STUDYING THE IMPACT OF MANGROVE INCREMENT ON ACCRETED COASTAL AREA

Penchala Vineeth Kurapati (1), Ashish Babu (1), Andriananja Mahery (1), Kennedy Ramahatra (1)

[1] Project Scientist, Centre on Geo-Informatic Applications in Rural Development, Ministry of Agriculture, Livestock and Fisheries, Nanisana, Antananarivo, 101, Madagascar
Email: penchala.vineeth3@gmail.com; ashishbabu619@gmail.com; maheryandrian@gmail.com; ramahatra@gmail.com

KEY WORDS: mangrove mapping; coastal accretion; google earth engine; CoastSat; regression

ABSTRACT: Mangroves are necessary near the coastal areas as it promotes reduction of coastal land from erosion by encouraging sediment deposition and most of the experts promote plantation of mangrove. This study is primarily focused on assessing the influence of increment in mangrove with accreted coastal area from 1990 to 2020. Google Earth Engine and CoastSat were used in this study for performing change in mangrove and coastline respectively. The entire analysis was performed at foktany level, an administrative unit below commune. Statistical analysis such as ANOVA, regression and correlation were used for identifying the relation between mangrove and coastal land. It has been observed that there exists a positive correlation, trend and significance between mangrove and coastal land, which means with the increase in mangrove cover accretion of coastal area took place.

1. INTRODUCTION

1.1 Background

Mangroves are one of the important ecosystems of nature; they are forests, yet they grow in salty, brackish waters. They serve as habitat for fish and shellfish and as nests for birds. They provide living ways to the local communities, providing seafood, timber, firewood and even natural compounds for traditional medicine. Madagascar is home to the second largest extent of mangroves in the Western Indian Ocean (WIO). They represent about 20% of Africa's mangroves and about 30% of the mangroves in the WIO. But these ecosystem faces lot of threats like conversion to rice fields and shrimp farms, logging for fuel and construction wood, sedimentation due to upstream deforestation. Mangroves support coastal environment in a great way by protecting high waves and erosion, as well as habitats for endemic birds, geckos and lemurs(Shapiro et al., 2018).

Mangroves will help in preservation of coastal area from erosion and losing of valuable land area to ocean. It also helps in the accretion of land by holding eroded soil from the inlands(Alison Clausen et al., 2010). The presence of mangrove will help in reducing the force of high waves which will reduce the impact on the shorelines. Many studies had shown that, deforestation of mangrove areas adjacent to the open sea has sometimes exacerbated coastal erosion from sea waves (Mazda et al., 2002). Realising the importance of mangrove efforts had been made for restoring either by sustainable rehabilitation of destroyed mangrove area or by promoting plantation in non-mangrove areas i.e., barren land or marshlands (Lewis, 2001).

In Madagascar, mangroves were concentrated along the entire west coast facing Mozambique Channel, with the largest stands located in the northern and central parts of the west coast where climate is more humid. The area of mangrove for the year 2020 was estimated as 1,955.44 km^2 i.e.; it occupies 0.33% of total area of Madagascar, it was estimated that extent of mangroves during the years 1990, 2000 and 2010 were 2,537.65, 2,207.92 and 2,004.92 km^2 respectively, so it has been observed that extent of mangrove has been continuously declining when compared from 1990 till 2020, the area of mangrove lost when compared with 2010 was 49.47 km^2 i.e., around 2.46% (Jones et al., 2016). This study is mainly focused on studying the impact of mangrove increment on accreted shore area, for which change analysis and shoreline detection was performed for the years 1990 and 2020 by using cloud computing image processing system i.e. Google Earth engine and CoastSat respectively and finally, statistical analysis was performed between increased mangrove cover and accreted coastal areas for identifying the relation between them.

1.2 Objectives of the study

The detailed objectives of this study were:

1. Mangrove mapping for the years 1990, 2020 using Landsat-5, Landsat-8 respectively and performing change detection.
2. Shoreline extraction for the years 1990, 2020 using CoastSat.
3. Statistical analysis between increased mangrove and accreted coastal areas.

2. STUDY AREA

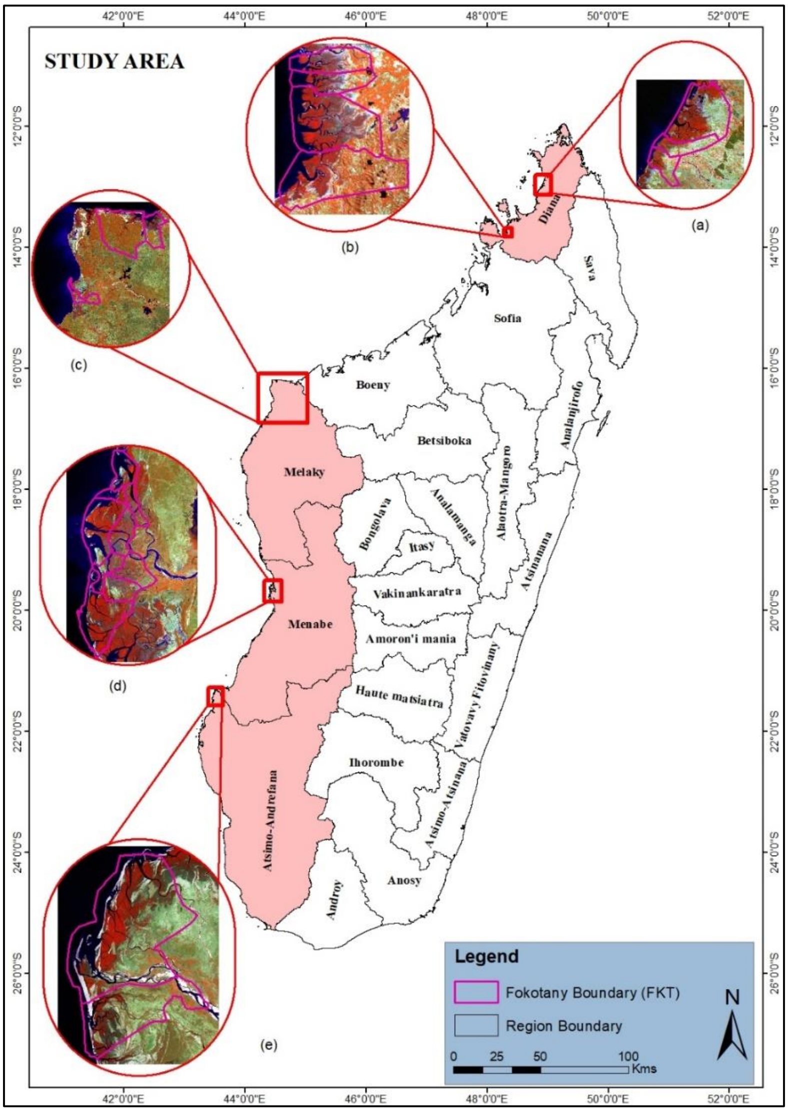


Figure 1: Location of Study area (a, b) Diana, (c) Melaky, (d) Menabe and (e) Atsimo Andrefana

Madagascar is a large island in Indian Ocean covering an area about 587,040 km^2. It is separated from the African coast by 400 km wide Mozambique Channel. As the western zones of Madagascar contain sedimentary deposit from Mozambique Channel it creates succession of hills. Western coastline holds by small dunes and majority of mangroves. Mozambique Channel currents helps in the creation of offshore deposit of alluvium soil and growth of river deltas. The gentle slope towards the western side of Madagascar creates drainage for inland rivers like the Onilahy, the Mangoky, the Tsiribihina, and the Betsiboka which carries fertile soil from vast plains resulted in many-channeled estuaries & sandbanks (Jean Dresch, 2020). About 4000 km of coastline of Madagascar, Mangrove forests covers 0.33 % of entire country. Mangrove forest concentrated in Mahajamba Bay, Bombetoka, South Mahavavy and Salala, and Maintrirano. As the difference in climatic and sea surface mangroves in this country varies over the places, those forest over the northwest are more diverse and taller compared to the southwest possibly due to lower rainfall and the absence of abundant freshwater(Giri & Muhlhausen, 2008). Mainly tropical, sub-humid climate are experienced over the area with majority of rainfall during October and March varying from 2,030 mm to 3,250 mm. The average monthly temperature ranges between 22°C in June and 29°C in March. This area is prone to cyclones and tropical storms on average twice a year which can cause inundation and other damages (Alison Clausen et al., 2010). In this study, some locations along the western coast is taken into consideration due to the availability of mangrove and its significance to the coastline. A total of 21 fokotany's were considered from regions of Diana, Menabe, Melaky & Atsimo-Andrefana as shown in figure 1.

3. DATA USED AND METHODOLOGY

3.1 Data used

A mosaic of cloud free Landsat-5 and Landsat-8 datasets acquired during the years 1990 and 2020 respectively were used for extracting the mangrove and shoreline. Google Earth Engine and CoastSat were used for performing change analysis of mangrove and shoreline respectively and ArcMap 10.5 is used for map generation.

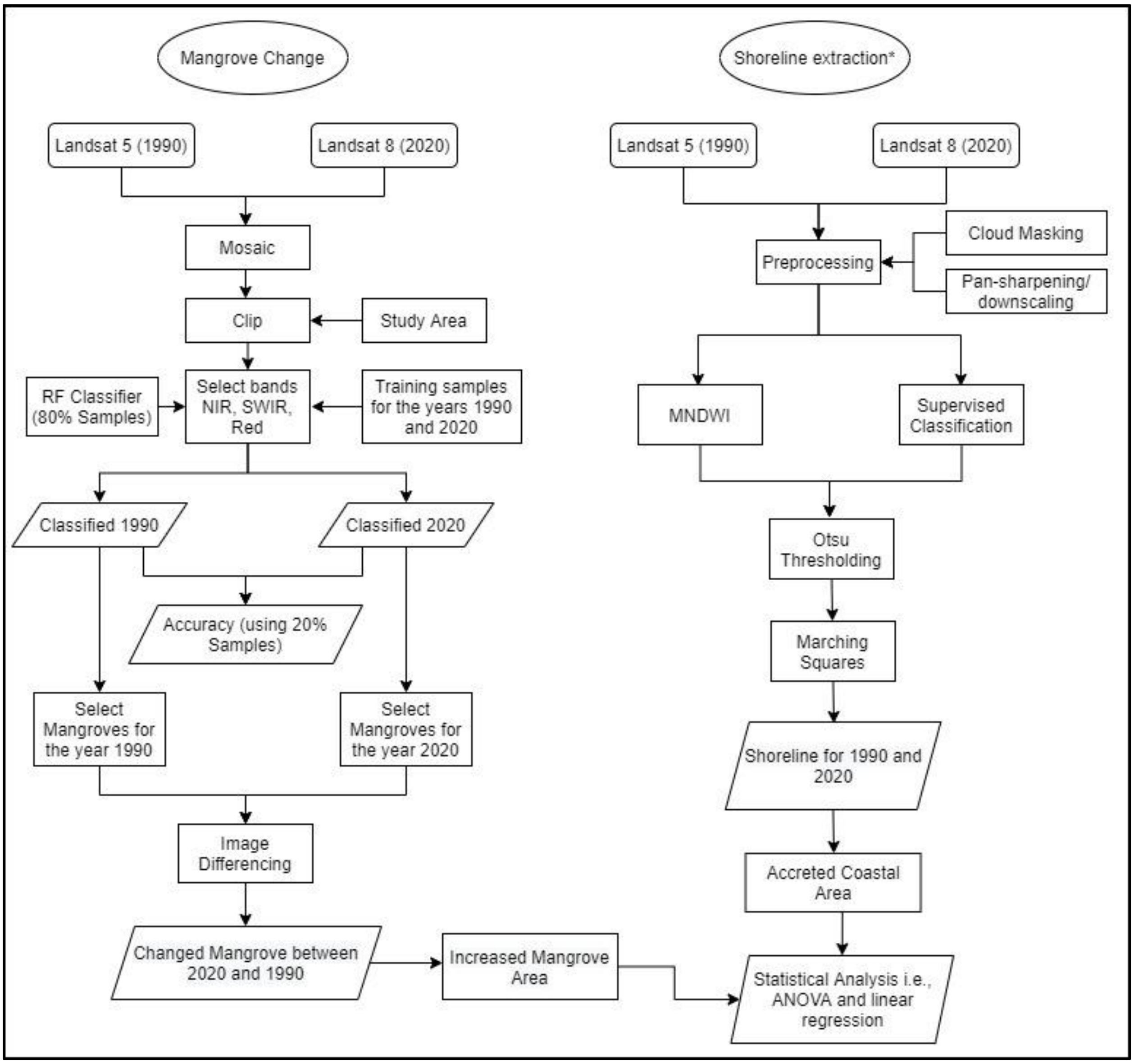
3.2 Methodology

The detailed methodology is shown in figure 2. In this study change analysis was performed in order to identify the impact of mangrove presence on shoreline for which Landsat-5 and Landsat-8 were used to extract mangrove and shoreline for two different two periods i.e., 1990 and 2020.

Mangrove change detection: Mangroves were determined through visual interpretation, they are considered as evergreen forest, where the property of greenness exists for whole year, they were separated from non-mangrove area by utilizing Landsat-5 and Landsat-8 surface reflectance composite images at band combination of NIR, SWIR and Red as shown in figure 3. Similar to other features mangroves possess unique spectral signature, which can be used for classification (Pagkalinawan, 2018). In Google Earth Engine image classification was performed using Random Forest algorithm, of which five land cover types were defined: (a) mangrove, (b) waterbody, (c) sand, (d) vegetation and (e) barren land (Lillesand and Keifer, 2002), a total of 487 and 557 samples of five regions for the year 1990 and 2020 respectively were used for analysis, out of which 80% of random samples were utilized for classifying Landsat-5 and Landsat-8 images and remaining 20% were used for assessing the accuracy of the classified outputs. As, present study is based on relationship between mangrove and coastal areas, mangroves were selected and image differencing technique was applied by using Eq. 1, (Celik, 2018) (Chunlei Ma et al., 2019) and increased mangrove area is extracted.

$$CD = P_t - P_0 \qquad (1)$$

CD is Change detection, P_t is Classified image at time period 2020 and P_0 is Classified image at time period 1990



*Source: (Vos, Splinter, Harley, Simmons, & Turner, 2019)

Figure 2: Flow diagram indicating methodology of the study

Shoreline extraction and coastal accretion: Accreted coastal area was estimated by extracting the shoreline for the years 1990 and 2020 using CoastSat which is an open-source software toolkit developed in Python that enables the user to develop time-series of shoreline position at any coastline worldwide from 30+ years (and growing) satellite imagery. The toolkit exploits the capabilities of Google Earth Engine to efficiently retrieve Landsat and Sentinel-2 images cropped to any user-defined region of interest. It was developed by Kilian Vos. It involves retrieval of the images from the GEE archive, pre-processing of the multispectral images (cloud masking, pan-sharpening and down-sampling); and automated extraction of shorelines from all the selected images using a sub-pixel resolution technique. By using MNDWI the boundary between sand and water is extracted. Otsu's thresholding algorithm used to find the variance between sand and water. The shoreline is created by applying Marching Squares algorithm to the sub-pixel level to the classification. CoastSat will provide accessibility to various TOA reflectance images like Landsat 5 (TM), Landsat 7 (EMT+)

and Landsat 8 (OLI) Tier 1 collections as well as Sentinel-2 (MSI) Level-1C products, which also represent TOA reflectance. CoastSat determines to monitor coastline changes globally at short (seasonal) and long (decadal) time series using satellite remote sensing to provide vital understanding of the relationship between climate & environment factors and coastline response into the future (Vos et al., 2019).

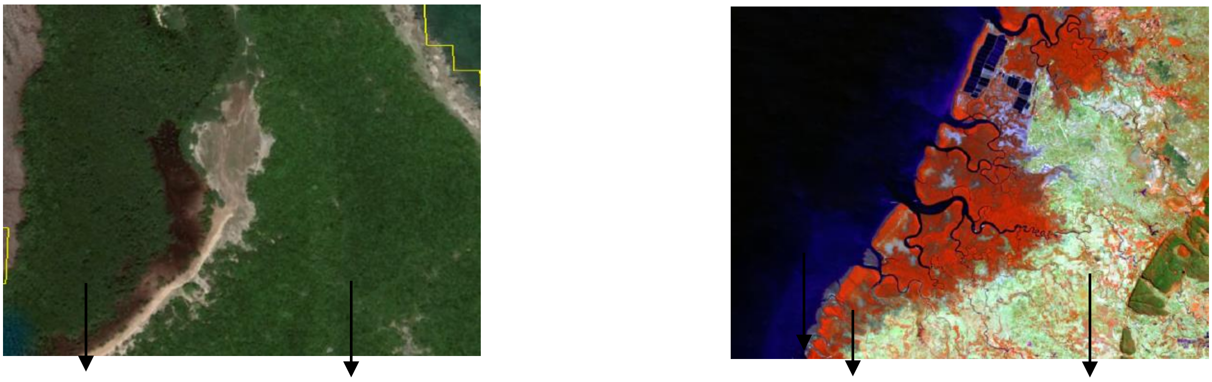


Figure 3: Differentiating mangrove from other vegetation a) using google earth b) using Landsat-5 or Landsat8 images with band combination of NIR, SWIR, Red

Relation between mangrove and coastal area changes: The relation between increased mangrove and accretion were assessed by using statistical analysis i.e., multiple linear regression as shown in Eq. 2, correlation and Analysis of Variance (ANOVA) which determines to identify statistical differences between the means of three or more independent groups as shown in Eq. 3 (Will Kenton, 2019).

$$Y = \beta M + \varepsilon \qquad (2)$$

Where Y is accretion of coastal area (in km^2), M is increment in mangrove area (change in mangrove cover (in km^2)), β is coefficient which measures the effect of increment in mangrove area on coastal area accretion and ε is the error.

$$F = \frac{MST}{MSE} \qquad (3)$$

Where F is ANOVA coefficient, MST is mean sum of squares due to treatment and MSE is mean sum of squares due to error.

4. RESULTS AND DISCUSSIONS

4.1 Change detection and accretion of coastal area

Classification of mangrove was done regionally and analysis was performed at foktany level. It has been observed that of the selected regions mangrove cover has been increased to 57.93 km^2 and 81.89 km^2 of mangrove has been decreased. Therefore 23.96 km^2 of net mangrove cover has been deforested. Accreted coastal area of the selected regions is 25.97 km^2 and 13.27 km^2 of coastal area was eroded. Therefore 12.7 km^2 of net coastal area has been accreted. For foktany level net mangrove cover in ambohibe is increased i.e., 6.64 km^2, whereas in ankatsao it has been decreased i.e., 9.11 km^2. The accreted coastal area in ambohibe is 4.19 km^2 which is highest and 3.75 km^2 of coastal area has been eroded in tsimandrafoza. The detailed statistics of mangrove cover and coastal area for each region and foktany were shown in table 1. The overall accuracy of the classified result for the regions Atsimo Andrefana is 96.8%, 100%; Diana 92.55%, 97.58%; Melaky 96.29%, 100% and Menabe 97.29%, 98.94% for the years 1990 and 2020 respectively. The entire analysis of mangrove change detection was performed in Google Earth Engine, the code link of the analyzed work and results were: https://code.earthengine.google.com/85cba467dc06557cbc8cbc2ea63cfd79. The mangrove cover and shoreline for the regions were shown in figure 4 & 6.

Table 1: Detailed statistics of Mangrove cover and coastal area

Region	Foktany	Increased mangrove cover (in km^2)	Decreased mangrove cover (in km^2)	Accreted coastal area (in km^2)	Eroded coastal area (in km^2)
Atsimo Andrefana	Ambohibe	10.212	3.574	6.394	2.196
	Bekoropoka	3.719	0.517	0.642	1.163
	Total	13.931	4.091	7.036	3.359
Diana	Ankotika	0.821	7.630	0.020	0.272
	Antrema	0.133	2.639	0.020	0.019
	Djangoa	1.446	2.592	0.009	0.083
	Marosely	0.078	2.052	0	0.075
	Ambatoharanana	3.508	11.165	2.089	0.117
	Analasatrana	1.155	4.345	2.480	0.005
	Andranofotsy	0.771	5.983	2.498	0.000
	Total	7.913	36.408	7.115	0.572
Melaky	Ankasakasa Tsibiray	7.401	4.499	0.594	0.385
	Anosimboalavo	4.375	0.773	0	0.176
	Makadany	10.019	0.773	1.923	0.667
	Total	21.795	6.045	2.517	1.228
Menabe	Ambakivao	0.346	0.548	0.111	1.279
	Andapotaly	1.290	0.780	2.125	1.741
	Ankatsao	0.617	9.736	0.196	0
	Antranoroa	0.184	3.364	0.037	0
	Antsakoa	0.645	2.857	0.499	0
	Antsakoamalinika	0.431	4.145	0.437	0.574
	Soarano Mer	5.309	5.196	5.832	0.695
	Tomboarivoa	0.590	1.914	0	0
	Tsimandrafoza	4.886	6.808	0.065	3.818
	Total	14.298	35.348	9.302	8.106
	Total	57.936	81.892	25.971	13.265

4.2 Statistical Analysis

The study is primarily focused on finding relation between area of increased mangrove cover and accreted coastal land, ANOVA and regression analysis were performed and results were shown in table 2. Here in linear regression the trend between increased mangrove cover and deposited coastal were positive as shown in graph (figure 5). The p value, r^2 and correlation coefficients were 0.008, 0.313 and 0.56 respectively. In this case as p value is less than 0.05 and correlation coefficient is positive which indicates there exists a statistical significance between accreted coastal land and mangrove cover, where it implies that foktany's with increased mangrove cover witnessed increase in accretion of coastal area. Out of 21 foktany's only three foktany's i.e., Marosely of Diana, Anosimboalavo of Melaky and Tomboarivoa of Menabe regions had witnessed no increment in coastal area with the increase in mangrove cover of 0.078, 4.375, 0.59 km^2 respectively.

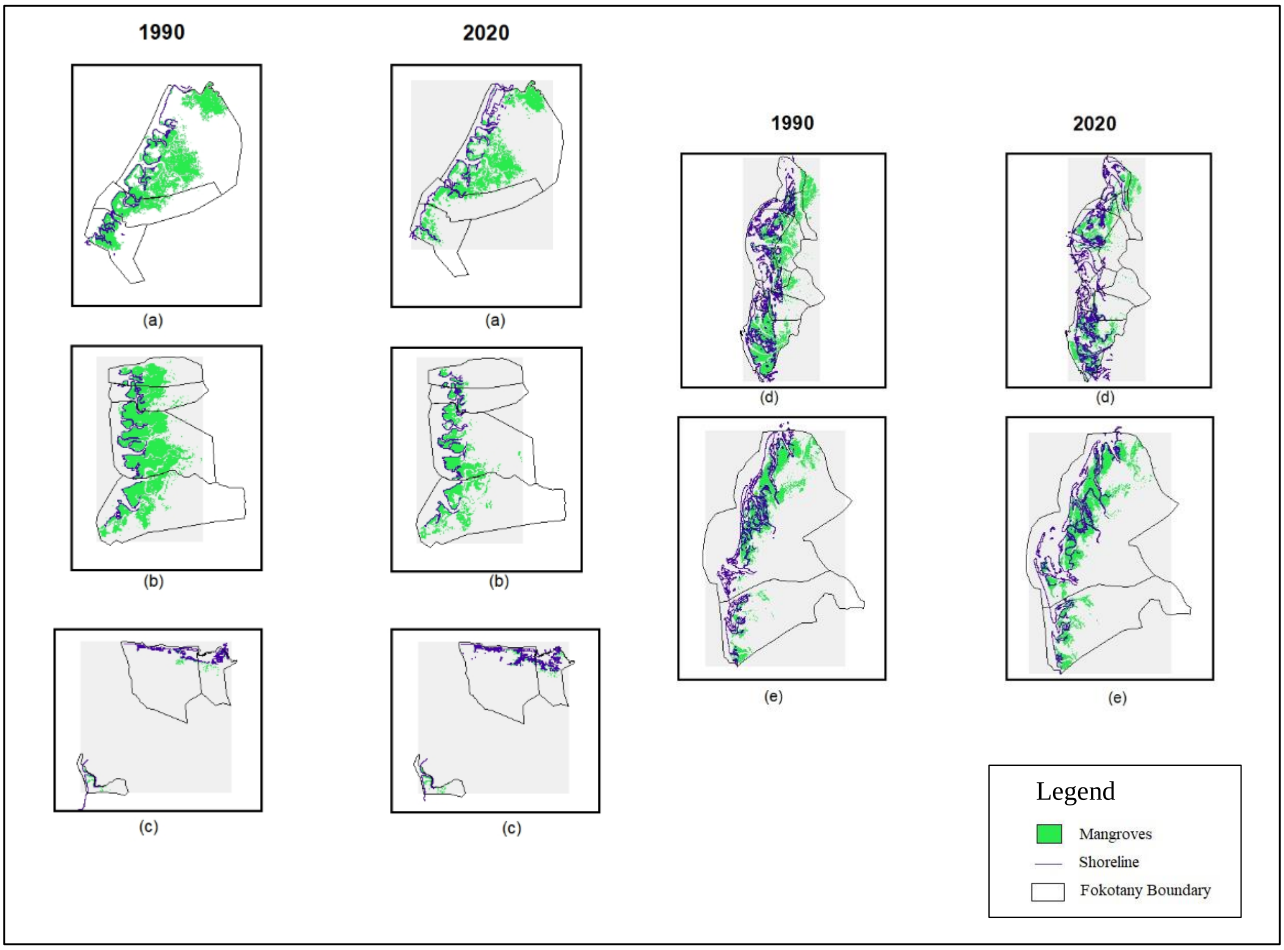


Figure 4: Mangrove and shoreline maps for the years 1990 and 2020 (a, b) Diana, (c) Melaky, (d) Menabe and (e) Atsimo Andrefana

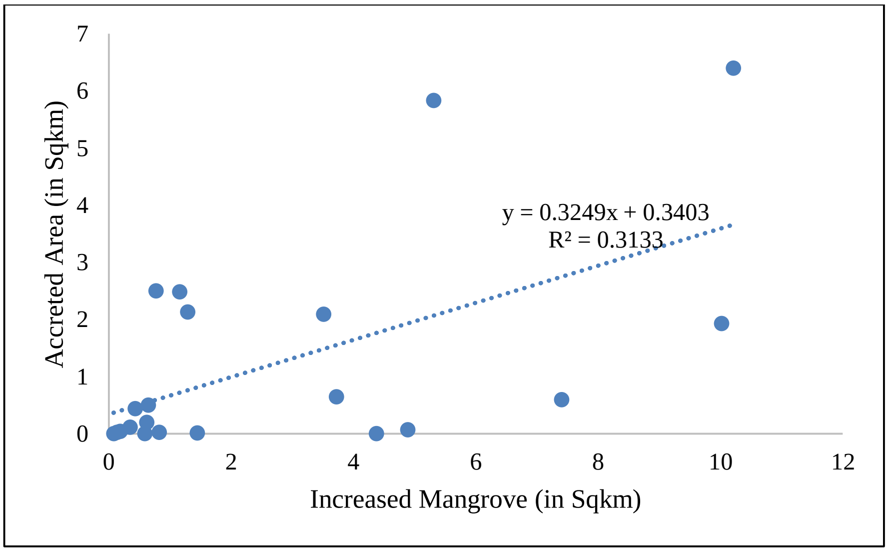


Figure 5: Linear regression between increased mangrove cover and accreted coastal area

Table 2: Detailed statistics of regression and Analysis of variance examining the effect of increment in mangrove with deposited coastal area

Regression Statistics	
Multiple R	0.560
R Square	0.313
Adjusted R Square	0.277
Standard Error	1.579
Observations	21

ANOVA

	df	SS	MS	F	Significance F
Regression	1	21.620	21.620	8.670	0.0083
Residual	19	47.381	2.494		
Total	20	69.001			

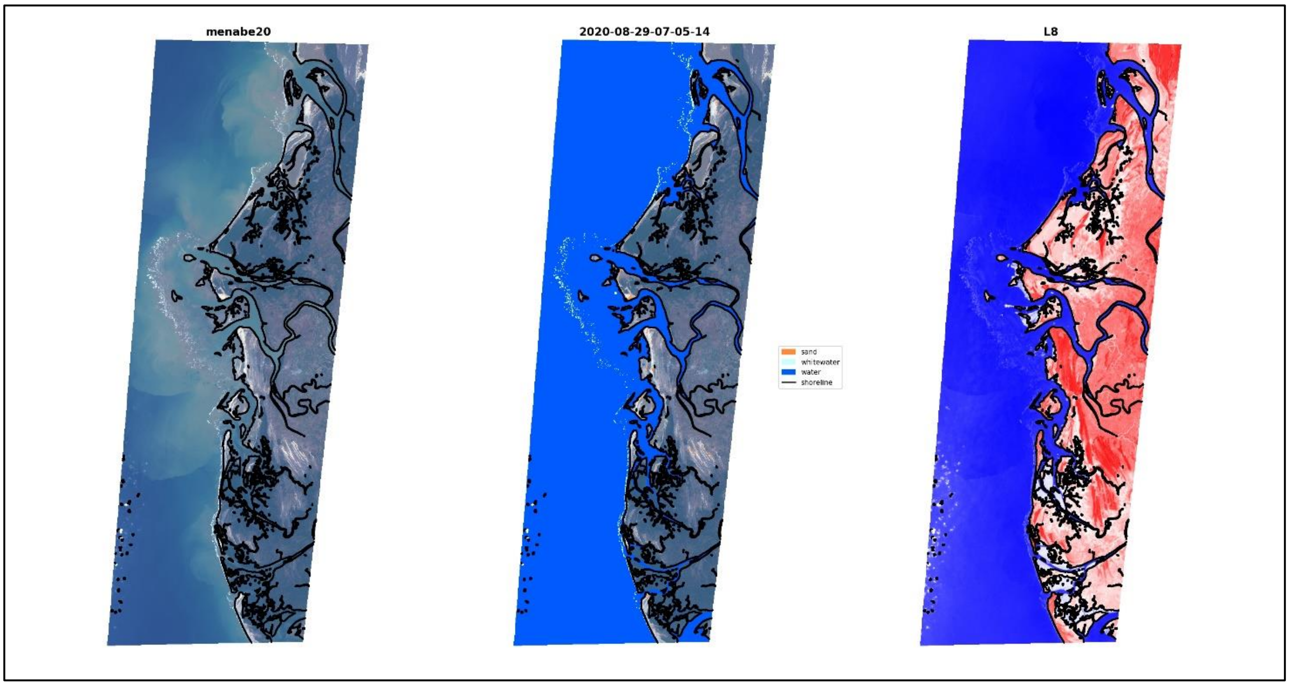


Figure 6: Extracted Shoreline using CoastSat for the year 2020 of Menabe

5. CONCLUSIONS

Classification of satellite images is one of the easiest way for extraction of mangrove area and performing change detection. CoastSat played a prominent role for clipping out shoreline at different time periods. Of selected foktany's Diana and Menabe had experienced highest net loss of mangrove i.e., 28.49 km^2 and 21.05 km^2 respectively, whereas Melaky and Atsimo Andrefana has shown net increment in mangrove i.e., 15.75 km^2 and 9.83 km^2 respectively. This study is primarily focused on studying the impact of increment in mangrove with shore land deposition, in most of the regions increased mangrove cover is almost equal or twice as accreted coastal area expect for Melaky, where 21.795 km^2 of increased mangrove cover experienced 2.517 km^2 of coastal accretion. Our statistical analysis, i.e., positive correlation, trend and significance between increased mangrove cover and shore land deposition implies that accumulation of sediments near coasts increases with the increase in mangrove. According to the report by WWF, the conservation of mangroves in various parts of Madagascar has been implemented a decade ago where most of the barren areas were successfully converted to mangroves (Shapiro et al., 2018) and also authorities should take necessary actions to prevent deforestation of mangrove.

5.1 References and/or Selected Bibliography

References from Journals:

Alison Clausen, Harisoa Rakotondrazafy, Harifidy Olivier Ralison, A. A. (2010). Mangrove ecosystems in western Madagascar : an analysis of vulnerability to climate change. International, Conservational Society, Wildlife Conservation.

Celik, N. (2018). Change Detection of Urban Areas in Ankara through Google Earth Engine. 2018 41st International Conference on Telecommunications and Signal Processing (TSP), 1–5.

Chunlei Ma, Bin Ai, Jun Zhao, X. X. and W. H. (2019). Change Detection of Mangrove Forests in Coastal Guangdong during the Past Three Decades Based on Remote Sensing Data. Remote Sensing, 11(10.3390/rs11080921). Retrieved from doi:10.3390/rs11080921.

Giri, C., & Muhlhausen, J. (2008). Mangrove Forest Distributions and Dynamics in Madagascar (1975–2005). Sensors, 2104–2117.

Lewis RR. (2001). Mangrove Restoration - Costs and Benefits of Successful Ecological Restoration. Universiti Sains Malaysia, 4–8.

Jones, T. G., Glass, L., Gandhi, S., Ravaoarinorotsihoarana, L., Carro, A., Randriamanatena, D., & Cripps, G. (2016). Madagascar ' s Mangroves : Quantifying Nation-Wide and Ecosystem Specific Dynamics , and Detailed Contemporary Mapping of Distinct Ecosystems. Remote Sensing. https://doi.org/10.3390/rs8020106.

Mazda, Y., Magi, M., Nanao, H., Kogo, M., Miyagi, T., Kanazawa, N., & Kobashi, D. (2002). Coastal erosion due to long-term human impact on mangrove forests, 1–9.

Pagkalinawan, H. (2018). Mangrove Forest mapping Using Landsat 8 Images, (November). https://doi.org/10.13185/SM2014.00117.

Shapiro, A., Randriamanantena, D., Kuechle, H., & Razafindramasy, F. (2018). The mangroves of Madagascar – cover, status and trends 2000-2018. WWF Madagascar.

Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. L. (2019). CoastSat : A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. Environmental Modelling and Software, 122(September), 104528. https://doi.org/10.1016/j.envsoft.2019.104528.

References from Books:

Lillesand, T. M & Kiefer, R. W., (2002). *Remote Sensing and Image Interpretation*, New York: John Wiley & Sons, Inc.

References from websites:

Jean Dresch (2020, September 9). Madagascar https://www.britannica.com/place/Madagascar.

Will Kenton (2019, April 2019). Analysis of Variance (ANOVA) https://www.investopedia.com/terms/a/anova.asp.