Impact Assessment of 2023 Cyclone Mocha on Vegetation and Flood Using Remote Sensing Image Analysis

2023年ミャンマー北西海岸に上陸したサイクロンによる被害：衛星画像分析による情報入手困難地域の間接的評価

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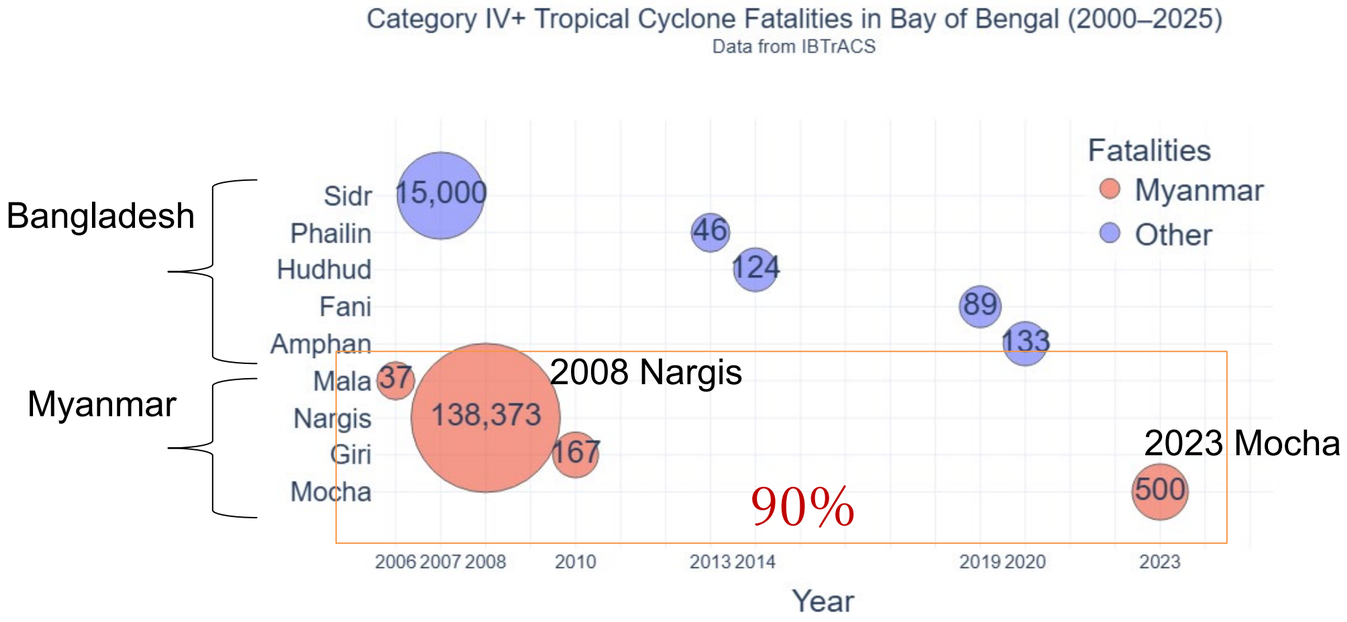
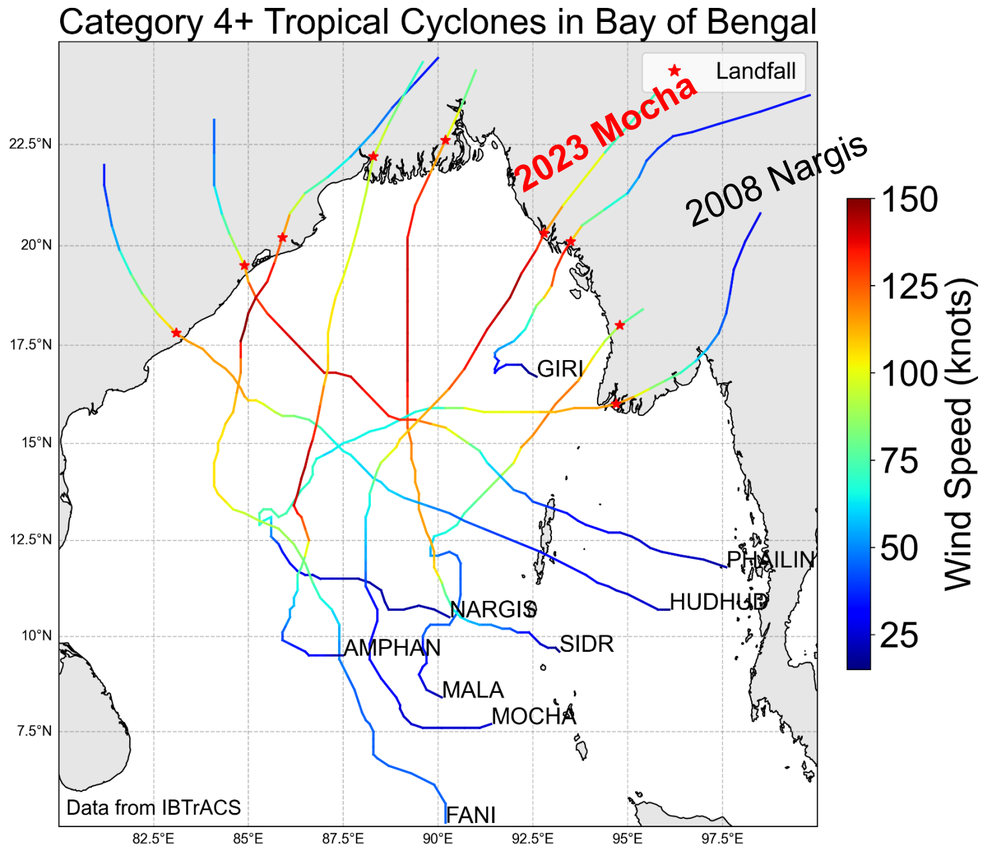
01 Background

- Between 2000 and 2025, 9 strong tropical cyclones (Cat 4 or higher) formed in the Bay of Bengal.
- Of these, 4 made landfall in Myanmar.
- Nearly 90% of the total fatalities occurred in Myanmar.
- Even excluding two strongest cyclones (Nargis and Sidr), Myanmar still accounts for about 60% of all cyclone-related deaths in the region.

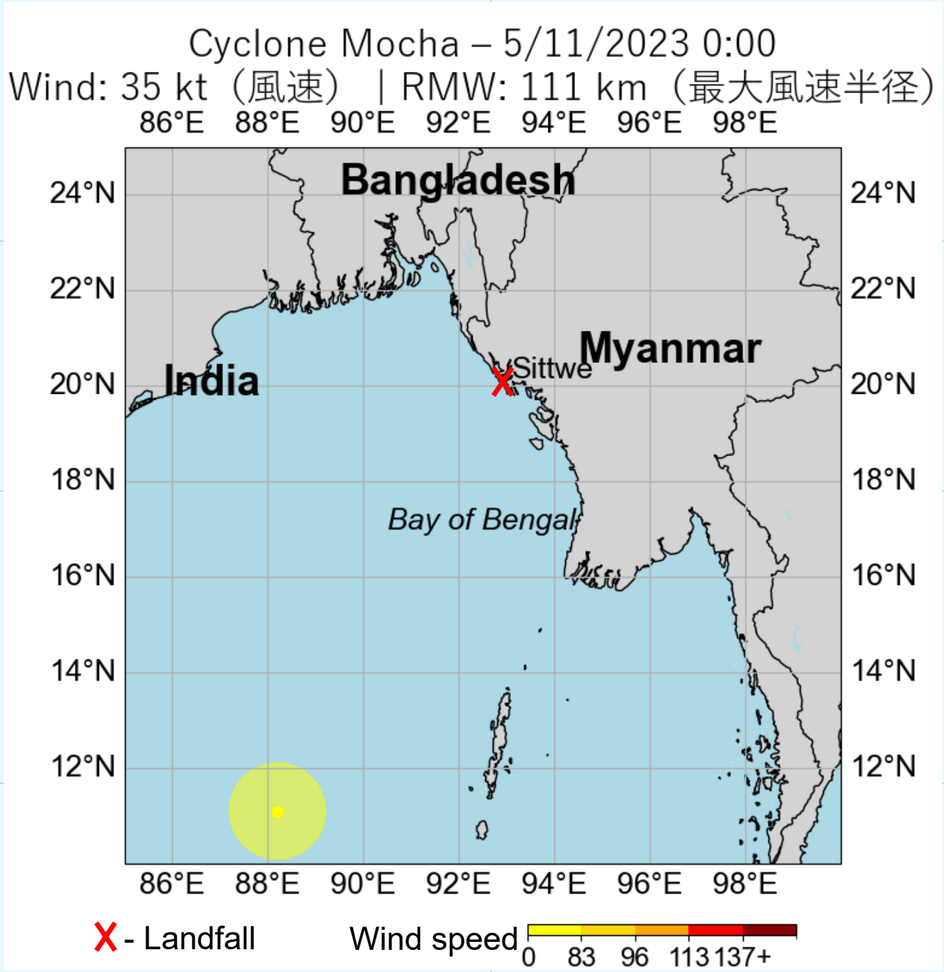
今世紀、ベンガル湾で発生した特に強いサイクロンは9つ。
うち、4つはミャンマーに上陸し、犠牲者の9割近くがミャンマーに集中したと推計されている。





01 Background

Understanding of cyclone behavior and the resulting initial damage due to 2023 Mocha remains limited in Myanmar, owing to restricted access, challenges in field data collection, and geographic barriers

Cyclone Mocha		• One of the strongest tropical cyclones in the Bay of Bengal in the past decade

Category V		• Landfall near Sittwe Township, Rakhine State (ラカイン州に上陸)
		• On-ground data collection was hindered by:
		  • Access restrictions
		  • Armed conflict
		  • Communication breakdowns

Wind speed 138 knots (71 m/s)		
>500 fatalities		ミャンマーのサイクロン被害の実態を海外から知ることは非常に難しい

02 Research Objectives

The objective of this study is to evaluate Cyclone Mocha's initial impact —specifically vegetation damage and inundation—through remote sensing technology.

研究目的：リモートセンシング技術を用いて、植生変化と浸水範囲を推定し、サイクロン被害の初期アセスメントを行う

(Source: CNN world)

Almost impossible to conduct on-ground survey

03 Data and Method

Optical satellite imagery for vegetation damage

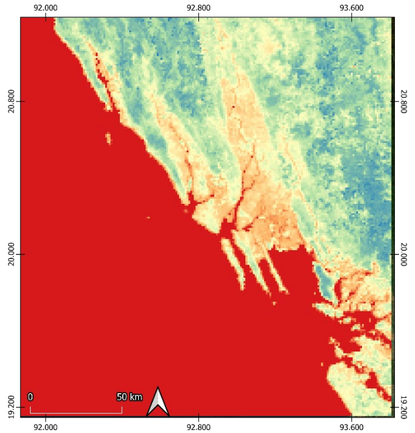
- The USGS EROS Visible Infrared Imaging Radiometer Suite (eVIIRS)
- Global Normalized Difference Vegetation Index (NDVI), 10-Day Composite images with 1 km resolution
- Data acquisition
  - Before the cyclone:
    2023 May 01 to May 10
  - After the cyclone:
    2023 May 21 to May 31

A difference of three weeks

Pre-event
(2023.05.01)

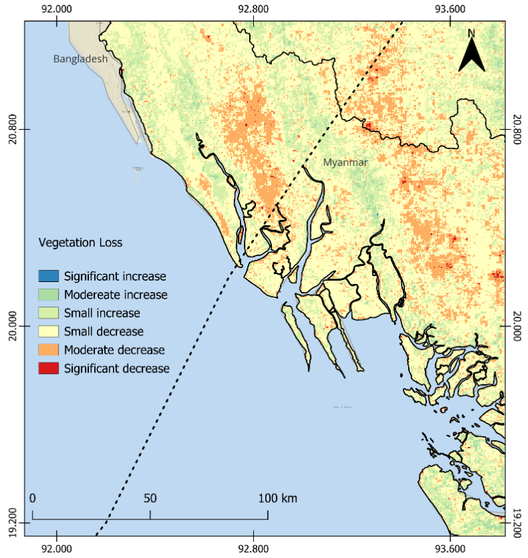
$NDVI_b$

$$NDVI = \frac{NIR - red}{NIR + red}$$



$$DNDVI = NDVI_b - NDVI_a$$

Reclassify

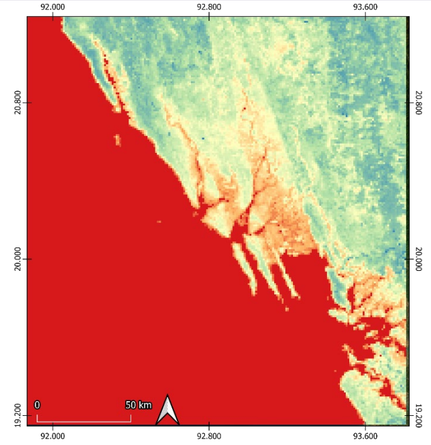


Vegetation damage assessment map

Post-event
(2023.05.20)

$NDVI_a$

$$NDVI = \frac{NIR - red}{NIR + red}$$



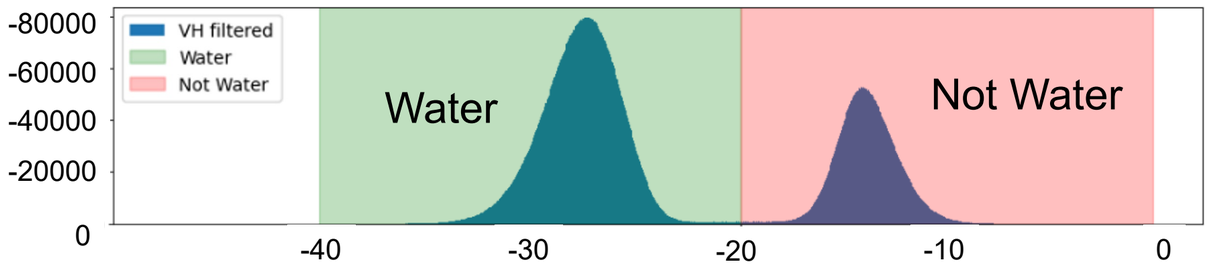
NDVIの差分DNDVIを計算し、植生被害マップを作成した。

03 Data and Method

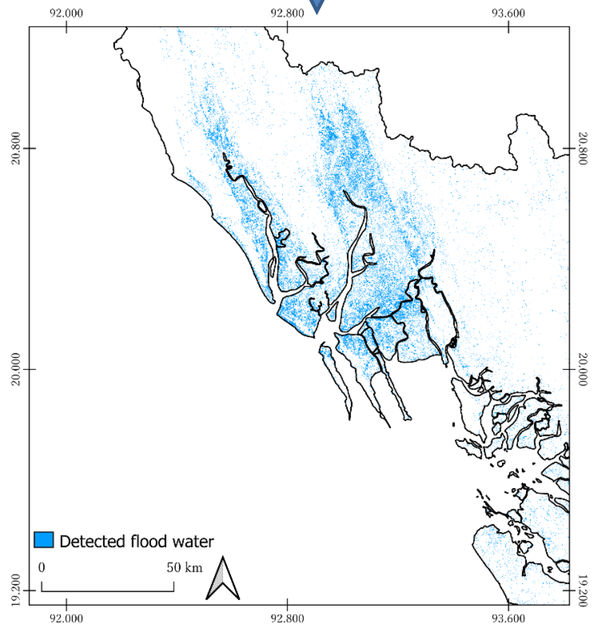
Synthetic Aperture Radar (SAR) imagery for flood analysis

- The Synthetic Aperture Radar (SAR) onboard the Advanced Land Observing Satellite (ALOS) by Japan Aerospace. Exploration Agency (JAXA)
- 100-meter resolution every two weeks.
- Data acquisition: The day of the Landfall, 2023 May 14.

Thresholding on radar waves (VH)

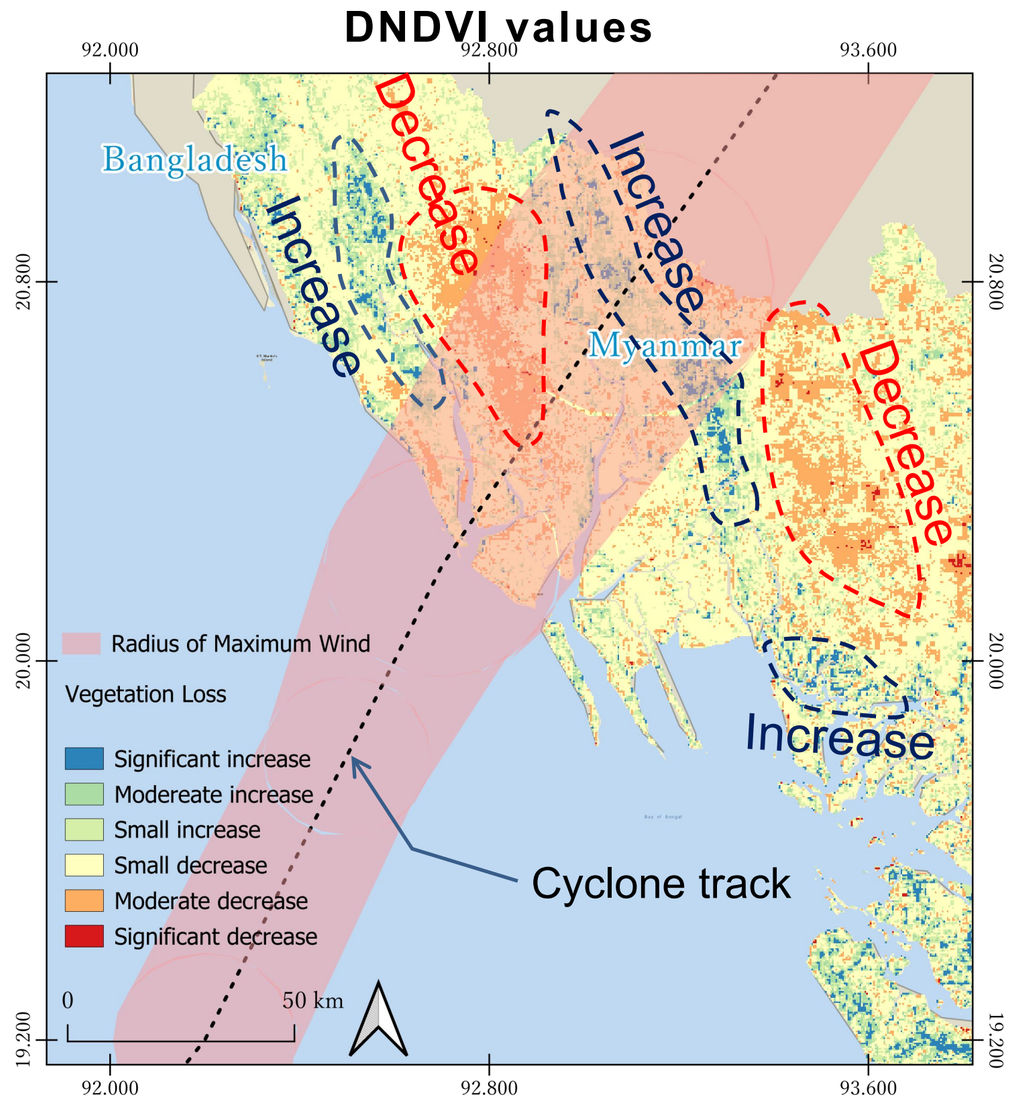


合成開口レーダーの偏波データを用いて、水域と非水域を判別



inundation assessment map

04 Vegetation damage assessment

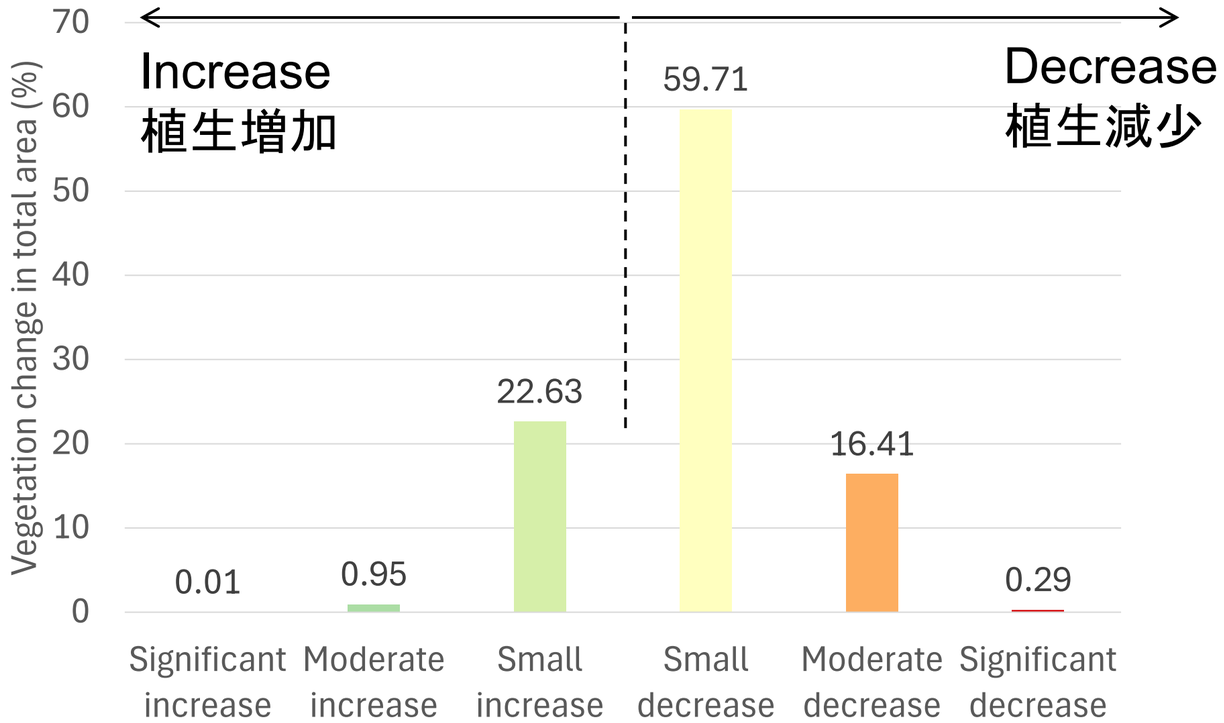


Vegetation changes before and after the cyclone

Key observation

- There are two distinct areas where vegetation either increased or decreased.
- Vegetation decrease was observed on the left side of the cyclone track within the radius of maximum wind (RMW), and on the right side outside the RMW.
- Vegetation increase was observed both inside and outside the RMW, suggesting that plant regeneration occurred even within the region affected by the strongest winds.

植生の減少：台風経路の左側 → 最大風速半径内，経路の右側 → 最大風速半径外
増加：台風経路の両側，最大風速半径内外で認められる



04 Vegetation damage assessment

➢ Vegetation damage by land cover types

The vegetation index was categorized into three land cover types based on the Copernicus classification.

Settlements
（集落）

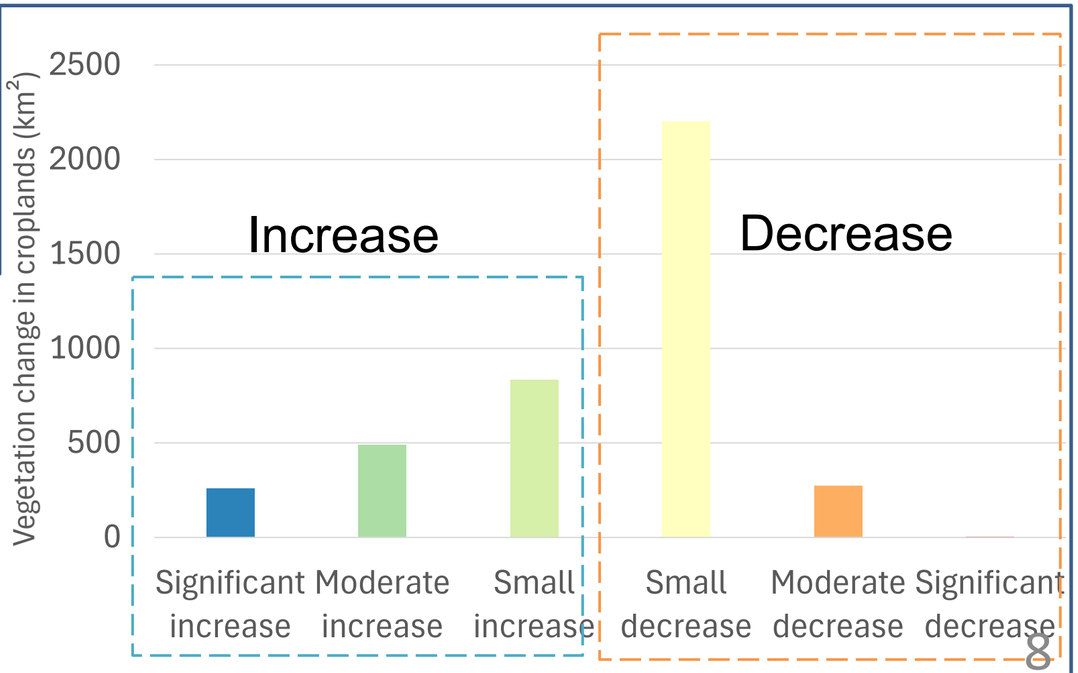
Forested areas
（森林地域）

Croplands
（耕作地）

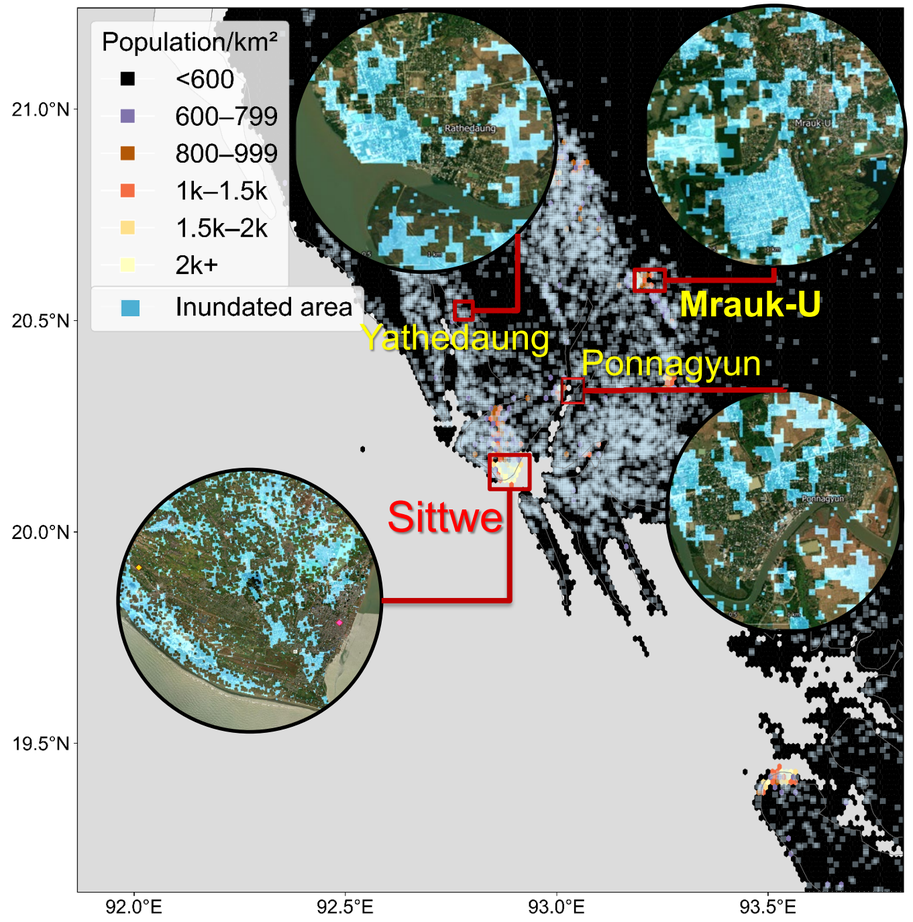
Vegetation Increase
- Some areas show an increase in vegetation
- Likely due to successional vegetation.

Vegetation Decrease
- The most dominant trend was partial damage, not complete destruction of vegetation cover

植生が少し減少した場所が目立つが、増加した場所もある
被害を受けた場所でパイオニア種が急速に成長した可能性



05 Inundation assessment



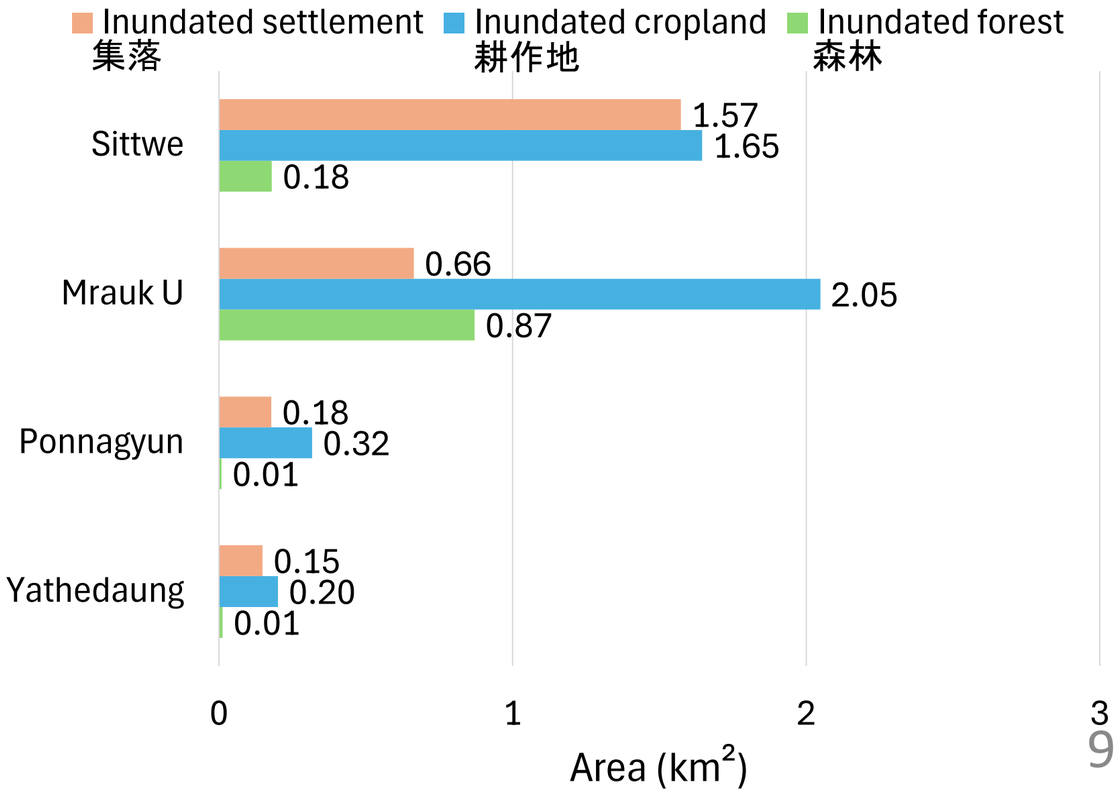
A closer view of 4 densely populated cities, affected by inundations

浸水被害を受けたと予想される4つの市町村

- Sittwe (coastal town): high inundation due to ***direct storm surge***.
- Mrauk-U (~60 km inland): significant inundation likely from ***river overflow + rainfall***.
- Yathedaung & Ponnagyun: affected by ***upstream surge*** along rivers.
- Despite similar inundation rates (~20–30%), impact causes differ.

Inundation Overview
Total affected area: ~4,000 km²
Settlements: ~7 km²
Cropland: ~870 km²
Forest: ~1,820 km²

Town	Population
Sittwe	100,748
Mrauk-U	36,139
Ponnagyun	12,691
Yathedaung	7,511

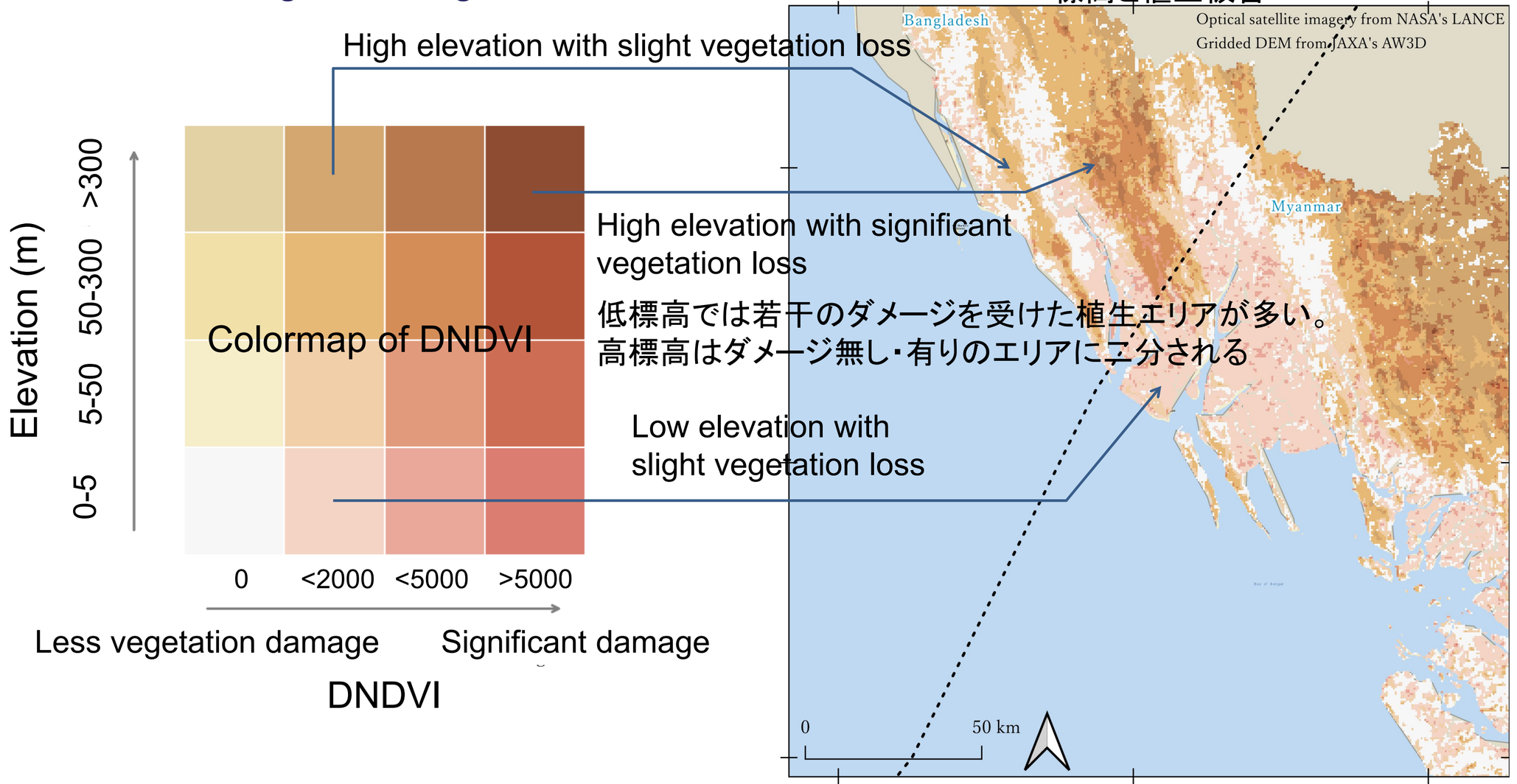


Inundation of each city classified according to land cover

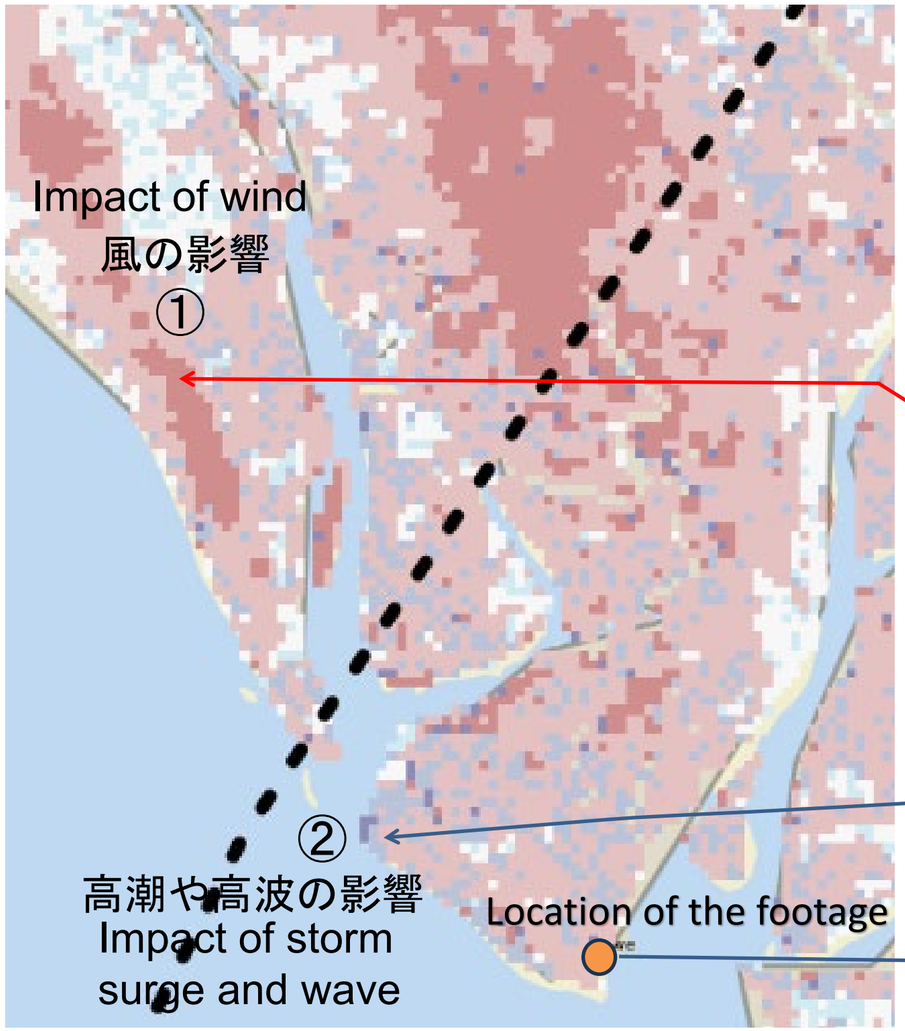
Sittweは高潮、Mrauk-Uは豪雨や河川洪水が主たる浸水要因か

06 Elevation and Vegetation Loss

- In low-elevation areas, ***slightly decreased*** vegetation is predominant.
- High-elevation areas are polarizing into two distinct types: those with ***slight vegetation loss***, and those with ***significant vegetation loss***.



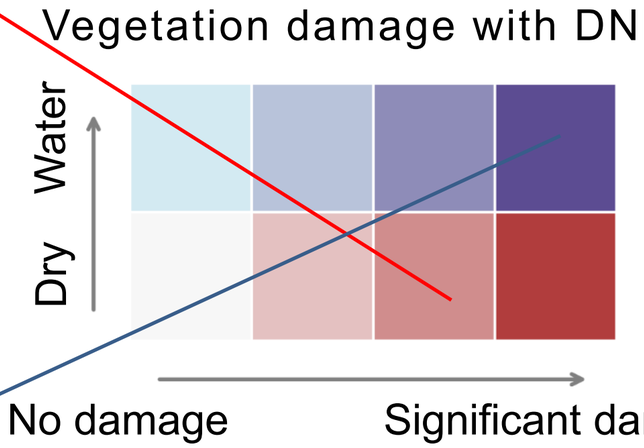
07 Inundation and Vegetation Loss



Extent of inundation and vegetation damage
浸水程度と植生被害

① **Some non-inundated areas show high vegetation loss, indicating pure wind damage.**

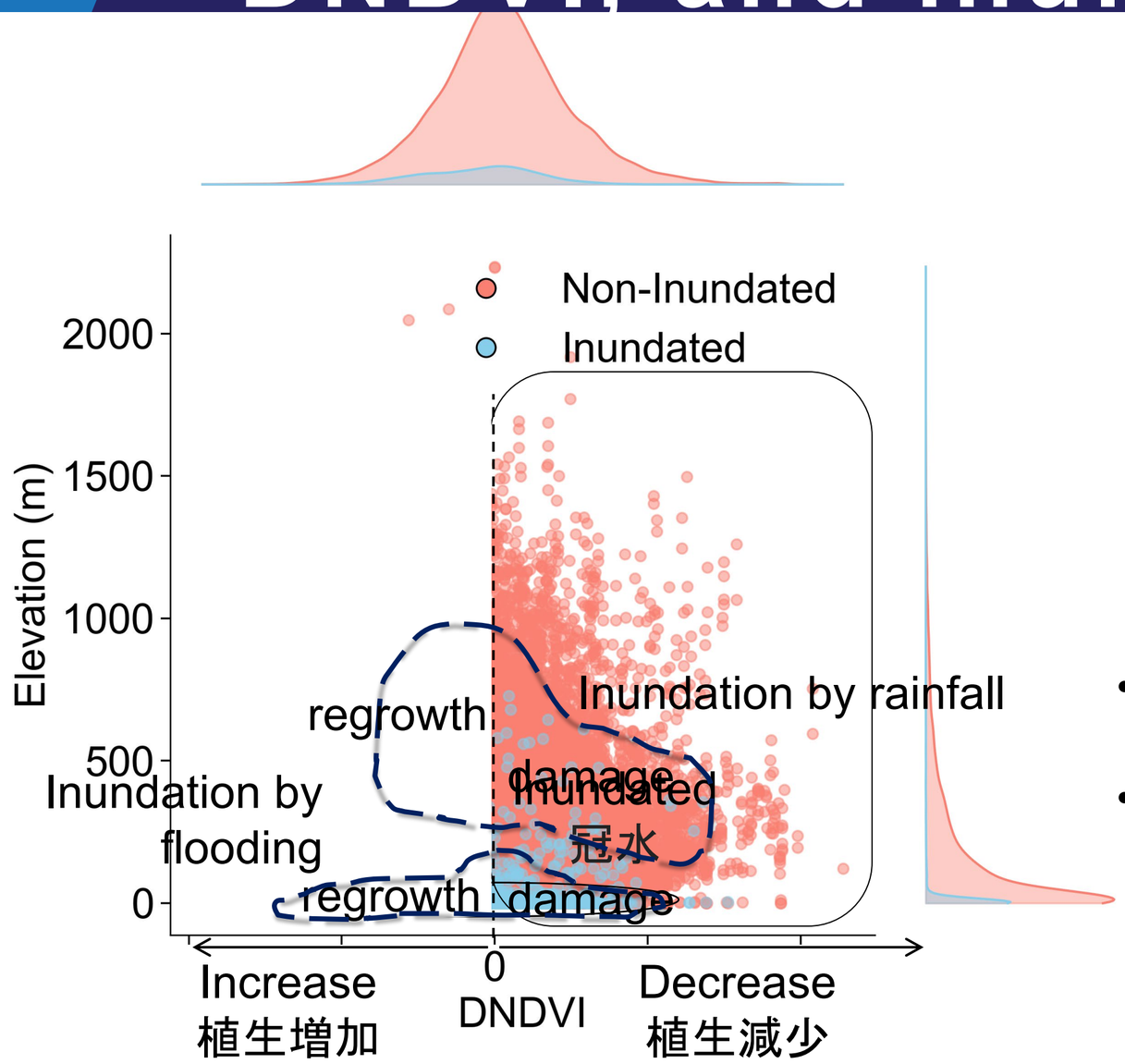
② **Some coastal areas experienced both inundation and significant vegetation loss, implying the effects of storm surge and high waves.**



Estimated ground level:
3 m above mean sea level (based on DEM).

Footage of the flood situation in Sittwe, captured by local media, indicates the possibility of storm surge in the coastal town.

08 Relationship between elevation, DNDVI, and inundation



Scatterplot of DNDVI, Elevation and Inundation

- Much of low-lying land suffered from inundation, whereas highlands did not.
- Declining vegetation is slightly noticeable than that with increasing vegetation.
- The increase in vegetation was likely caused by increased inundation.

- 低地は浸水の被害を受けたが、高地は影響が限定的である。
- 植生が減少した地域が多いが、増加も一部見られ、短期間での植生の再生が示唆される。

09 Conclusion

This study aimed to estimate the damage caused by Cyclone Mocha. As local information was difficult to obtain, we attempted an indirect assessment by investigating vegetation impact and inundation extent using satellite data, including USGS eVIIRS and ALOS SAR. As a result, the following became clear:

- Damage due to strong wind seems to be predominant. The secondary factor is flood damage.
- There were also areas where vegetation increased due to the rapid growth of pioneer species in devasted areas.
- In low-elevation areas, widespread inundation occurred. Heavy rainfall, river flooding, and storm surge are considered potential causes.
- In the coastal town of Sittwe, local media footage confirms the presence of storm surge.
- If we can obtain satellite images immediately after cyclone, we can assess the damage without the interference of regrowth.

USGS eVIIRS やALOS SAR など衛星データを用いて、植生への影響や浸水範囲を調べることで、サイクロン・Mochaによる被害の推定を試みた。その結果、以下のことが明らかになった。

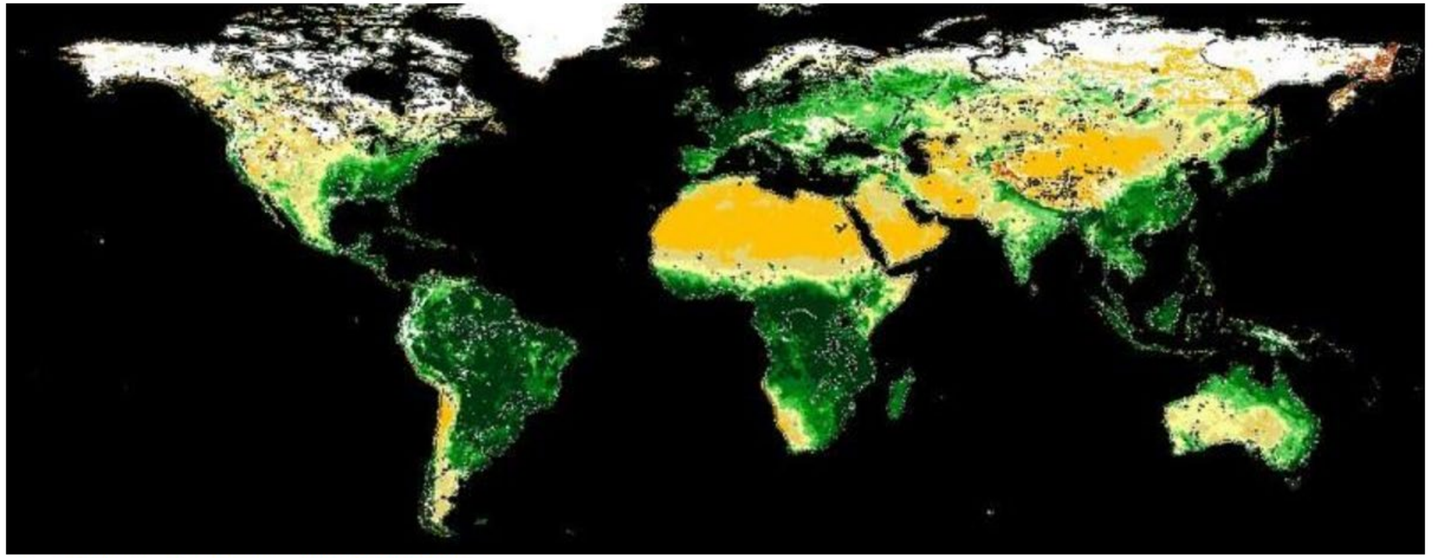
- 広範囲の土地で植生の消失が生じていたが、比較的軽微で、大規模な被害箇所は少なかった。
- 植生被害は強風の影響が大きいと考えられる。
- 植生が増加した場所もあった。サイクロンで荒廃した土地にパイオニア種が急速に繁茂したためと推察される。
- 広範な範囲で浸水が生じていた。豪雨や河川氾濫、高潮の影響が考えられるが、原因まで特定するのは困難
- 現地メディアの映像によると、ラカイン州都の海岸都市・Sittwe で3m以上の高潮が生じていた可能性が高い。

0 Supplementary

0 Supplementary

- NDVI is created from the known equation: NDVI = (NIR – red) / (NIR + red)
- The minimum NDVI values allowed are -0.1999, and all NDVI values (which normally fall between -1.0 and 1.0) are scaled by 10,000. Thus, the output NDVI values from this application fall between -2000 and 10,000 (with the exception of negative surface reflectance values)
- Difference of NDVI, $DNDVI = NDVI_b - NDVI_a$, $NDVI_b$ = NDVI before, $NDVI_a$ = NDVI after

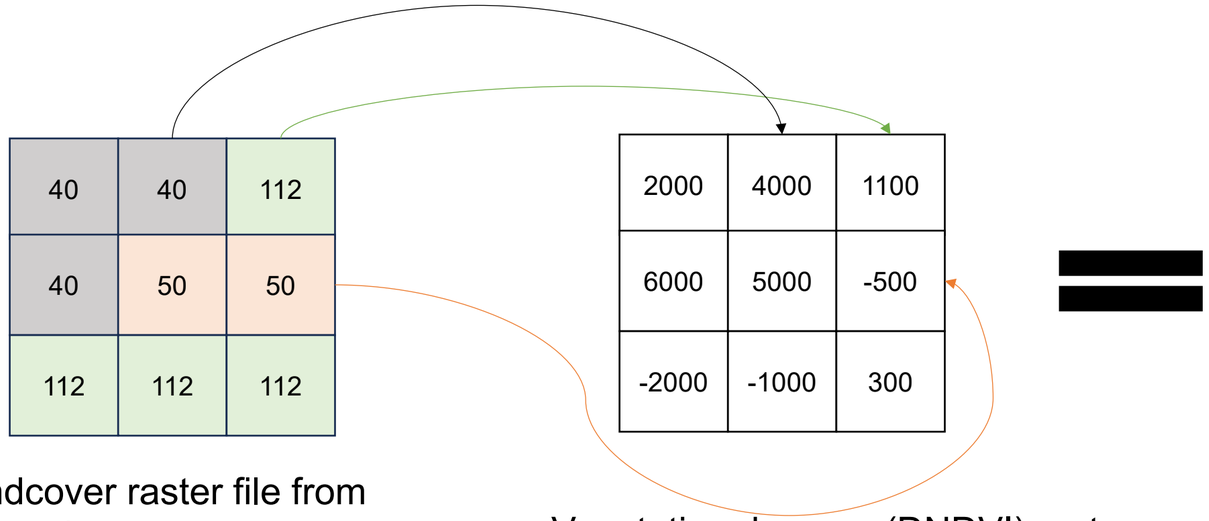
Classification	NDVI range
Significant increase	-5000 to -10000
Moderate increase	-2000 to -5000
Small increase	-2000 to 0
Small decrease	0 to 2000
Moderate decrease	2000 to 5000
Significant decrease	5000 to 10000



Sources/Usage: Public Domain. View Media Details

eVIIRS Global NDVI, 10-Day Composite, April 1 - April 10, 2023. Entity ID: EVGNDVIS20230401202304101

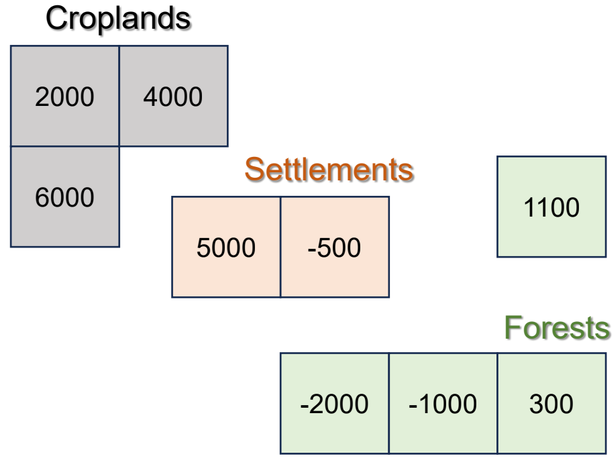
0 Supplementary



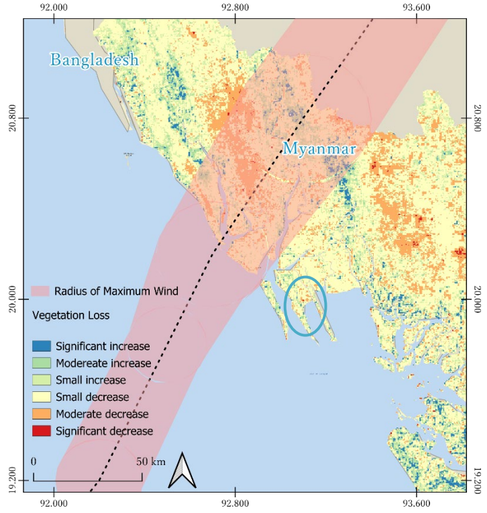
Landcover raster file from Copernicus.
Where, 40 – croplands
50 – settlements
112 – forests

Vegetation damage (DNDVI) raster

Classification	NDVI range
Significant increase	-5000 to -10000
Moderate increase	-2000 to -5000
Small increase	-2000 to 0
Small decrease	0 to 2000
Moderate decrease	2000 to 5000
Significant decrease	5000 to 10000



Vegetation damage (DNDVI) raster distinguished according to landcover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Bangladesh
Myanmar
Radius of Maximum Wind
Vegetation Loss
Significant increase
Modereate increase
Small increase
Small decrease
Moderate decrease
Significant decrease
0
50 km


09/2019
Legend
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Google Earth
Image © 2024 CNES / Airbus
900 ft
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04/2024
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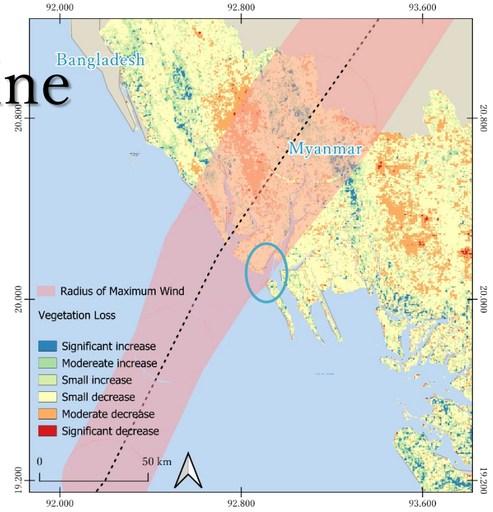
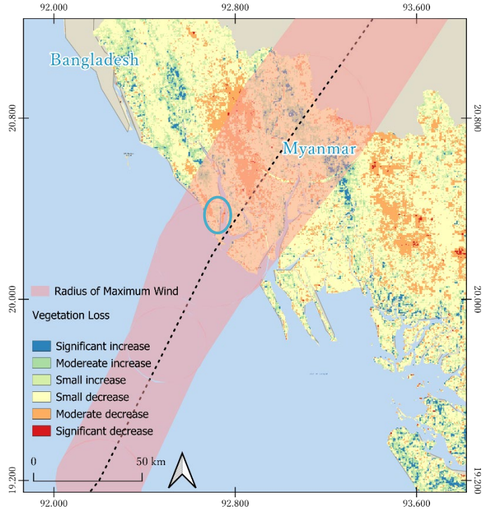
Cyclone Mocha (05/2023), Rakhine

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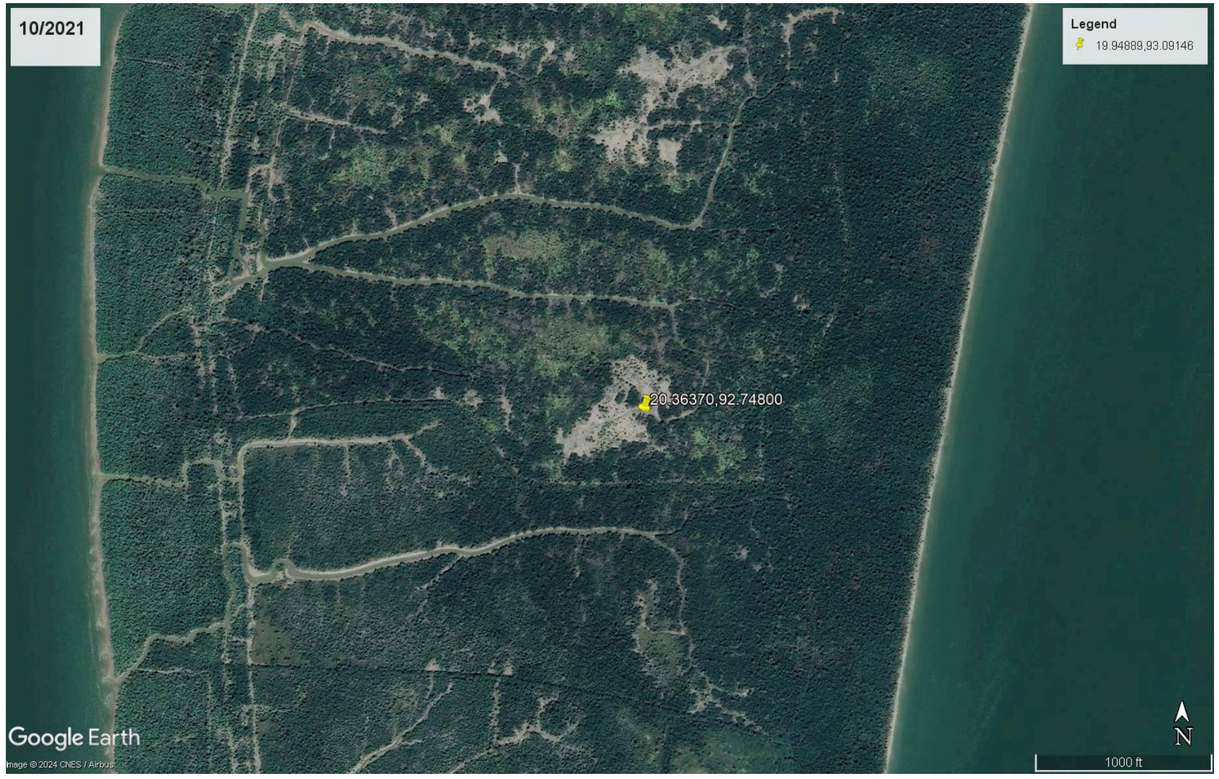
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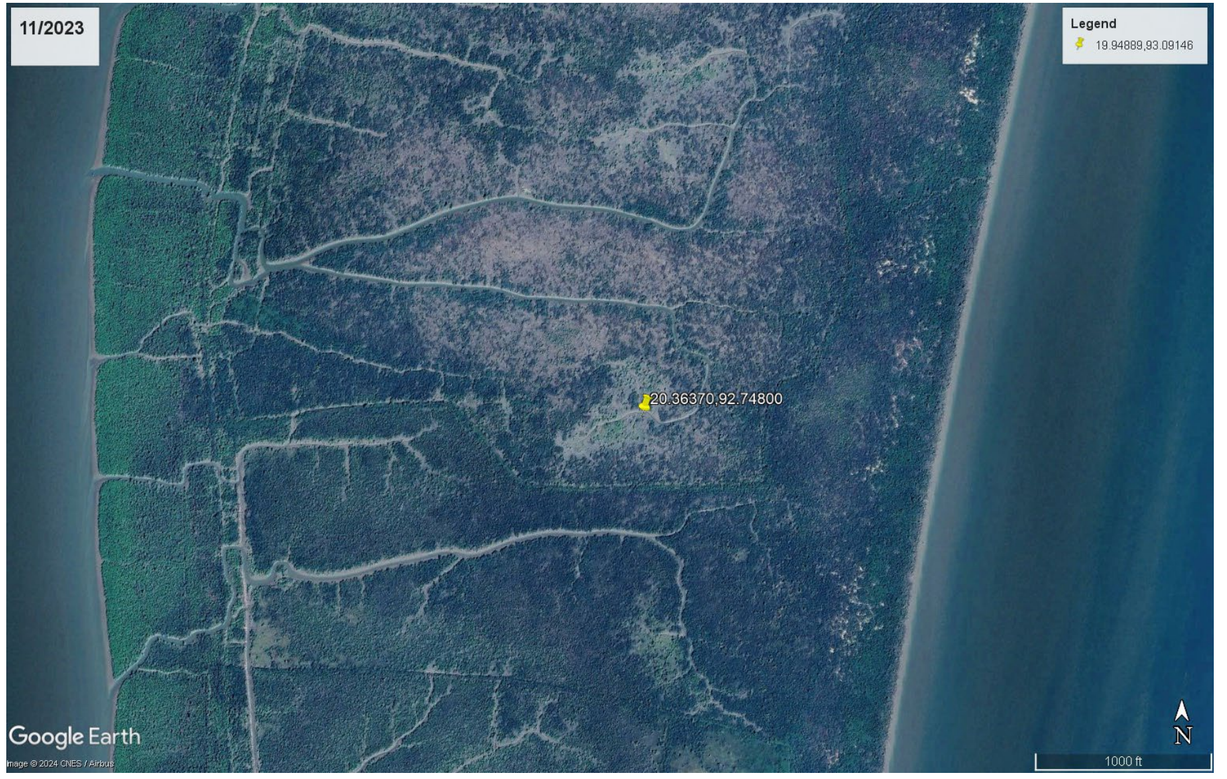
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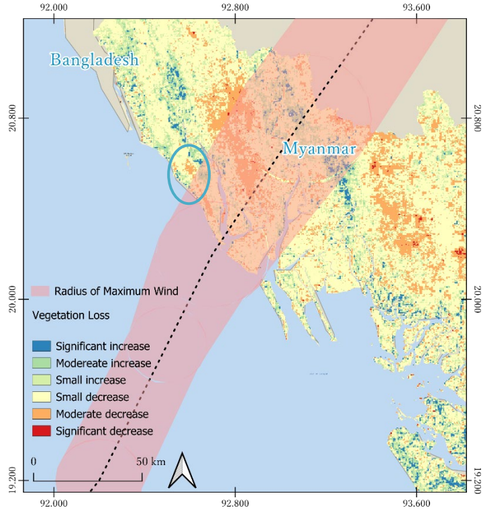
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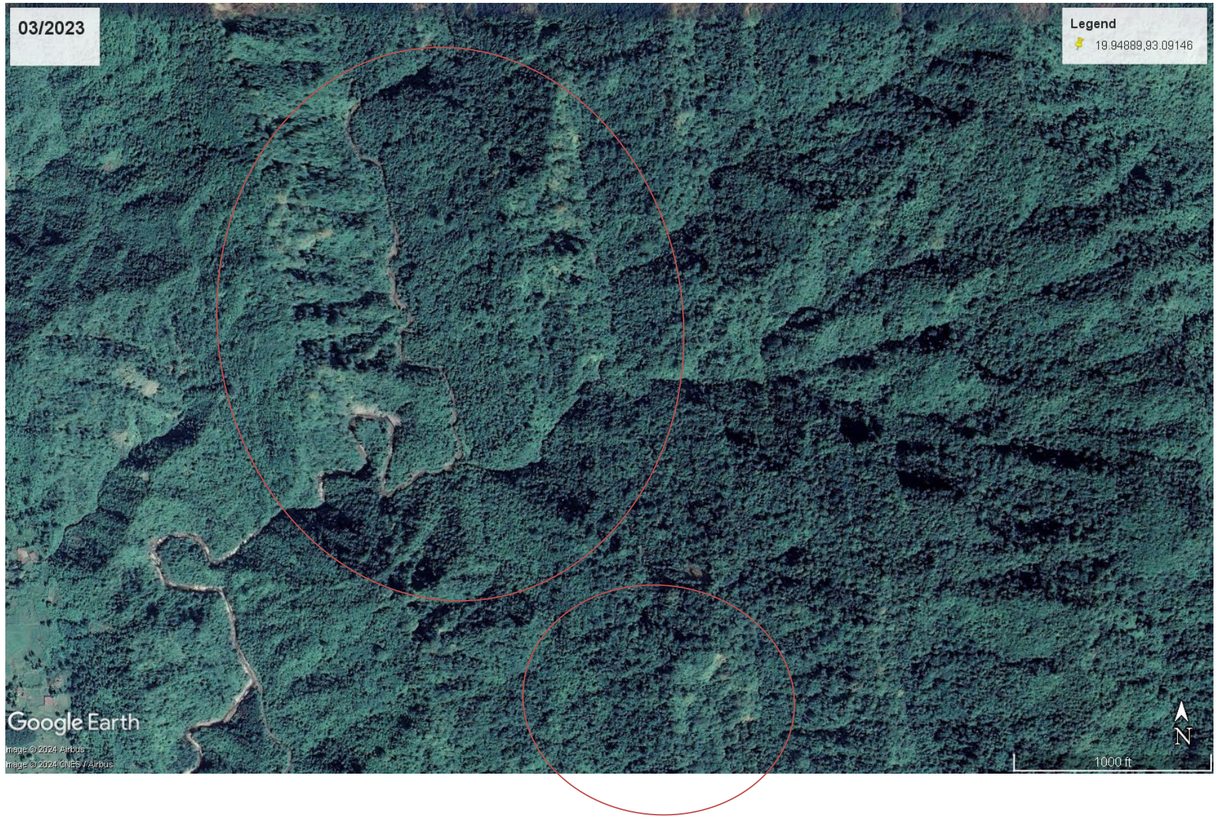
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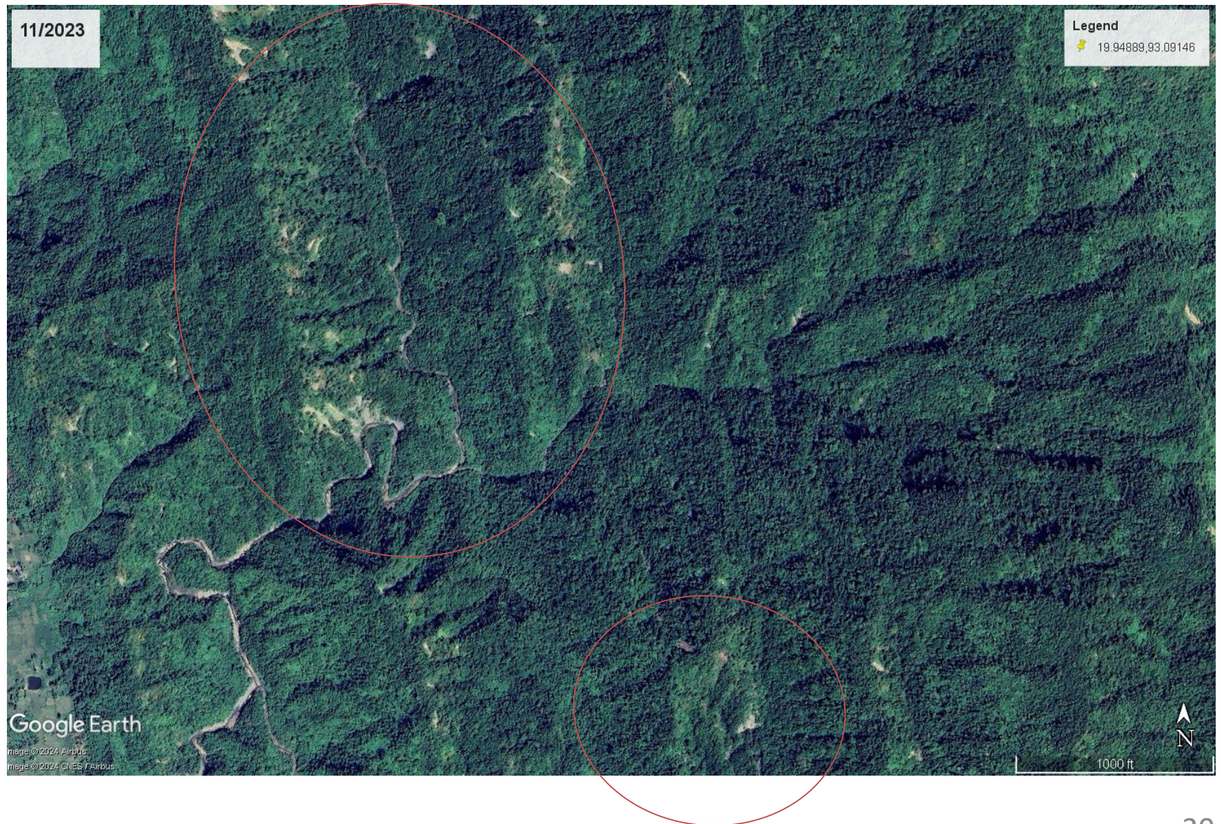
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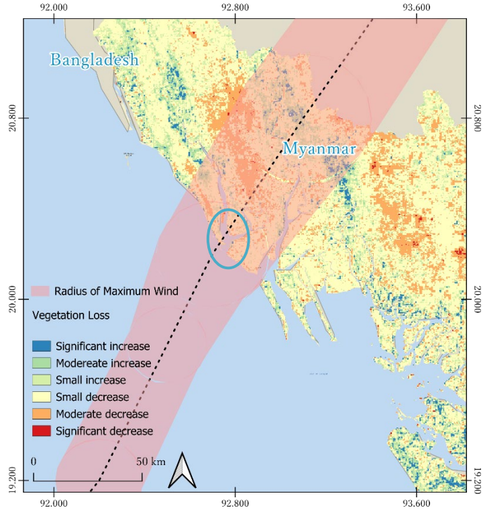
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