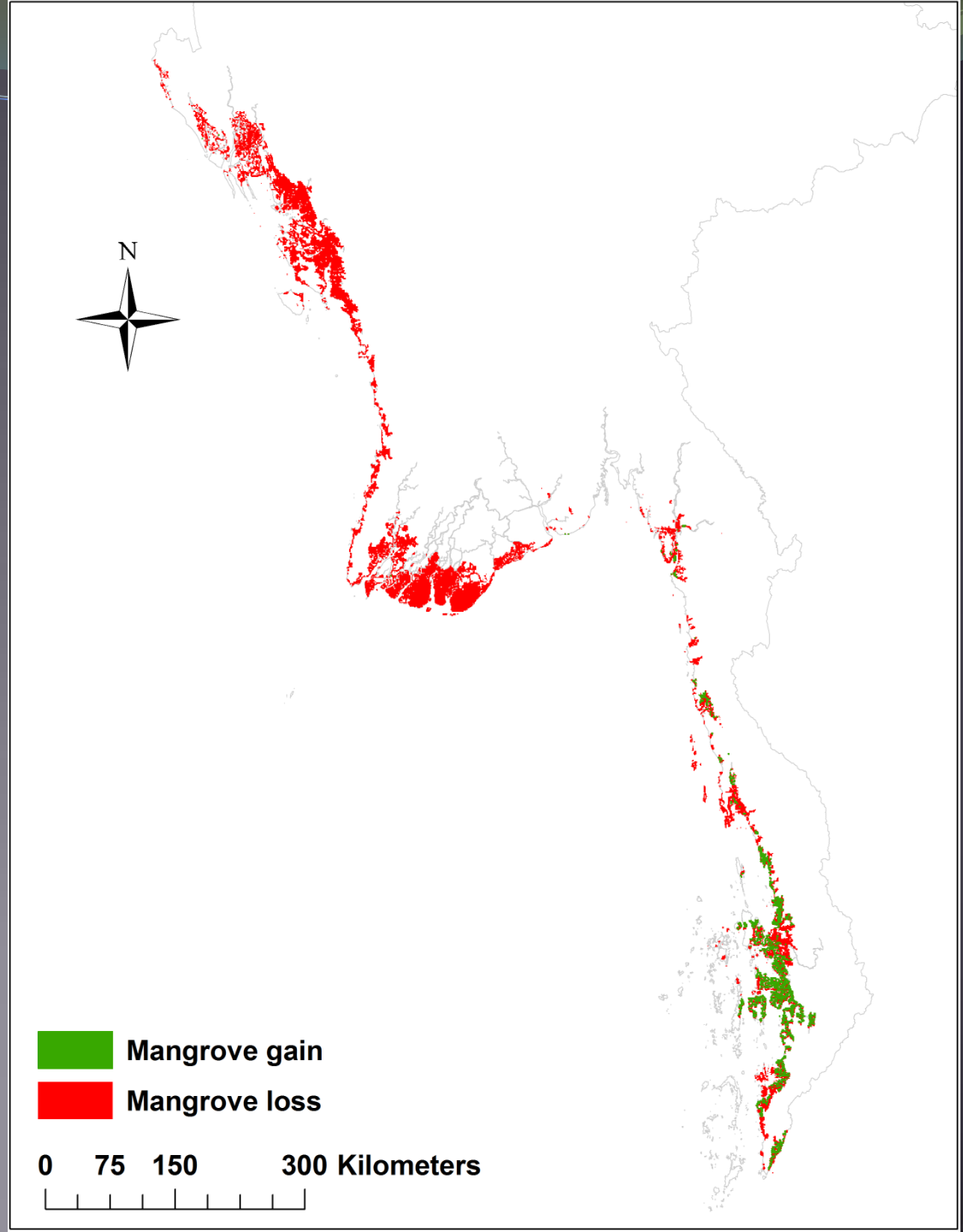
Ecosystem Services	ESV (in Million US$ per year)		
	2000	2014	Net Change (2000-2014)
Fisheries	16,475	11,765	-4,709
Forestry	26,593	18,991	-7,601
Coastal protection	2,174	1,552	-621
Recreation & tourism	26,462	18,897	-7,564
Nutrient retention	30	21	-8.78
Carbon sequestration	674	481	-192
Nonuse (existence and bequest)	12,121	8,656	-3,464
Biodiversity	36	25	-10
Water and air purification/waste assimilation	3,312	2,365	-946
Traditional uses	79	56	-22
TOTAL	**87,960**	**62,816**	**-25,143**
Total Decrease (% of 2000)			**28.59**

Note: Values are in 2010 US$ based on the Ecosystem Service Value (**ESV**) coefficients of Salem and Mercer (2012).

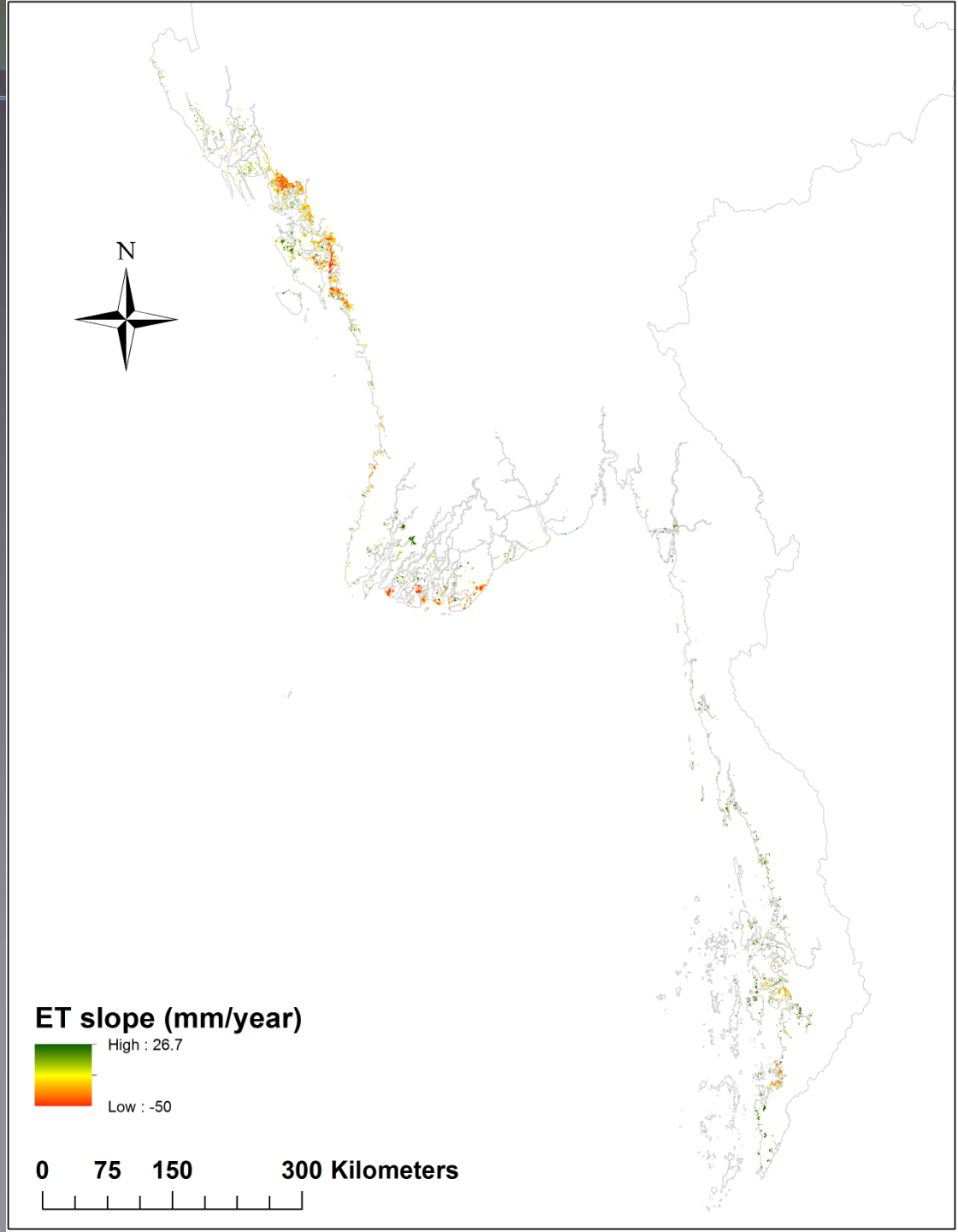
Valuation of Ecosystem Services (States and Regions)

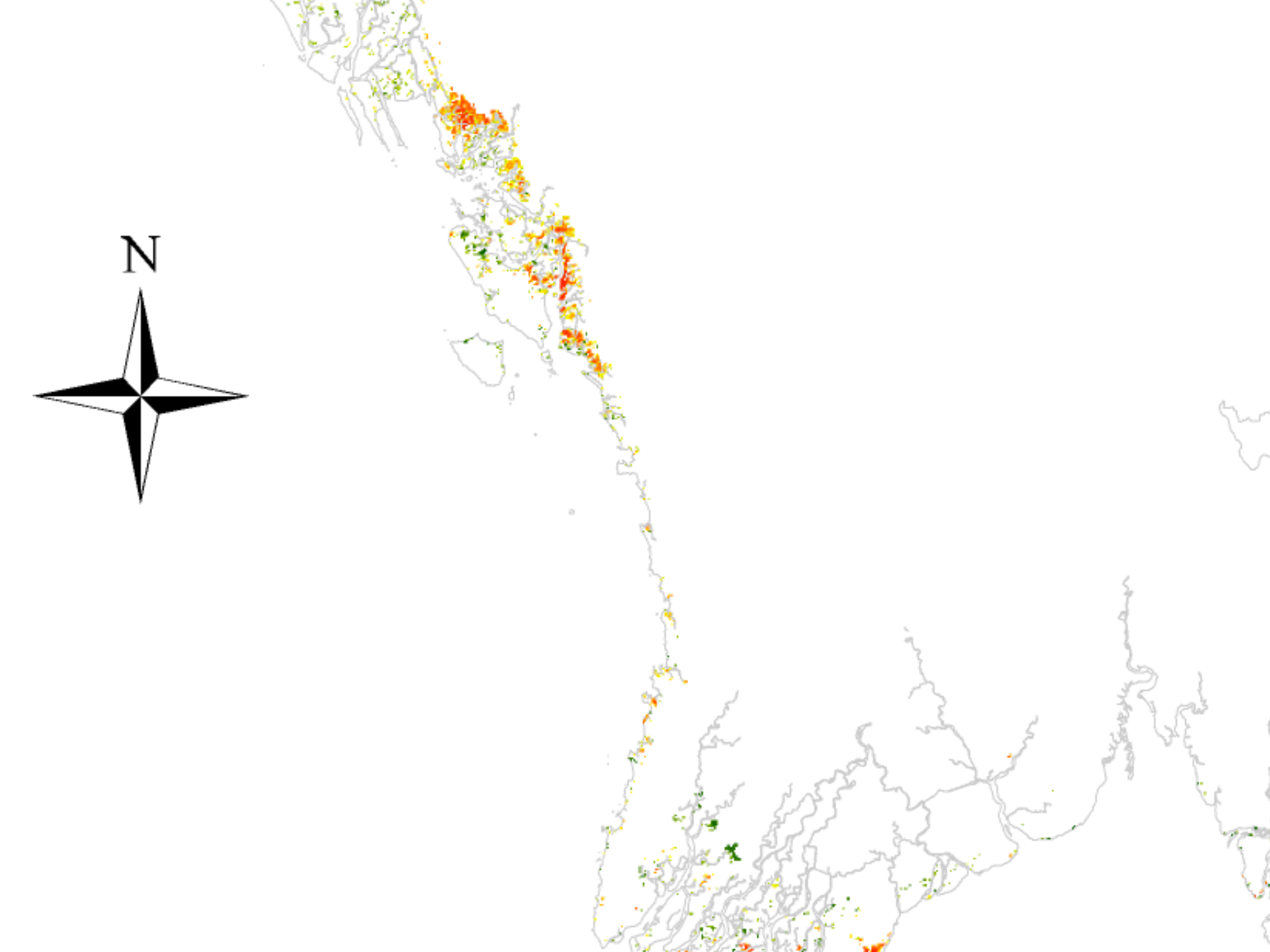
State/Region	ESV (in Million US$ per year)			Total Decrease (% of 2000)
	2000	2014	Net Change (2000-2014)	
Ayeyarwady	21,974	13,210	-8,763	39.88
Kayin	49	9	-40	81.70
Mon	1,033	319	-714	69.08
Rakhine	25,817	16,300	-9,517	36.87
Tanintharyi	34,976	29,979	-4,997	14.29
Yangon	313	184	-129	41.20

Mangrove Gain and Loss

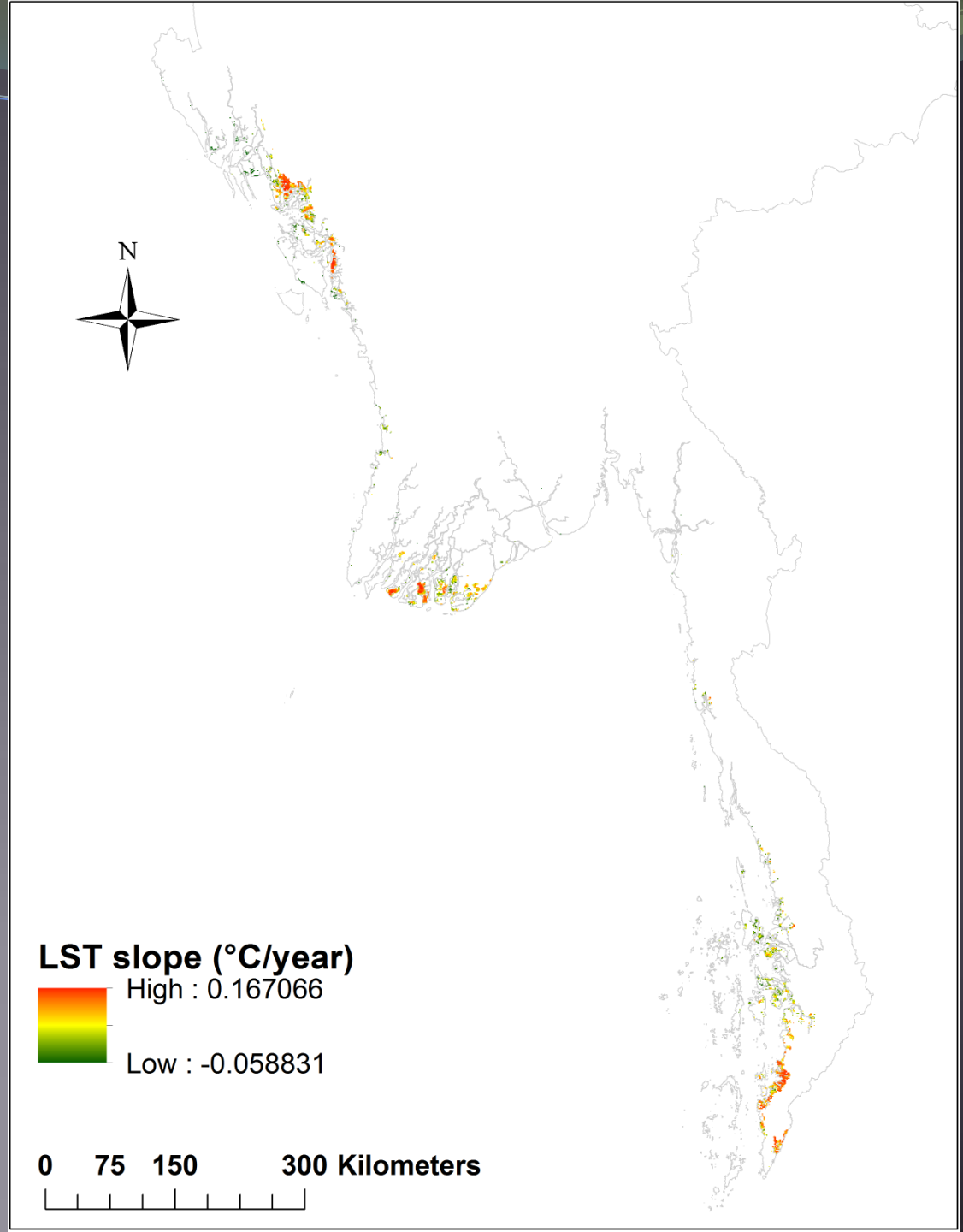


ET Trend (Slope)

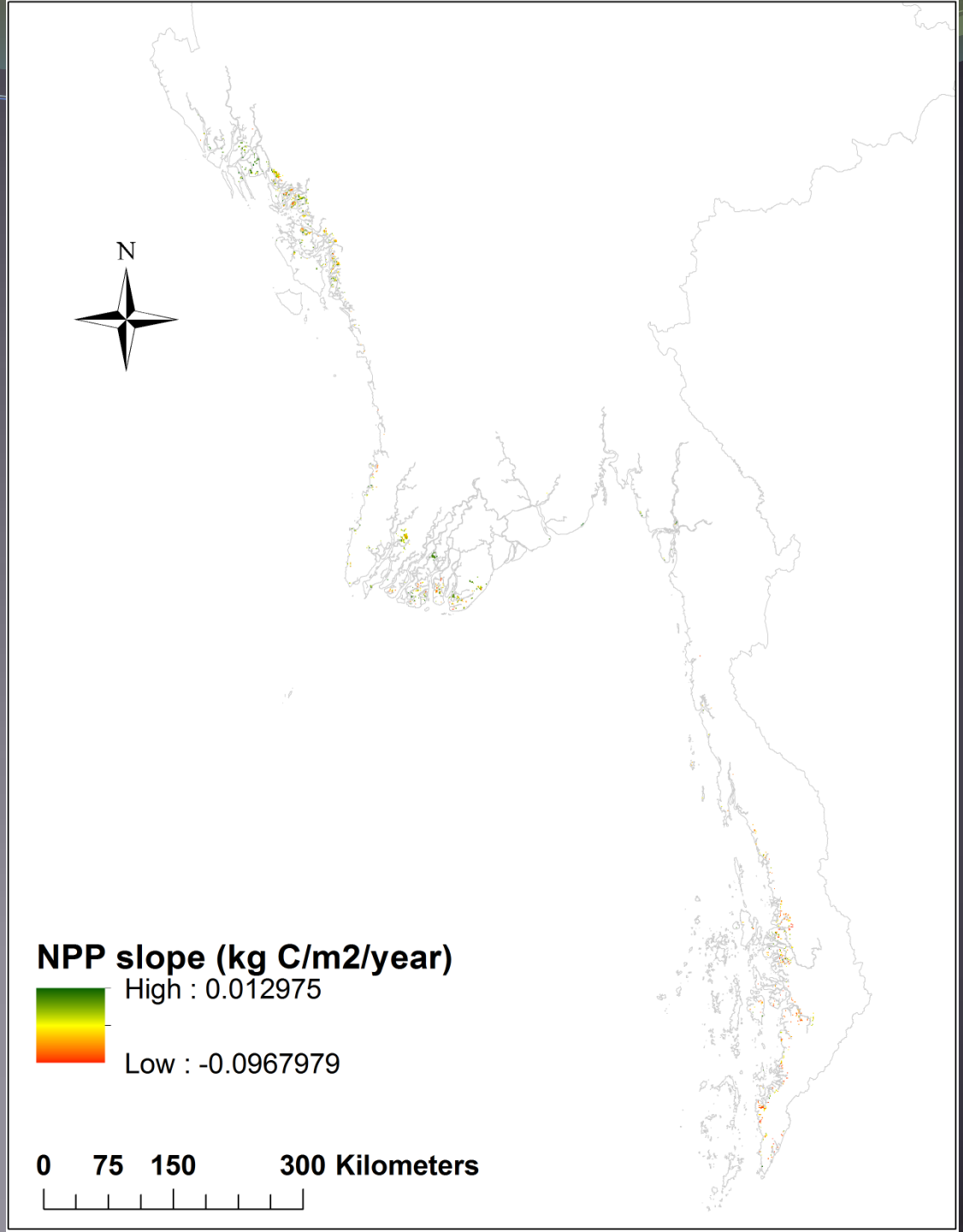


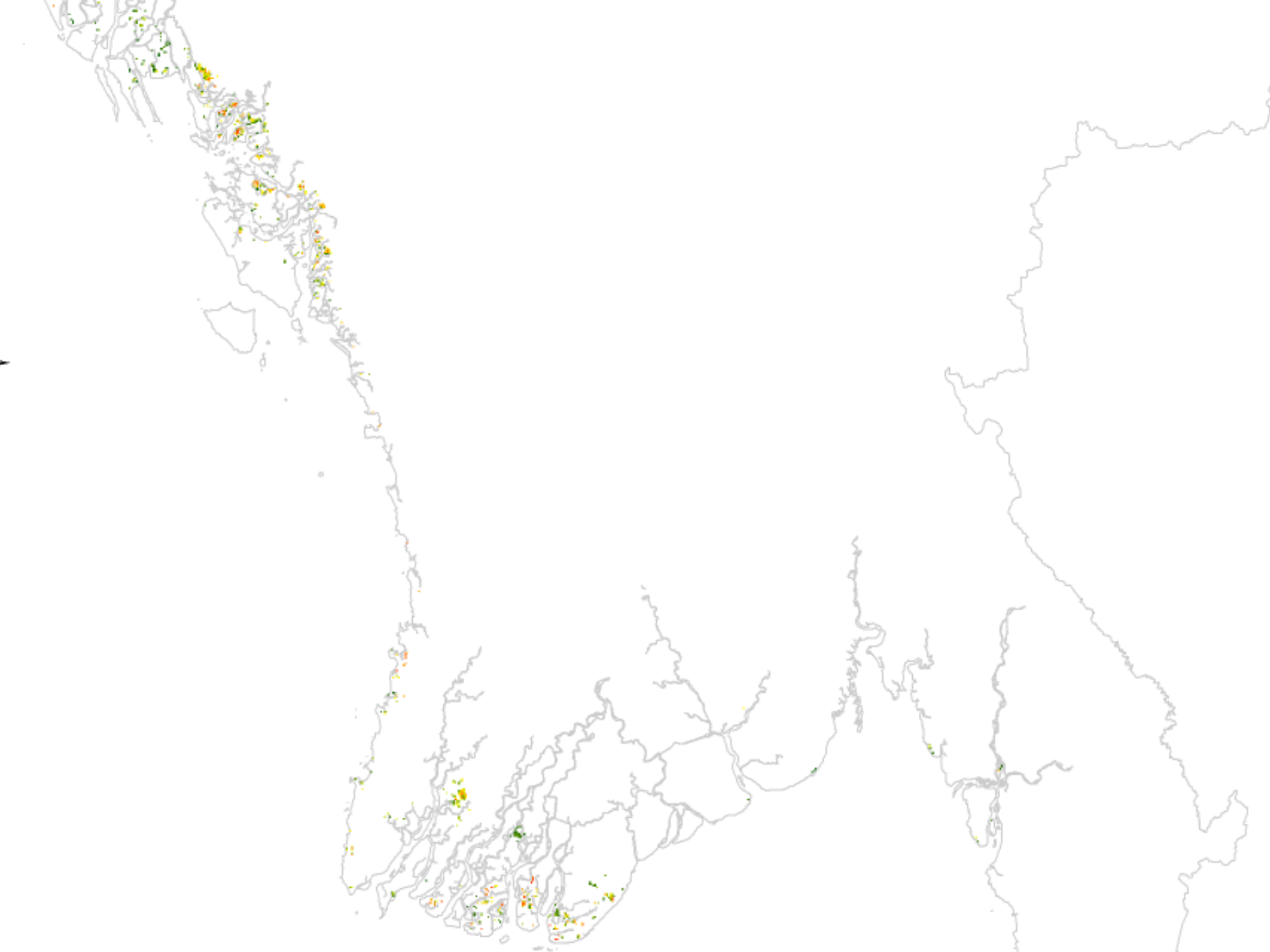

N

LST Trend (Slope)

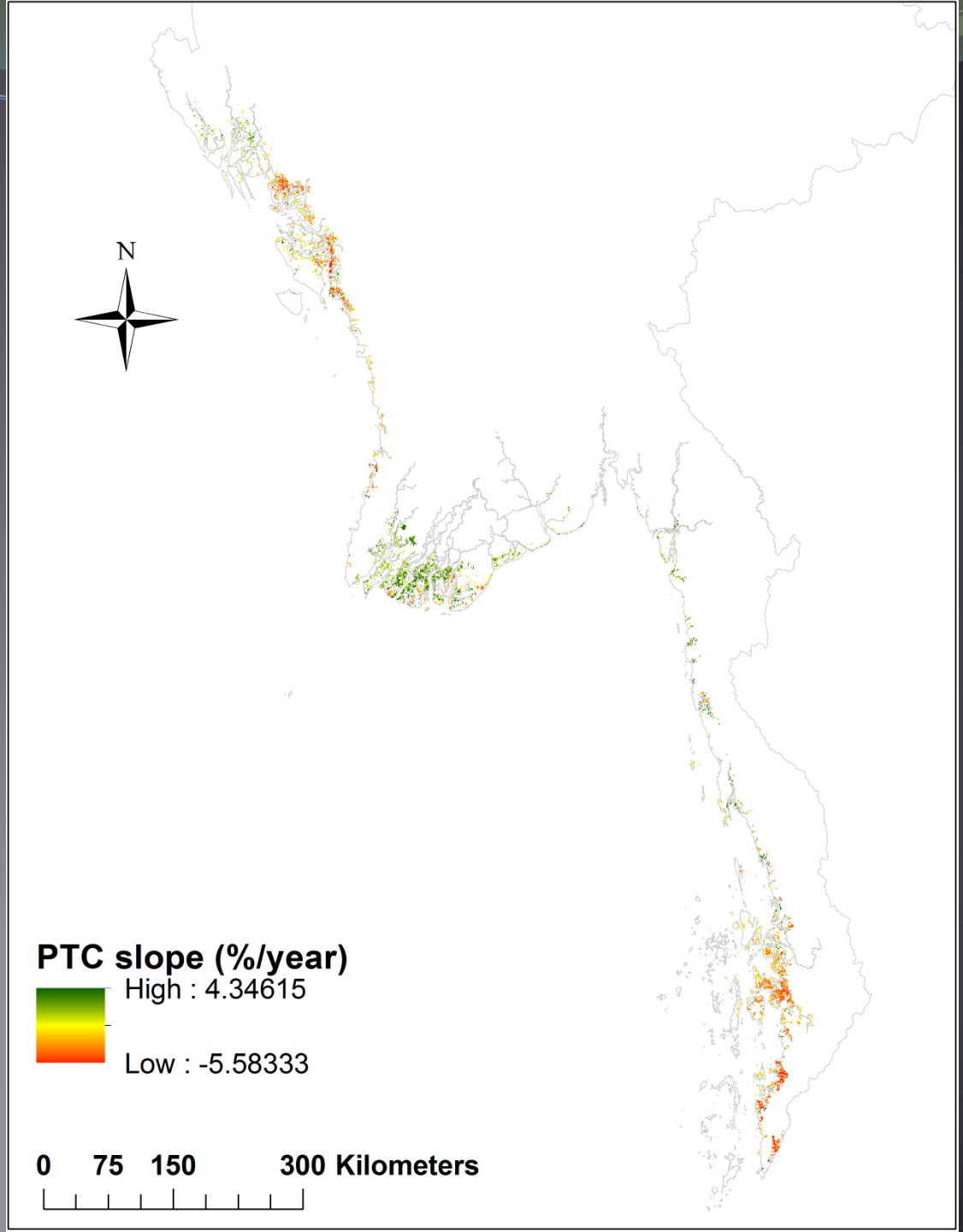


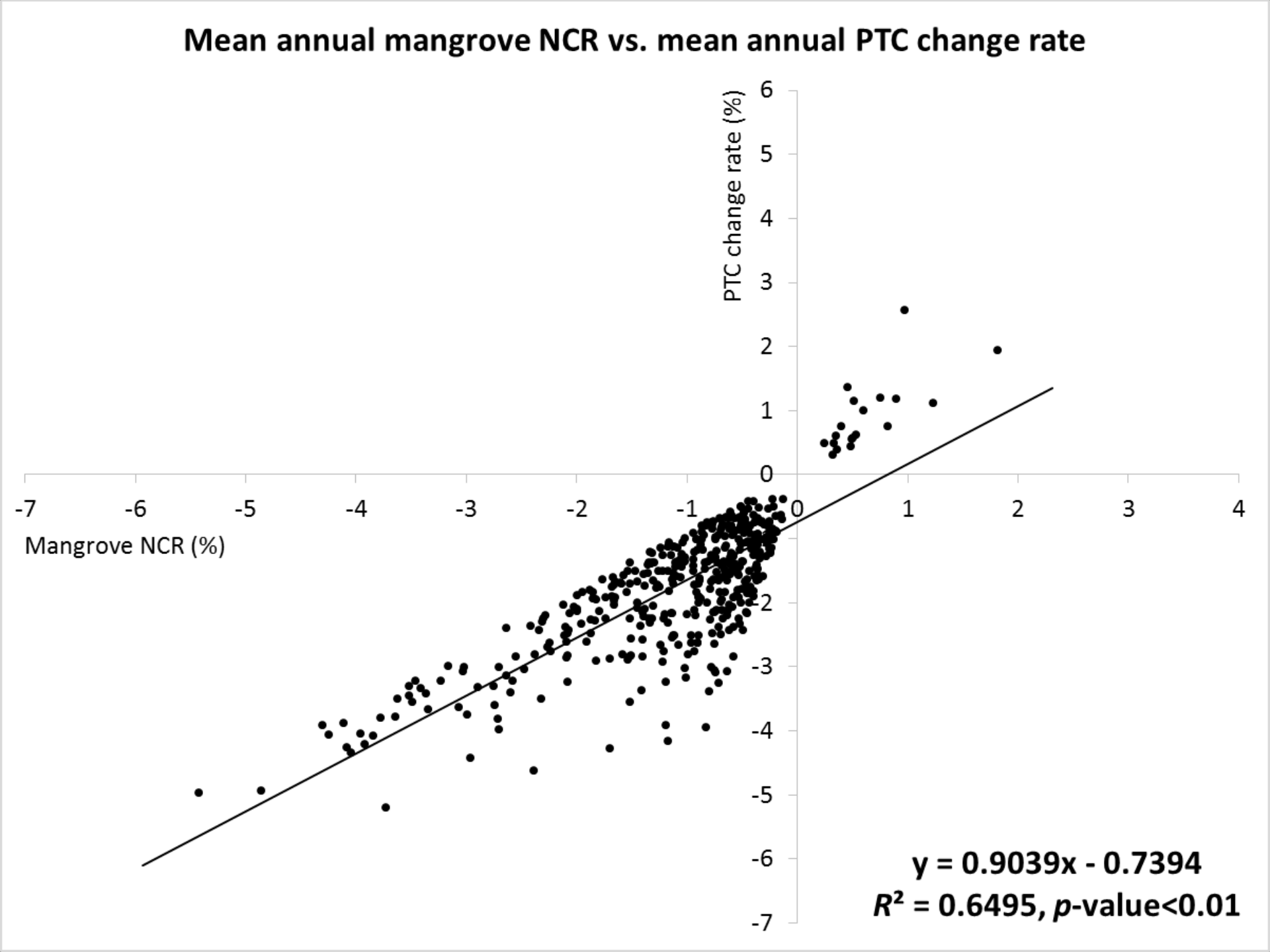
NPP Trend (Slope)

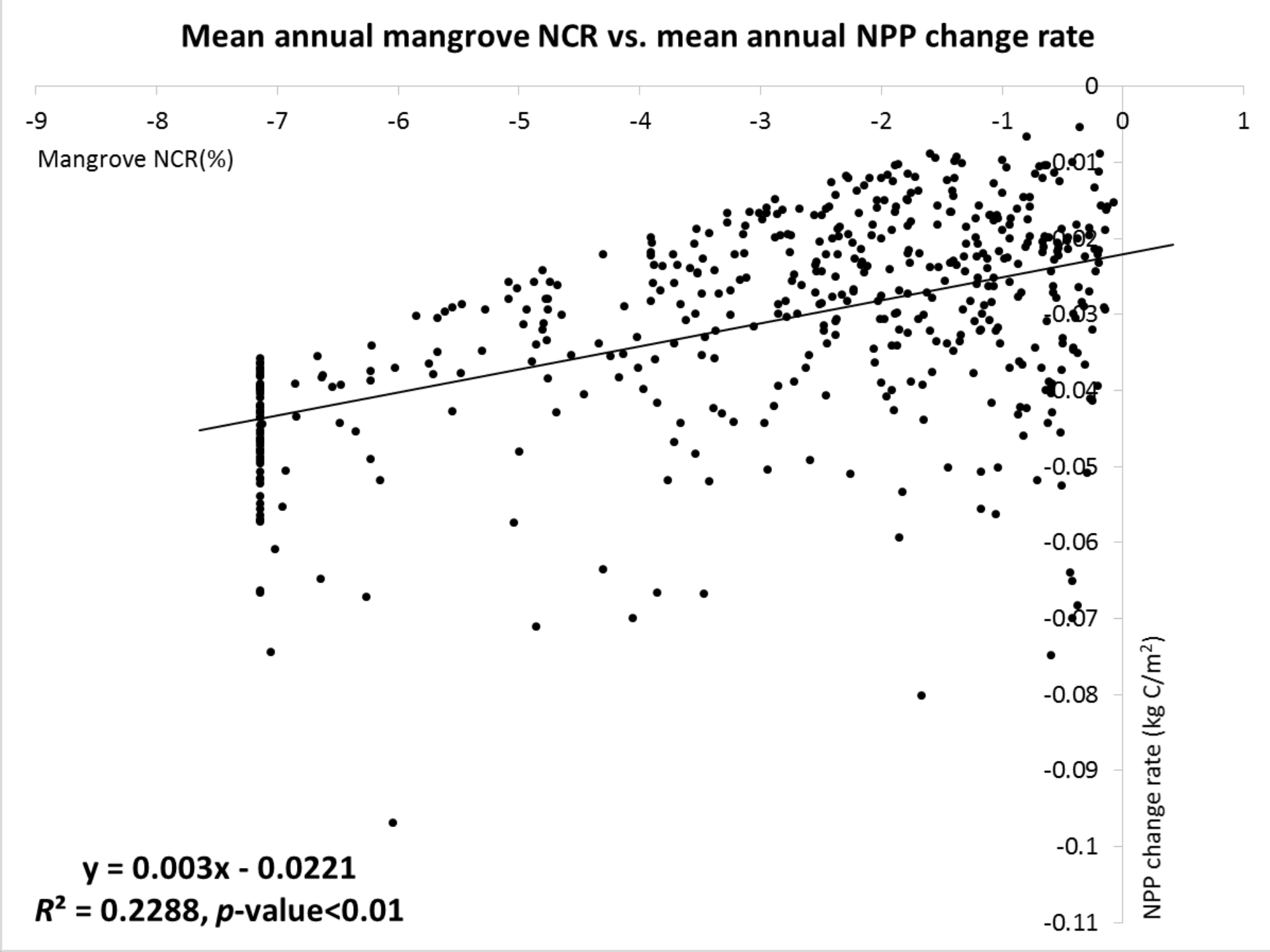


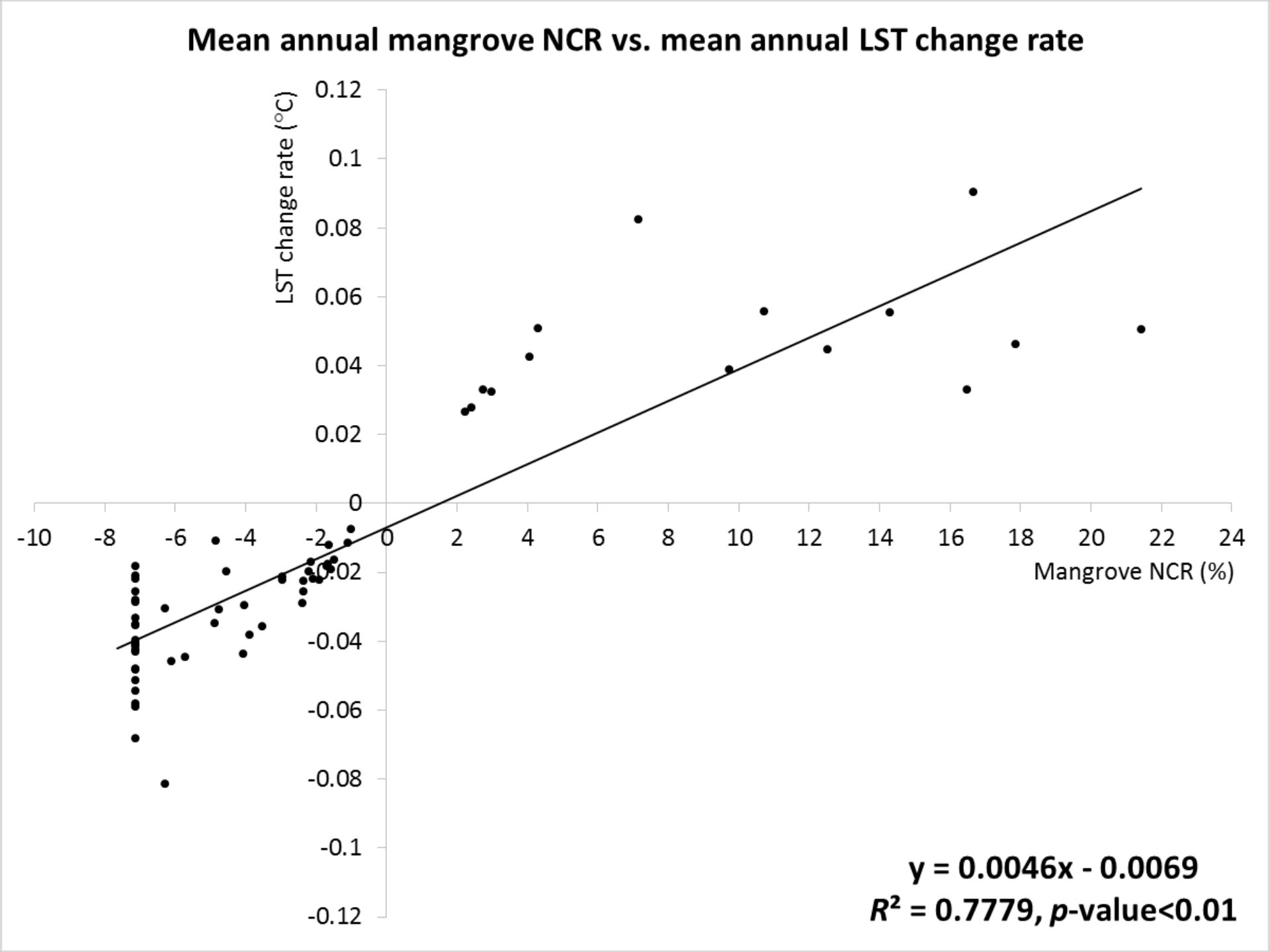


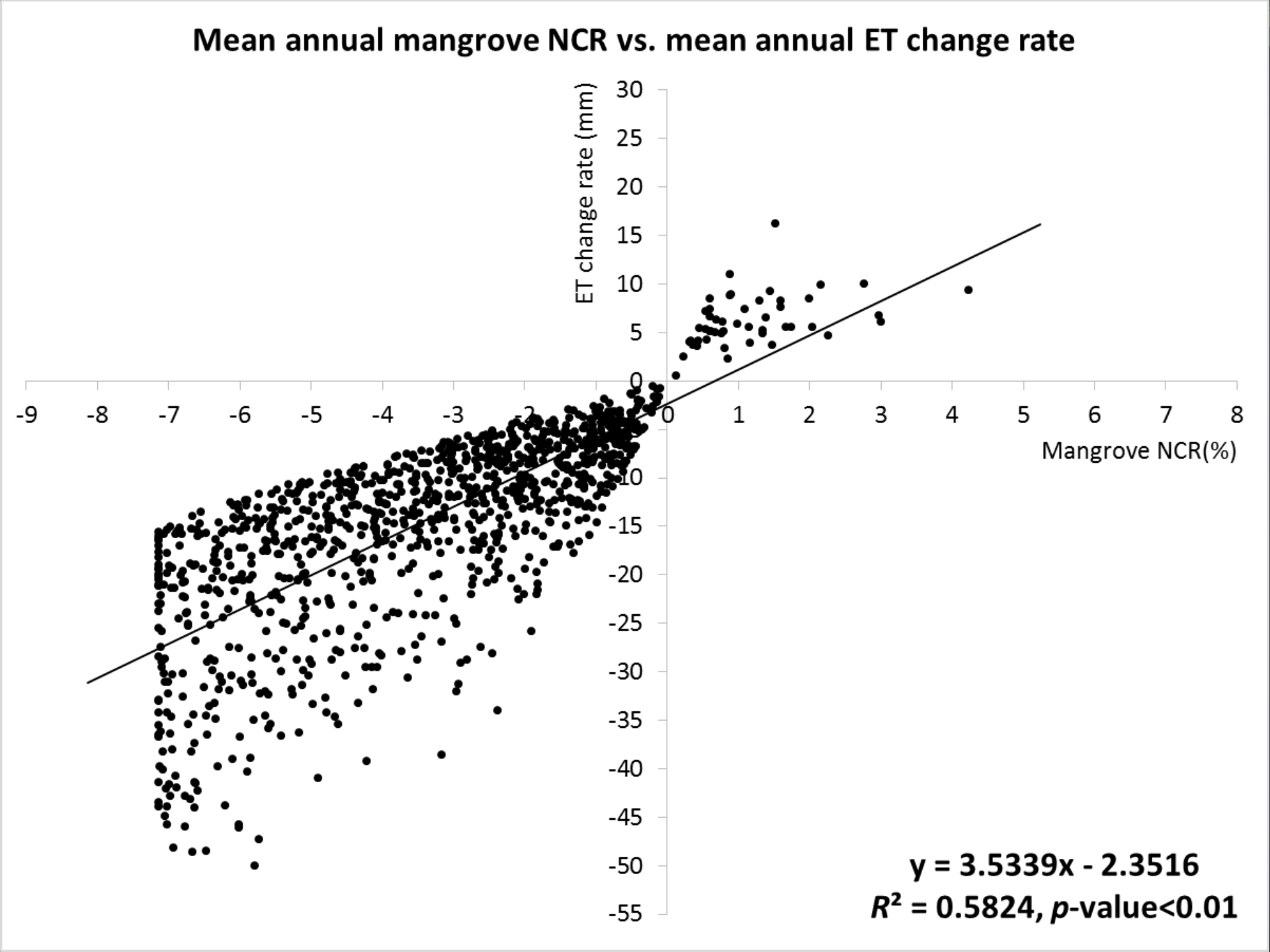
PTC Trend (Slope)




Mean annual mangrove NCR vs. mean annual PTC change rate
PTC change rate (%)
Mangrove NCR (%)
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
y = 0.9039x - 0.7394
R² = 0.6495, p-value<0.01


Mean annual mangrove NCR vs. mean annual NPP change rate
Mangrove NCR(%)
NPP change rate (kg C/m²)
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
-0.11
y = 0.003x - 0.0221
R² = 0.2288, p-value<0.01


Mean annual mangrove NCR vs. mean annual LST change rate
LST change rate (°C)
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
24
Mangrove NCR (%)
y = 0.0046x - 0.0069
R² = 0.7779, p-value<0.01


Mean annual mangrove NCR vs. mean annual ET change rate
ET change rate (mm)
Mangrove NCR(%)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
y = 3.5339x - 2.3516
R² = 0.5824, p-value<0.01

Conclusion

- This study suggests that the total mangrove area in Myanmar was 482,034 ha in 2000 and 498,272 ha in 2014.

- Within 14 years (2000-2014), a total of 215,680 ha of mangrove forest was lost, with a deforestation rate of 30.91% with a mean annual deforestation rate of 2.21%.

- The highest mangrove loss occurred in Rakhine state (75,496 ha; 5,393 ha/yr), followed by Ayeyarwady region (69,518 ha; 4,966 ha/yr) and Tanintharyi region (52,781 ha; 3,770 ha/yr).

- Total mangrove forest carbon release was about 3,335,145 metric tons between 2000 and 2014 (238,224.6 metric ton C yr^{-1}) with a mean annual rate of 1.72%/year.

- A net change rate of 1% mangrove per year will result in a mean annual PTC change rate of 0.9% (at least), or a total of 12.6% PTC change between 2000 and 2014.

- A net change rate of 1% mangrove per year will result in a mean annual NPP change rate of 3 metric ton C per year within a 1*1 km cell, or a total of 42 metric ton C change between 2000 and 2014.

- A net change rate of 1% mangrove per year will result in a mean annual LST change of 0.0046°C. This is almost negligible. So mangrove deforestation and afforestation have little impact on LST.

- A net change rate of 1% mangrove per year will result in a mean annual ET change of 3.53 mm, or a total of 49.42 mm change between 2000 and 2014.

- The mangrove deforestation of Myanmar during the 2000-2014 period resulted in the decrease of the mangrove's Ecosystem Services Value (ESV) of approximately 25 billion US$ (1.8 billion US$/year loss) at the rate of -28.59% per year that is based on ten ecosystem services.

Thank you!