Gulf of Mottama Project (GoMP)

Assessment of Coastal Land Use / Land Cover Change (2016-2022) in the Gulf of Mottama, Myanmar

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1 INTRODUCTION

The Gulf of Mottama (GoM) is situated in southern Myanmar and bordered by Yangon Region in the west, Bago Region in the north, Mon State in the east, and the Andaman Sea in the south (Figure 1). With the flow from the two major rivers, Sittaung and Salween, the GoM is one of the most important and unique intertidal wetland systems in the world with important habitats, species of conservation concern, commercially important fisheries, and communities that rely on its natural resources. The importance of the GoM was recognized in 2017 by the Ramsar Convention to be a Ramsar site, a wetland of international importance and by the expansion of the site in 2020 covering a total area of 161,030 ha in Mon State and Bago Region. Major land classes in the GoM include water, mudflat, grassland, cropland, mangrove, farmland and forest orderly from sea to inland. Being one of the most dynamic estuaries in the world, the GoM is characterized by sediment redistribution, erosion and accretion on a large scale. According to Robinson et al. (2007), the flow of sediments from the rivers caused an extensive area of mudflats in the GoM. Coastal erosion is an ongoing dynamic process removing farmland and mangrove, depositing sediment elsewhere, and causing some areas infertile due to saltwater intrusion. On the other hand, when some stable lands (e.g., grasslands, mangroves) are formed after sedimentation, conversion of such lands to different land uses (e.g., croplands) is a wide-spreading issue of land insecurity.

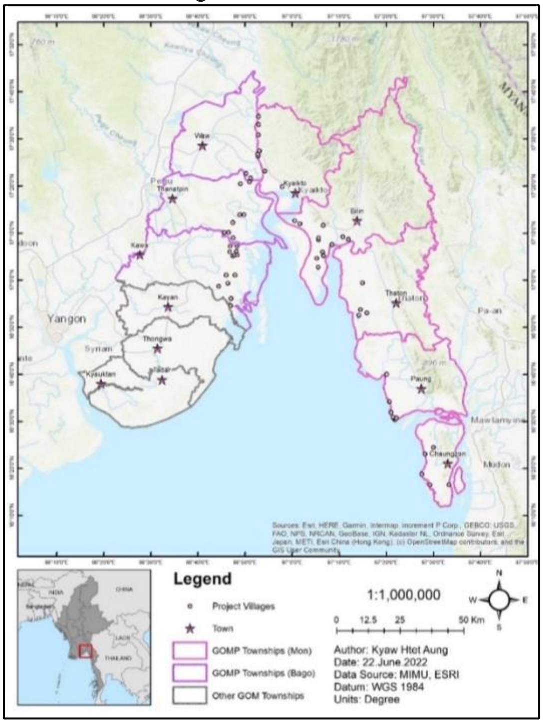


Figure 1. Study area, Gulf of Mottama

Schmid et al. (2021) analyzed land cover change in the coastal area of Myanmar between 2002 and 2016, however the study was paid attention to Tanintharyi Region near the GoM. De Alban et al. (2020) explained patterns of net and gross mangrove cover change (loss, gain, persistence) for the period of 1996–2016 across six States and Regions of Myanmar including the GoM area and quantified that net national mangrove cover declined by 52% over 20 years. Substantial erosion in Bago side led to loss of farmlands, consequently displacement of communities, and accretion in Mon side that drives drastic habitat changes for species in that area (Whitty et al., 2017; Aung, 2019). However, no recent study has been found to identify erosion hotspots and to assess land use change from newly-formed mudflat, mangrove and grassland to other land uses in Mon and Bago coastal areas.

This study has three objectives:

- To spotlight the coastal areas of massive erosion, mangrove loss and newly formed lands;
- To assess land use / land cover change of mangroves, mudflats and grasslands into other land uses;
- To identify the patterns of coastal land use / land cover change between 2016 and 2022.

2 METHODOLOGY

2.1 Materials

a. ArcGIS/QGIS for image analysis and mapping
b. Google Earth Pro for timeline image viewing
c. Google Earth Engine (GEE) for Remote Sensing Analysis
d. Digital survey app (e.g., Qfield, ODK) for data collection
e. Drone

2.2 Data collection

a. Sentinel-2 satellite image (downloaded from earth explorer)
b. Digital Elevation Map (downloaded from SRTM)

c. Administrative boundary shapefiles (downloaded from MIMU website)

d. Residential areas, town points, village points (downloaded from MIMU website)

e. High resolution satellite image for validation and accuracy assessment (Google Earth)

f. Ground truth data collection by GPS, digital survey application and drone

2.3 Defining classes

The land use/land cover classes used in this study are shown in Table 1 below:

Table 1: Land use / land cover classes used in this analysis

Land Use / Land Cover	Description
Water body	Ocean, reservoirs, lakes, irrigated rice paddies, rivers
Mudflat	Mud area along the coastal line (NB appearance of mudflat quite depends on tide time when satellite captured the image, mudflat in this analysis might be water in other image depending on tide time)
Grassland	Naturally grown grass on mudflat
Mangrove	Natural or planted mangrove
Cropland	Agricultural land (both cultivated and fallow)
Forest	Natural forest and plantation

2.4 First step classification

In the first step, satellite images were analyzed using supervised classification on ArcGIS after consideration of common land use / land cover classes in the GoM. We decided to classify water body, mudflats with and without vegetation, croplands and forests. Different bands of Sentinel-2, B2, B3, B4, B5, B6, B7, B8, B8A, B11 and B12 were merged as a composite layer in ArcMap to use in the supervised classification. Then, the composite layer was viewed by a couple of false color combination to detect the mangrove and other land classes. When training data are created, band combination B4, B3, B2 (Figure 2) was used to check natural color as seen by human eyes in order to compare with other false color composite. Band combination B8, B4, B3 (Figure 3) was mainly applied to detect healthy and unhealthy vegetation. Furthermore, bare lands were also highly reflected and thus it was easy to identify. Band combination B12, B8A, B4 (Figure 4) was especially suitable to visualize water body and moist objects such as mudflat, grassland and mangrove. High resolution Google Earth image (Figure 5) was applied to visualize detailed images through the timeline.

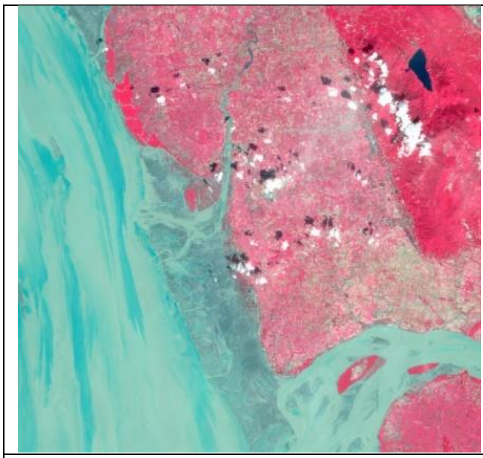


Figure 2: Band 4-3-2, natural color combination

Figure 3: Band 8-4-3, false color combination to identify vegetation

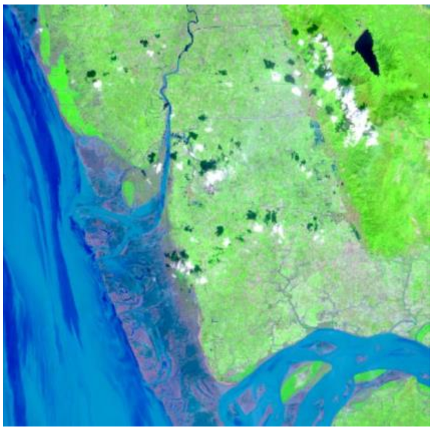


Figure 4: Band 12-8-4, false color combination to detect moist objects

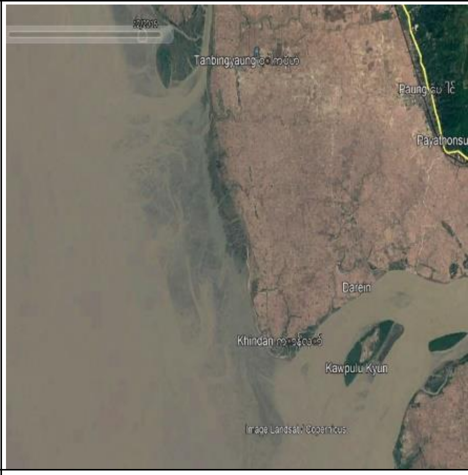


Figure 5: Google Earth Pro image of Paung township

2.5 Training data and classification

For all land classes, training data were collected on different five tiles (47QKU, 47QKV, 47QLV, 47QLU and 47PLT) for each year (Figure 6). Furthermore, images were classified by the maximum likelihood method on ArcMap and results were overlaid with satellite images to review. When classification for two times images were done, they were utilized to calculate the change between 2016 and 2022. As a result, in the first step, the land cover change map of the GoM was created, in which changes from mudflat to cropland and cropland to mudflat were identified along with other land use changes.

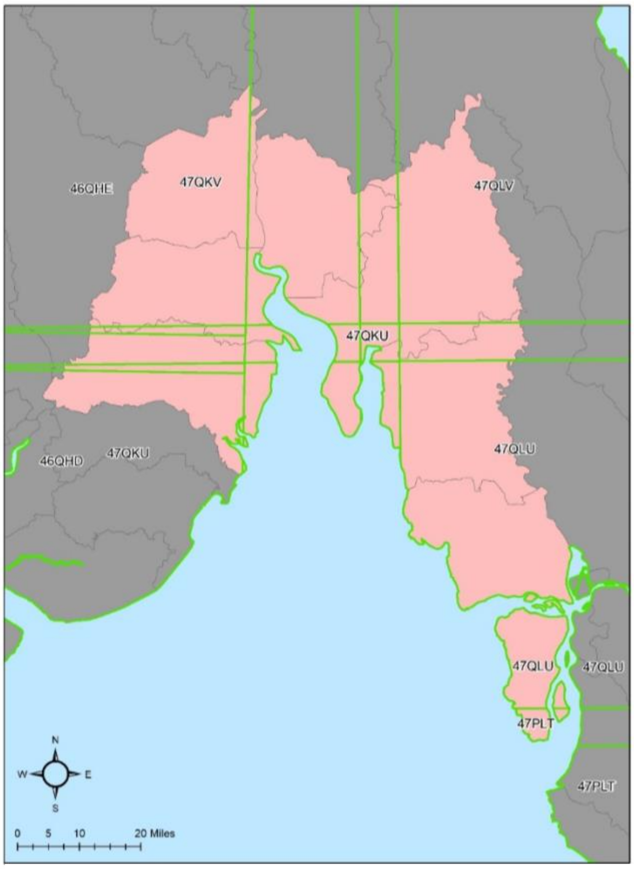
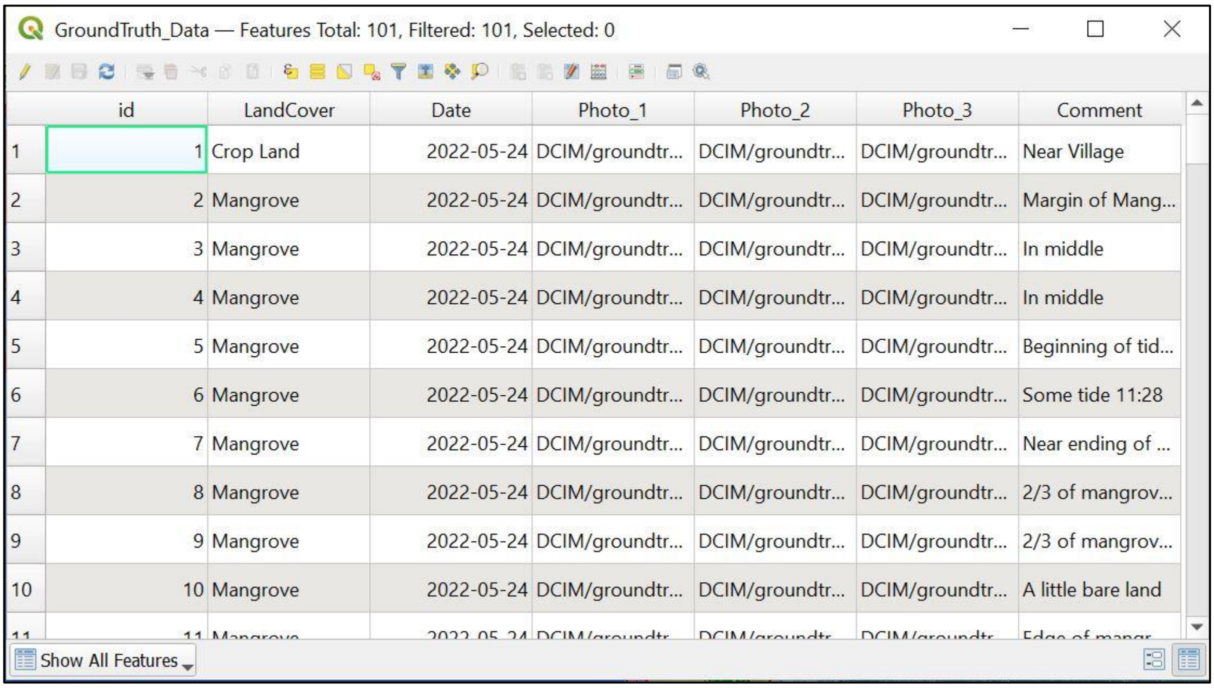


Figure 6. Sentinel 2 tiles used in analysis

2.6 Collection of ground truth data

In order to ensure the quality of analyzed results and data validation, we collected ground truth data in both Mon State and Bago Region except Kawa township where we could not visit due to unstable political conditions. We used QField spatial data collection app in which we developed a survey form (Figure 7) consisted of LandCover, Date, Photos and Comment columns. During the survey, we mainly focused on the coastal areas where mudflat, grassland and mangrove were found because these classes were of interest and difficult to classify by viewing satellite images. Spatial data of other land classes were also collected. In most townships, we applied drone to get mosaic image and panoramic view of a given area.



GroundTruth_Data — Features Total: 101, Filtered: 101, Selected: 0

	id	LandCover	Date	Photo_1	Photo_2	Photo_3	Comment
1	1	Crop Land	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Near Village
2	2	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Margin of Mang...
3	3	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	In middle
4	4	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	In middle
5	5	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Beginning of tid...
6	6	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Some tide 11:28
7	7	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Near ending of ...
8	8	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	2/3 of mangrov...
9	9	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	2/3 of mangrov...
10	10	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	A little bare land
11	11	Mangrove	2022-05-24	DCIM/groundtr...	DCIM/groundtr...	DCIM/groundtr...	Edge of mangr...

Show All Features

Figure 7: QField ground truth survey form to collect spatial data and photos

Figure 8: Ground truth survey by boat (left) and drone (right)

Figure 9: Ground truth survey in mangrove, Chaungzone township

2.7 Data validation and mapping

Remote sensing could not provide 100% accurate result, and it was especially difficult to differentiate between grassland and mangrove without ground knowledge. Therefore, the data collected from ground truth survey were applied to validate the previous results. At this step, six land classes mentioned above in the Table 1 were classified.

Previously analyzed data were initially reviewed with the field data. From this comparison of first step analyzed data and ground truth data, misclassified areas were identified. Thus, edition of training data and addition of new training data were carried out to improve the accuracy. At this time, GEE was utilized for analysis of all tiles at the same time because it saved time and gave consistency more than analyzing tile by tile.

After exporting 2016 and 2022 analyzed images, they were run in QGIS to calculate the change during the timeframe. Then, the change data were prepared in change matrix in the format suitable for mapping. Finally, three maps, 2016 land use / land cover map (Figure 10), 2022 land use / land cover map (Figure 11) and coastal area change from 2016 to 2022 (Figure 12) were created as the outputs of this analysis together with a change matrix (Table 2)

3 RESULTS AND DISCUSSIONS

3.1 Coastal erosion and formation of new lands

In 2016, the main branch of the Sittaung River was on Bago side and the channel moved toward the Mon side starting in 2022 (Figures 10 and 11). All over the study area, 20,091 ha of land were lost due to erosion, however 61,693 ha of new lands were formed during the last six years. Large areas of lands were lost on the eastern side of the gulf (Mon State) and new lands were formed on the western side (Bago Region) where no tenure of these lands was settled yet. This pattern of deposition and erosion, which results in rapid land accretion and erosion, is driven by long-term shifts in the main channel of the Sittaung River, which enters the northern end of the gulf. However, due to the nature of tide, this study had some uncertainty in where water and mudflat are interchangeable. During the low tide, a given area tended to be mudflat, but during high tide, it could be water. The satellite images in 2022 were probably taken at low tide and hence they showed more mudflats in the coastal line.

3.2 Conversion of mudflats, grasslands and mangroves into other land uses

A considerable extent of mudflat (8,414 ha; 16% of 2016 mudflats) was converted to grasslands and 2,916 ha (6% of 2016 mudflats) was converted to cropland (Table 2). Between 2016 and 2022, the area of mudflat increased from 51,104 to 98,358 ha (Table 2). Since erosion and deposition are assumed to be in balance over the long-term, the difference is assumed to be primarily due to the difference in tide height when the images were captured. Massive area of grasslands (13,243 ha; 37% of 2016 grassland) was converted to croplands, especially in Bilin and Kyaikhto townships. Conversion of mudflats and grasslands into croplands could be a common phenomenon in the area.

The other common type of land use change was conversion of mangroves into croplands. A total of 1,486 ha (18% of 2016 mangroves) was converted to cropland although this was offset by the conversion of 1,633 ha of grasslands into mangroves. Such change was mainly observed in small islands and near the populated villages between Chaungzone and Paung Townships. According to our rapid assessment conducted to identify community forest areas, the likelihood of converting mangrove was high near By Laung village in Paung Township. In Chaungzone Township, there was a high extraction of mangrove resources near Zee Gone and Taw Ka Mar villages (Wint Hte et al., 2022). We also noted that the mangroves in the Taw Ka Mar village are also under planning to be converted by the State level government institutions, and some of the operations have been started in the area. Therefore, the conversion pattern from mangroves to croplands in the Gulf is expected to be higher in coming years.

Table 2: Land cover and change in the GoM area between 2016 and 2022

		2022						
	Hectares	**Water**	**Mudflat**	**Grassland**	**Mangrove**	**Cropland**	**Forest**	**Total**
2016	**Water**	194,882	52,020	7,379	51	2,228	15	**256,575**
	Mudflat	13,133	26,538	8,414	96	2,916	7	**51,104**
	Grassland	3,491	9,492	7,320	1,633	13,243	182	**35,360**
	Mangrove	1,489	779	164	3,796	1,486	426	**8,140**
	Cropland	1,963	9,501	4,720	937	174,895	3,537	**195,553**
	Forest	15	28	22	147	8,204	18,852	**27,267**

	Total	**214,973**	**98,358**	**28,019**	**6,660**	**202,972**	**23,018**	**573,999**
	2022							
2016	Percentage*	**Water**	**Mudflat**	**Grassland**	**Mangrove**	**Cropland**	**Forest**	**% of Total****
	Water	76%	20%	3%	0%	1%	0%	**45%**
	Mudflat	26%	52%	16%	0%	6%	0%	**9%**
	Grassland	10%	27%	21%	5%	37%	1%	**6%**
	Mangrove	18%	10%	2%	47%	18%	5%	**1%**
	Cropland	1%	5%	2%	0%	89%	2%	**34%**
	Forest	0%	0%	0%	1%	30%	69%	**5%**
	% of Total**	**37%**	**17%**	**5%**	**1%**	**35%**	**4%**	**100%**

* Percentages (%) are calculated dividing the corresponding values by the row totals.
** Percentages of Grand Total are calculated dividing the corresponding values by the grand total.

3.3 Pattern of coastal land use / land cover change

Table 2 shows that the 8,140 ha of mangroves in 2016 only remained 47% in 2022. The 18% was converted to water (probably because a higher tide in 2022 submerged young mangroves) and 18% to cropland. The conversion to cropland, while small (1,486 hectares), is potentially significant in terms of reducing the area of mudflat available for mud crab collection, a high-value livelihood of particular importance to landless families. Table 2 also shows that out of 6,660 ha of mangrove in 2022, about 3,976 ha were also mangrove in 2016. The remaining new mangroves came primarily from grassland (1633 ha) and cropland (937 ha). These changes reflect the very dynamic nature of the gulf's land cover in response to both natural and human forces.

Perhaps, mudflats could be precursor to grasslands which are then converted to croplands or grown into young mangroves. In the local context, people believe that when the vegetations such as *Oryza sativa* (locally known as Nat Sa Par) were started to grow on grassland, these areas are stabilized enough to do farming and thus they are being converted. According to our communications with local people, they believed that these lands would be wasted if they were not converting into farmland. However, due to different risks (such as saltwater intrusion), these coastal croplands are not economically profitable compared to those in high land (Wint Hte et al., 2022).

Furthermore, local people reportedly said that stable mudflats of two years are supposed to grow grasses and then turned to natural mangroves if they are left untouched for a few years. Nowadays, people are expanding croplands by transforming grasslands directly for business proposes. This is also one of the threats to natural mangroves.

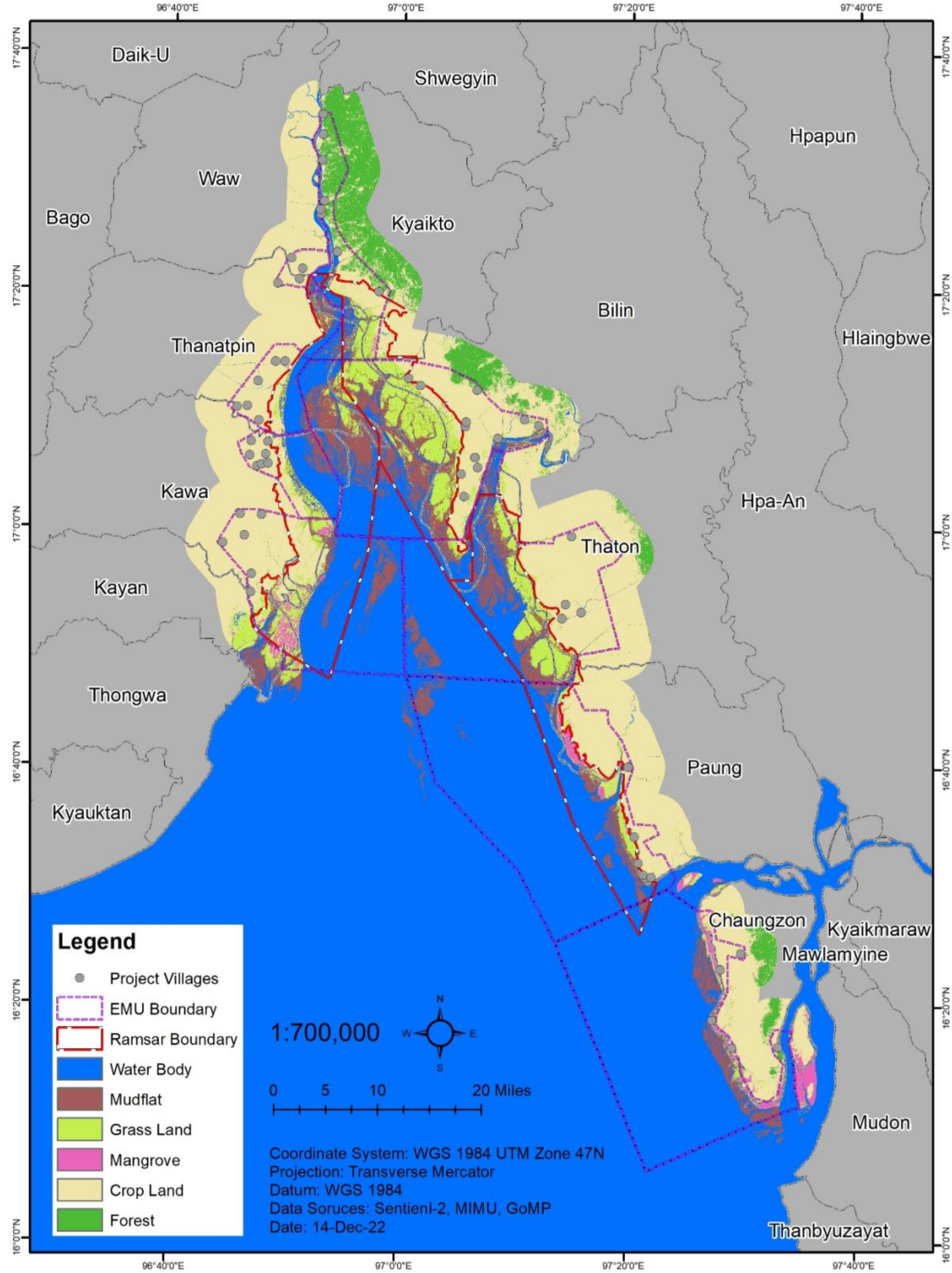


Figure 10: Land use / land cover map of the GoM area in 2016

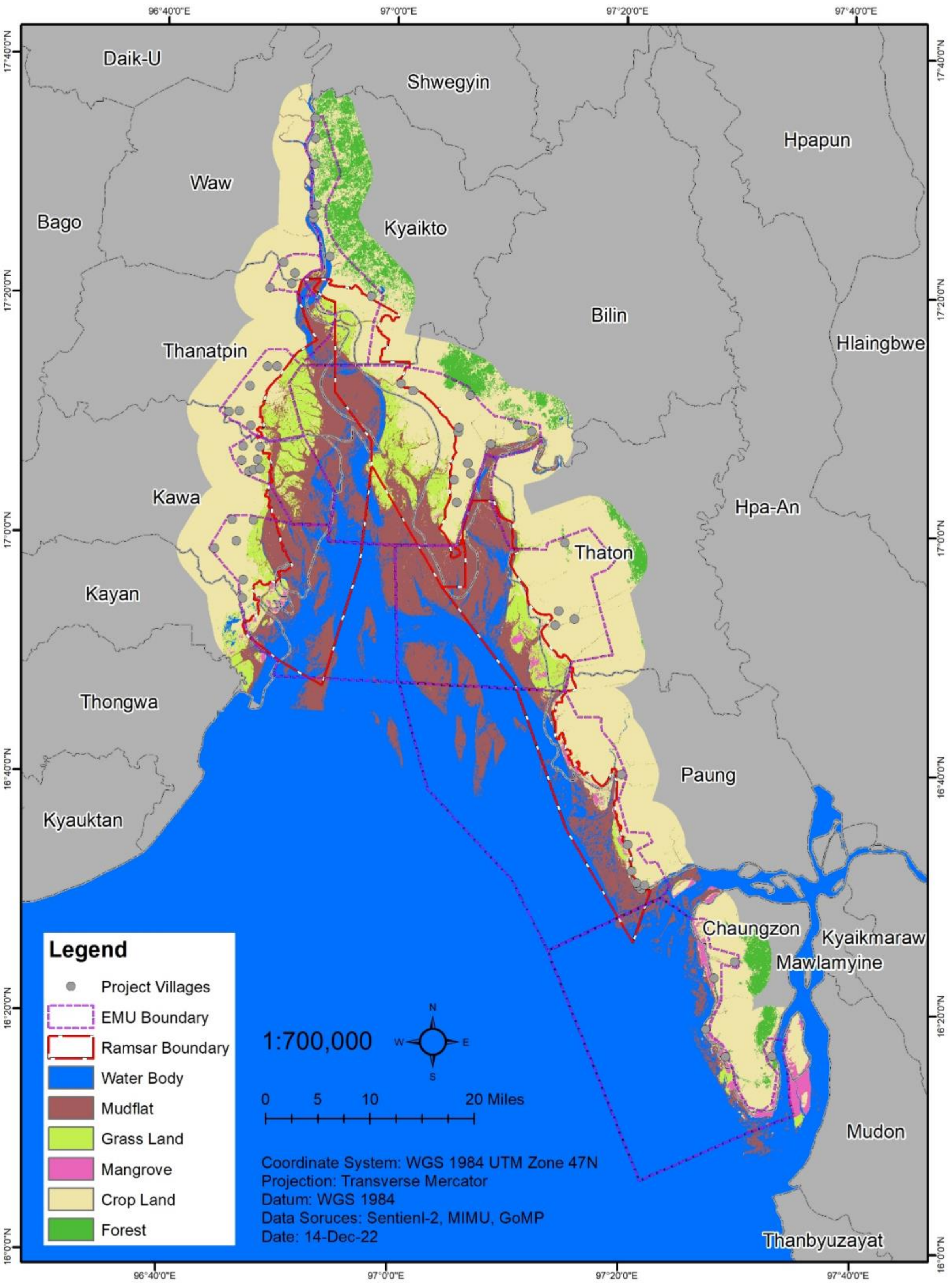


Figure 11: Land use / land cover map of the GoM area in 2022

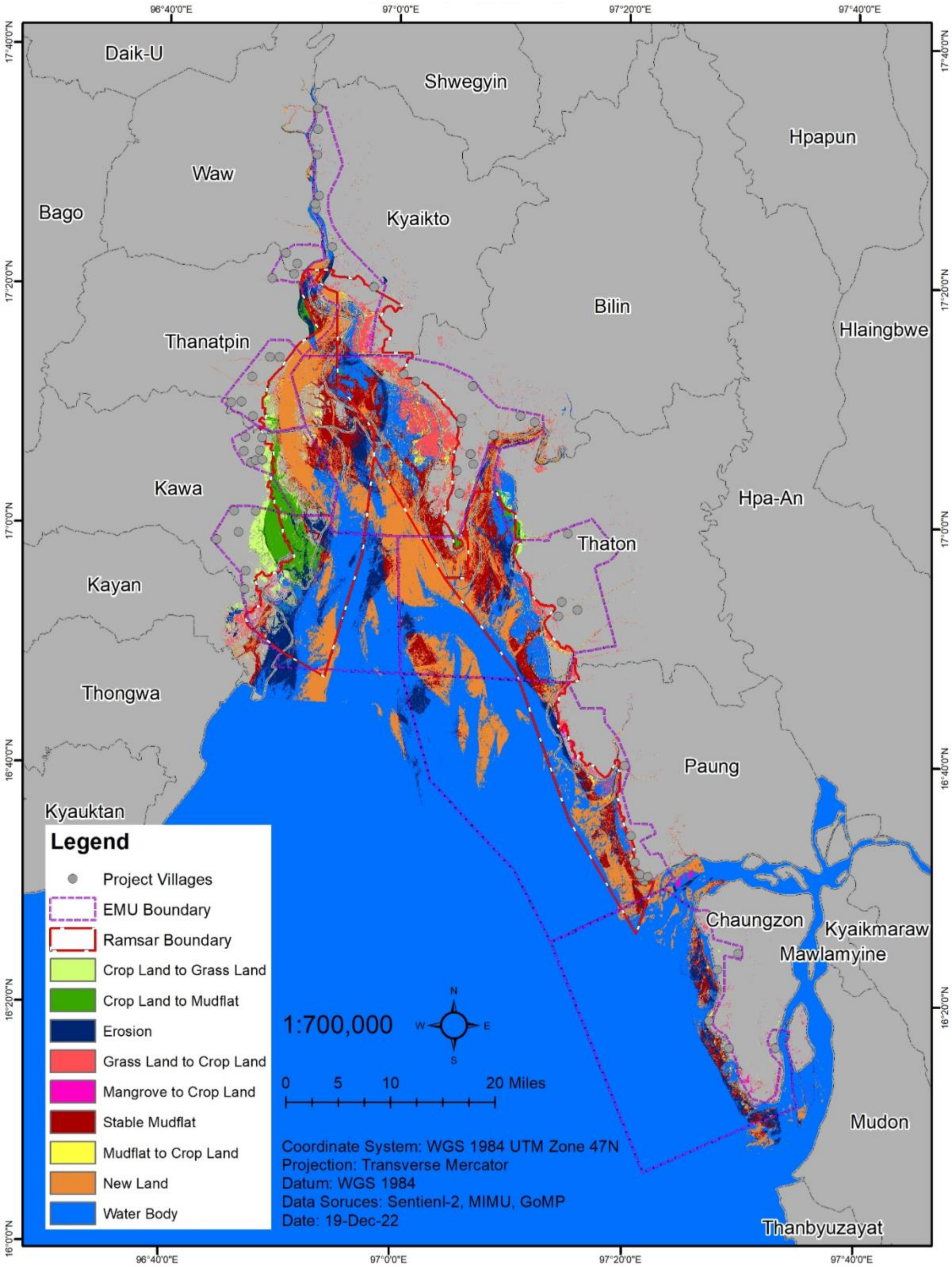


Figure 12: Coastal land use / land cover change in the GoM area between 2016 and 2022

4 CONCLUSION

The present study could identify coastal land use/ land cover change during a six-year interval on both Mon and Bago sides in the GoM area. The results showed that a greater extent of land has been lost on Mon side due to erosion, especially in Bilin and Kyaikhto townships, and new lands were formed, for example on Bago side, where no tenure of these lands was settled yet. We can expect that there would be more land loss on Mon side in the coming years. Expansion of croplands was also found in such areas as grassland and mangrove. Our study identified the patterns of the land use/ land cover change in the GoM area and assumed that mudflats could be precursor to grasslands which are then converted to cropland or grown into young mangroves. From this analysis, we could identify the current land cover of mudflats, grasslands and mangroves in 2022. These results could contribute to conservation planning, e.g., identification of stable mangroves for potential Community Forests to be conserved by local communities.

ACKNOWLEDGEMENTS

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