Pak. j. eng. technol. sci.
Volume 5, No 2, 2015, 134-151
ISSN: 2222-9930 print
ISSN: 2224-2333 online

Worldview-2 and Landsat 8 Satellite Data for Seaweed Mapping along Karachi Coast

Muhammad Danish siddiqui
Department of Remote Sensing and Geoinformation Science
danish769@yahoo.com
(Corresponding Author)
Arjumand Z. Zaidi
Institute of Space Technology, Karachi
arjumand.zaidi@ist.edu.pk

Running Title: Seaweed Mapping along Karachi Coast using Satellite Data

ABSTRACT

Seaweed is a marine plant or algae which has economic value in many parts of the world. The purpose of this study is to evaluate different satellite sensors such as high-resolution WorldView-2 (WV2) satellite data and Landsat 8 30-meter resolution satellite data for mapping seaweed resources along the coastal waters of Karachi. The continuous monitoring and mapping of this precious marine plant and their breeding sites may not be very efficient and cost effective using traditional survey techniques. Remote Sensing (RS) and Geographical Information System (GIS) can provide economical and more efficient solutions for mapping and monitoring coastal resources quantitatively as well as qualitatively at both temporal and spatial scales. Normalized Difference Vegetation Indices (NDVI) along with the image enhancement techniques were used to delineate seaweed patches in the study area. The coverage area of seaweed estimated with WV-2 and Landsat 8 are presented as GIS maps. A more precise area estimation wasachieved with WV-2 data that shows 15.5Ha (0.155 Km^2)of seaweed cover along Karachi coast that is more representative of the field observed data. A much larger area wasestimated with Landsat 8 image (71.28Ha or 0.7128 Km^2) that was mainly due to the mixing of seaweed pixels with water pixels. The WV-2 data, due to its better spatial resolution than Landsat 8, have proven to be more useful than Landsat 8 in mapping seaweed patches.

Keywords: NDVI, Remote Sensing, Seaweed, WorldView-2

1. INTRODUCTION

What are sea weeds?

Seaweeds or marine algae are the groups of plants that found either in marine or brackish water. More than 17,000 species of marine plants are identified so far and 95 percent of these are algae [10]. Seaweeds contain chlorophyll like photosynthetic pigment that helps them to produce their food in the presence of sunlight and nutrient. Rich resources of seaweed are found in South Australia, Mediterranean, Japan, South Africa and north pacific regions. More than 10,000 species of marine plant have been reported all over the world [17]. Approximately 220 different types and 740 seaweed species were documented in India of which around 60 species are of commercial worth [14].

Importance of seaweed

Like other marine plants, seaweeds are also the useful part of tropical ecosystems providing shelter and food for near shore fisheries and marine animals. Seaweeds also play a role as a water purifier in fish aquaculture and provide fish breeding places. Seaweeds due to their chemical properties and nutritional values are utilized in many countries as food, fodder, fertilizer and phycocolloids. Apromising industry demand for raw material of seaweed exists in the local market.

Seaweed resources along Karachi Coast

Seaweed is an important part of the marine ecosystem of Karachi coast beside mangroves and coral reef providing habitats for marine life. Large quantities of seaweed are present along the coastal water of Pakistan that grow under the sea and can also be found on the beaches as floats or tangled in the rocks when sea water recedes. The coastal areas of Pakistan houses around seventy classes and twenty-seven categories of seaweed [22]. A past survey report indicates the largest seaweed biomass collected from the Manora coastal area weighing around 6 kilograms/m^2 from drifted seaweed and 21 kilograms/m^2 from attached kelp[22]. Ulva Fasiata, Chondria tennussima, Sargassum spp and Valoniopsis pachyema are the most richly available species of seaweeds at Karachi coast as stated by the previous studies [1, 11, 24]. However, in a personal communication with an expert diver, a very limited stock of Ulva Fabiana was reported.

Mapping seaweed

The need to find out the accurate and effective techniques for mapping and monitoring marine plants such as seagrass and seaweed is already established[19]. Traditionally, marine scientists describe shallow and intertidal water marine habitats through sampling method. This method is time-consuming, expensive and requires a lot of manpower. On the other hand, satellite imagery, aerial imagery, and other remote sensing techniques are proven to be the most convenient method for measuring and mapping marine habitats.

Remote sensing for seaweed mapping

Remote sensing is a vital tool for observing benthic habitats such as benthic algae and coral-reef ecosystems. Many researchers have already used airborne and space systems such as MODIS, MERIS Landsat, and high-resolution satellites such as WorldView-3 (WV-2)for marine and coastal resource mapping including seaweed [2, 9 ,12-13]. The satellites sense the intensity of the light that reflectsback from the surface of Earth. Further processing can convert a raw image into a meaningful information regarding the features on the surface of Earth. Various satellite sensors are being used for developing different indices to extract features including seaweed area. Different image enhancement techniques and vegetation indices are usually employed to map seaweed patches. In this study WorldView-2 and Landsat 8 images are used for this purpose.

Justification of the study

Besides a worldwide economic value of seaweed, the local fishermen of Karachi considerit a useless plant and a nuisance that restricts their fishing activities entangling in the fishing nets. An awareness campaign had been carried out by few researchers in Karachi to make these fishermen aware of the economic potential of seaweed resources and their utilization in many industries including food, cosmetics and pharma. The fishermen of Buleji area had shown a keen interest in participating seaweed related economic activities. Now the need was to estimate the available stock of seaweed along coastal areas of Karachi to utilize its market potential.A lot of coastal resources in Pakistan are still unexplored and unmapped. The geospatial techniques utilized in this study for mapping spatial distribution of seaweed resources with high-resolution satellite data willnot only be helpful to assess the seaweed stock along Karachi coast but would further be utilized in future seaweed related studies. The use of high multispectral satellite remote sensing to map marine habitats and macroalgae along Karachi coast has not been done earlier.

2. STUDY OBJECTIVES

There are two (02) main objectives of this research which are described below;

1. tomap seaweed patches along Karachi coast using WV-2 and Landsat 8 images and image processing methods
2. to do a comparative analysis of the results of the two satellite sensors

MATERIAL AND METHODS

Study Area

The study area of Karachi coast is shown in Fig. 1. A wide range of seaweed species including red, brown, and green, is present in the intertidal and subtidal zonesof Manora, Sandspit, and Buleji beaches. The coastal area of Karachi contains shallow beaches, marine terraces and lagoons. Four major inlets, Manora Channel (Karachi harbor) Korangi creek, Phitti creek, and Kheuddi creek, join the sea in the study area.

Landsat 8 and WorldView-2 satellite data

Landsats are the series of satellites developed by the United States National Aeronautics and Space Administration (NASA). The United States Geological Survey (USGS) operates Landsat satellites. Landsat 8 is the latest of that series that was launched in February 2013. Landsat 8 is effective for studies of coastal areas, lakes, and oceans with the help of an additional spectral band.The Landsat 8 image of February 26, 2014, was acquired from the Earth explorer website (http://earthexplorer.usgs.org).

The WV-2 is a commercial satellite which was recently launched by Digital Globe with enhanced spatial and spectral resolutions. The WV-2 data include 0.5-meter spatial resolution of the panchromatic band (450-800nm) and 2-meter multispectral eight (08) bands: four (04) standard blue, green, red and infrared bands. It has additional new four bands such as near infrared-2 (860–1040 nm), the coastal band (400–500 nm), the yellow band (585–625 nm), and the red edge (705–745 nm) which are beneficial for coastal research [7, 23]. Since 2010, WV-2 satellite data have been efficiently used for mapping of seagrass, macroalgae and submerged vegetation [4-5,15-16 , 20-21).The WorlView-2 image of January 19, 2010, was provided by Digital Globe (https://digitalglobe.com) for research purpose.

Field survey

Fig. 2 shows the ground survey points that were collectedon February 26, 2014. The field survey was conducted to identify the seaweed patches in the study area. The GPS points were taken where seaweed patches were observed.

Methodology

A detailed methodology flowchart is shown in Fig.3. Further detail of each step is presented in the following subsections.

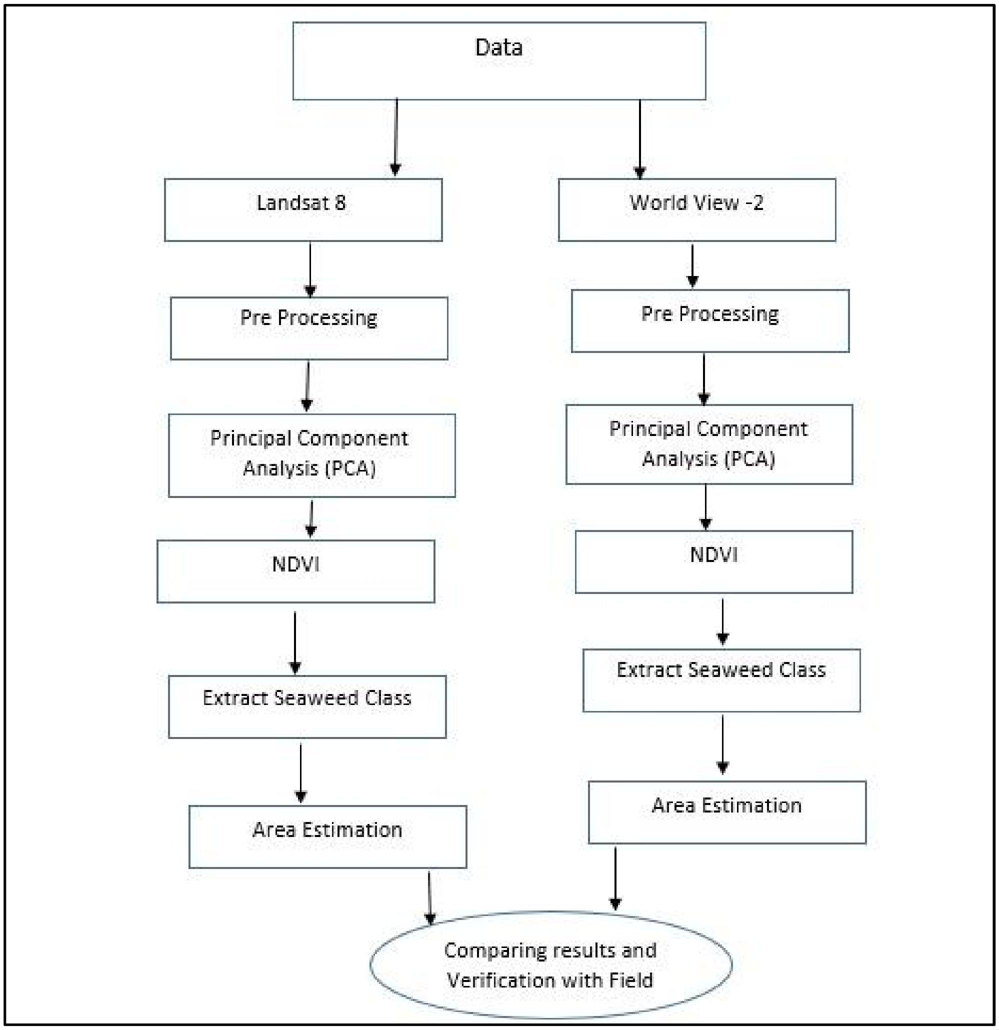


Figure 3 Workflow Diagram

Landsat 8 Data processing

After acquiring the satellite data, the next step was to convert the digital numbers (DN) to reflectance values.The digital numbers are the raw pixel values of a satellite image. For this purpose, first, the image was converted into radiance (Lλ) using Eq.1.The next step was to convert radiance image into the reflectance image using Eq. 2.

$$L\lambda = (LMAX - LMIN)/255 * DN + LMIN \quad (1)$$

$$p\lambda = \pi * L\lambda \frac{d^2}{ESUN\lambda} * COS\theta s \quad (2)$$

Where;

Lλ	=Spectral Radiance
LMax	=spectral radiance which scaled to QCALMAX in watts/(meter squared * ster * µm)
LMin	=the spectral radiance which scaled to QCALMIN in watts/(meter squared * ster * µm)
DN	=digital number
Pλ	=Unit less TOA reflectance

Lλ = Spectral radiance (at-satellite radiance)

D = Earth-Sun distance

Esun λ = Mean solar exo-atmospheric irradiances

θs = Solar zenith angle

Worldview -2 data processing

First, the layer stacking of eight (08) multispectral bands of WV-2 was done. The subsetting of the study area wasdone second. The pixel values of satellite images, expressed as digital numbers (DNs), can beused to calculate the reflectance value of each pixel. The calculation of reflectance is necessary for a meaningful analysis of satellite data[8]. In this regard, first, the conversion of DNs to radiance is required that can be achieved throughEq. 3 [23].Eq.4 is useful to calculate the Top-of-Atmosphere spectral reflectance for WV-2 satellite image from spectral radiance (Lλ)[23].

$$L\boldsymbol{\lambda} pixel, Band = \frac{KBand * qpixel, Band}{\Delta\lambda Band} \quad (3)$$

$$\rho p = (\pi * \lambda * d2)/(ESUN\lambda * COS(\theta S)) \quad (4)$$

Where;

L λpixel, Band = Top-of-Atmosphere Spectral Radiance image pixels [W-m^{-2}-sr^{-1}-μm^{-1}]

KBand = absolute radiometric calibration factor [W-m^{-2}-sr^{-1}-count-^{1}] for a given band

qPixel, Band = radiometrically corrected image pixels [counts or Digital Numbers]

Δλ = effective bandwidth [μm] for a given band

ρp = unit less planetary reflectance

π = constant (22/7)

Lλ = spectral radiance

d = earth-sun distance

Esun =mean solar exoatmospheric irradiance(s)

Cos(θ**s)** **=** Solar zenith angle

Normalized Difference Vegetation index

The vegetation spectral indices are simple and can be used to compare data obtained under changing brightness conditions. However, the effectiveness of the conventional vegetation indices for submerged vegetation is questionable [6]. The normalized difference vegetation index (NDVI) is being used widely to estimates vegetation extent including coastal plants with high-resolution satellite data which are essential for underwater habitat studies [15].NDVI can be calculated with the red (R) and near-infrared (NIR) bandsof the electromagnetic spectrum(Eq. 5). The NDVI values range from -1 to +1 as shown in

Fig.4. In WV–2 data, there are two (02) infrared bands;NIR1 and NIR2. In this study, NDVI2wasused which is calculated using the NIR2 and RED bands [3, 18].

$$NDVI = NIR - RED/NIR + RED (5)$$

Principal Component Analysis (PCA)

PCA is one of the image enhancement techniques in image processing which is considered to be the most powerful method among others. Through PCA multi-dimensional data are reduced for analysis and visualization. This method used statistics to convert a correlated variable set into principal components that make a linearly uncorrelated variable set. In this study, PCA technique was applied on Landsat 8 and WV-2 to assessits capability in enhancing the submerged seaweed patches. A comparison of PCA enhanced patches with NDVI derived seaweed area was also done in this study.

Reclassification and Area Estimation

In this phase, the threshold for seaweed resources was defined for NDVI values.Three classes of *low, medium* and *high*were defined based on NDVI values for identification of seaweed. NDVI1 and NDVI2 raster images were reclassified accordingly and converted to the vector format to estimate seaweed stock along Karachi coast.

3. RESULTS AND DISCUSSIONS

Landsat 8

The maximum and minimum values of NDVI were noted to be 0.16 and 0.011(Figure 4)at seaweed locations identified through field surveys. Similarly,NDVI for water pixelsrangesbetween 0.011 to -1. The Principal component analysis (PCA) has been applied to the Landsatimage that enhanced the submerged seaweed patches as shown in Fig.5.During analysis, it was observed that NDVI could not map submerged seaweeds patches as effectively as PCA of Landsat 8 has done (Fig. 6).

Worldview -2

The WV-2 NDVI2index enhanced the seaweed patches much better than Landsat 8 NDVI (Fig.8) with values ranging from -1 to 0.44. Further classification is done to extract seaweed pixels as shown in Fig.9.The range of NDVI2 values for seaweed was identified as -0.03 to 0.47. The estimatedseaweed cover is about 15.5ha as shown in Fig.10.The PCA techniques were applied to the WV-2 image to enhance seaweed resources as shown in Fig.11.The PCA of WV-2 is very similar to WV-2 NDVI2results in identifying seaweed patches as shown in Fig.12.The low, medium and high seaweed zones, classified in NDVI2, were 0.4545 km^2, 0.198 km^2, and 0.0603 km^2 respectively as shown in Fig.7.

Comparison - NDVI of Landsat 8 and NDVI2 of WV-2

A precise detection of seaweed using satellite data and algorithms depends on the spatial resolution of satellite images or algorithm restrictions [2].Duringanalysis, it was noted that Landsat 8 area estimation mixed water pixels with seaweed pixels resulting in an overestimation of seaweed area. Landsat 8 also failed to enhance the submerged seaweed. The seaweed areas estimated through WV-2 and Landsat 8 are presented in Table 1.

Table 1 Area Estimation

Landsat 8	WorldView-2
71.28Ha (0.7128Km^2)	15.5Ha (0.155 Km^2)

4. CONCLUSIONS

In this study, different indices were applied using two different sensors. The following trends were found.

1. Landsat 8 NDVI enhanced seaweed resources but overestimated the seaweed area by mixing seaweed and water pixels.
2. Landsat 8 NDVI also failed to enhance submerged seaweed that was below the water surface.
3. Principal component analysis of Landsat 8 effectively enhancedthe submerged seaweed patches.
4. NDVI2of Worldview 2 enhanced seaweed patches much better than NDVI of Landsat 8.
5. Field observations also verified PCA ofWV- 2 producing good results.

Remote sensing techniques when applied on the coast of Karachi to identify seaweed patches fulfilled the purposeeffectively. The accuracy of such analysis greatly depends on the spatial and spectral resolution of satellite data. In this study, it was possible to identify seaweed locationswith high-resolution WV-2 data more precisely than Landsat 8 data. The outcome of the study was verified through field observations. This methodology will help not only in further seaweed stock assessment studies but in selectingsuitable sites for seaweed cultivation. A sustainable stock of either naturally growing or cultivated seaweed will benefit the country'seconomy in the longer run.

Limitations

Theunavailability of field data on the WV-2 image acquiring date, could not make the exact date field validation for WV-2 results. It was assumed, therefore, that the same seaweed cover, as observed during field visit, would be present on WV-2 image acquisition date.

ACKNOWLEDGMENT: The Authors are highly grateful to Digital Globe for providing Worldview-2 data.The authors are also obliged to the Centre of Excellence in Marine Biology, the University of Karachi for helping during the field survey.

References

1. Aliya, R. and M. Shameel. Phycochemical evaluation of four coenobitic green Seaweeds from coast of Karachi. *Pak. J. Marine Biology* 5(1): 65-76 (1999).
2. C.Hu. A Novel ocean color index to detect floating algae index in the global oceans. *Remote Sensing of Environment*. pp: 2118-2129(2009).
3. Campbell, J.B. *Introduction to Remote Sensing*.The Guilford press. New York, US(2002).
4. Cerdeira-Estrada, S.; Heege, T.; Kolb, M.; Ohlendorf, S.; Uribe, A.; Muller, A.; Garza, R.; Ressl, R.; Aguirre, R.; Marino, I.; Silva, R., and Martell, R.,. Benthic habitat and bathymetry mapping of shallow waters in Puerto Morelos reefs using remote sensing with a physics based data processing. *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (Munich, Germany).*pp: 4383–4386(2012).
5. Chen, P.; Liew, S.C.; Lim, R., and Kwoh, L.K.,. Mapping coastal ecosystems of an offshore landfill island using WorldView-2 high resolution satellite imagery. *Proceedings of the 34th International Symposium on Remote Sensing of Environment (Sydney, Australia)* pp: 767–769(2011).
6. Cho, H. J., & Lu, D. A water-depth correction algorithm for submerged vegetation spectra. *Remote Sensing Letters1*(1):29-35(2010).
7. DigitalGlobe Staff,. The Benefits of the 8 Spectral Bands of WorldView-2: Applications Whitepaper. London: *DigitalGlobe, Technical Report WP-8SPEC Rev* 01/13:12p (2013).
8. Elsharkawy, A., Elhabiby, M., & El-Sheimy, N. Quality Control on the Radiometric Calibration of the WorldView-2 Data. In *Global Geospatial Conference* (2012).
9. Gower, J., Hu, C., Borstad, G., & King, S. Ocean color satellites show extensive lines of floating Sargassum in the Gulf of Mexico. *IEEE Transactions on Geoscience and Remote Sensing* 44: 3619−3625 (2006).
10. H.S. Baig, S. M. Saifullah, and A. Dar.Seaweed Resources of Pakistan.*Utilization of Marine Resources*, *ISESCO, Karachi, 20-22 Dec*: pp. 160-171(2002).
11. Haider, S., X.L. Zhen, L. Hong, K. Jamil and C.G. Yong. Anti-allergic effects of ethanol extracts from brown seaweeds. *J. Zhejiang Univ. Sci. B. 10*(2): 147-153(2009).
12. Hu, C., Feng, L., Hardy, R. F., & Hochberg, E. J. Spectral and spatial requirements of remote measurements of pelagic Sargassum macroalgae.*Remote Sensing of Environment* 167: 229-246(2015).
13. Hyun Jung Cho, Deepak Mishra and John Wood. Remote Sensing of Submerged Aquatic Vegetation, *Remote Sensing - Applications*, Dr. Boris Escalante (Ed.) (2015).
14. Kaliaperumal, N. Marine plants of Mandapam coast and their uses (2000).
15. Maheswari, R. Mapping the under water habitat related to their bathymetry using Worldview-2 coastal, yellow, rededge, NIR- 2 satellite imagery in Gulf of Mannar to conserve the marine resource. *International Journal of Marine Science* 3(11): 91–97(2013).
16. Midwood, J. and Chow-Fraser, P. Mapping floating and emergent aquatic vegetation in coastal wetlands of eastern Georgian Bay, Lake Huron, Canada. *Wetlands* 30(6):1141–1152(2010).

17. Mohan, V. Mapping of seaweed research: A global perspective. *Kelpro Bulletin 11*(1): 1-14(2007).

18. Pu, R., & Landry. A comparative analysis of high spatial resolution IKONOS and WorldView-2 imagery for mapping urban tree species. *Remote Sensing of Environment* 124: 516-533(2012).

19. S.Mohd, M.Ibrahim, Samsudin, and Yahiya. Seagrass and seaweed mapping using alos Avnir-2 and landsat-5 TM satellite data," *MRSS 6th International Remote Sending & GIS Conference and Exhibition (MRSS 2010)*, Kuala Lumpur, 28-29 April (2010).

20. Seoane, J.C.S.; Arantes, R.C.M., and Castro, C.B. Benthic habitat mapping at Recife de Fora, Brazil: Imagery and GIS. *Proceedings of the 12th International Coral Reef Symposium* (Cairns, Australia): pp. x1–x5(2012).

21. Soo-Chin, L. and Chew-Wai, C. Detecting submerged aquatic vegetation with 8-band WorldView-2 satellite images. *Proceedings of IEEE International Geoscience and Remote Sensing Symposium (Munich, Germany)*: pp. 2560–2562(2012).

22. T.Haq, F.A.Khan, R.Begum and A.B.Munshi. Bioconversion of Drifted Seaweed Biomass into Organic Compost Collected from the Karachi Coast.*Pak.J.Bot,*:pp. 3050-3051(2010).

23. Updike, T., & Comp, C. Radiometric use of WorldView-2 imagery.*Technical Note*:1-17(2010).

24. Zahid, P.B. and H. Usman. Evaluation of seaweed resources of Pakistan.*Proceedings of National O.N.R. Symposium on Arabian Sea as a resource of biological diversity*, H.E.J. Research Institute of Chemistry University of Karachi: pp. 115(2000).

FIGURES

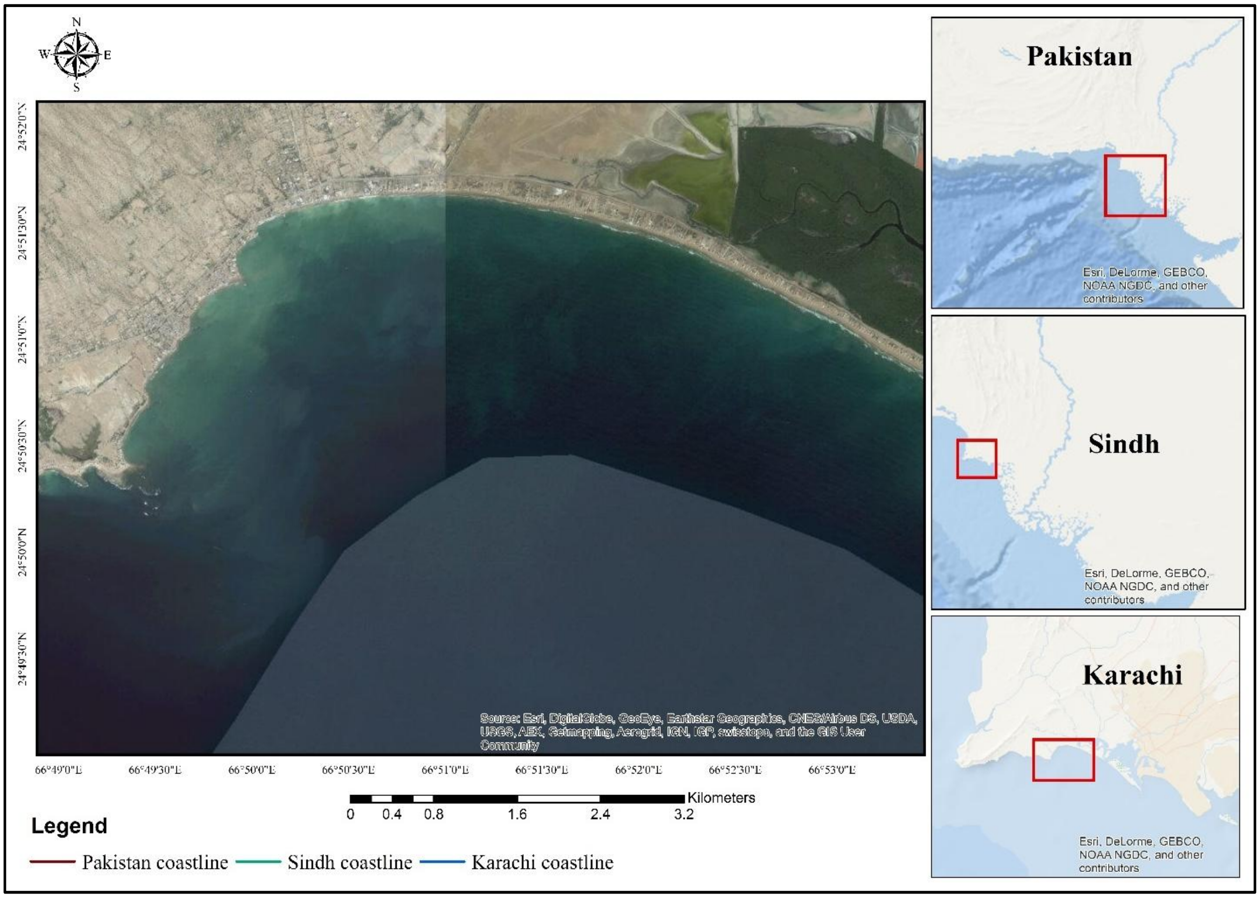


Figure 1 Study Area

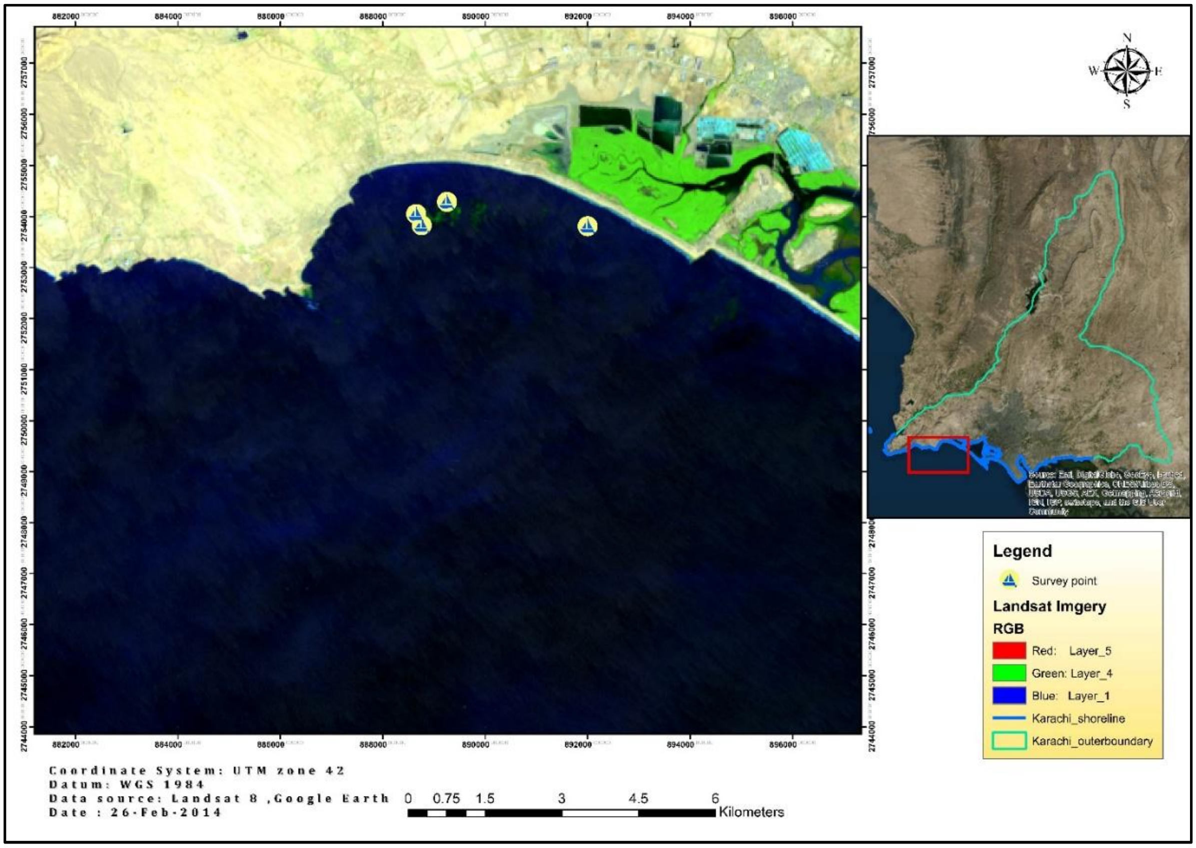


Figure 2 Field GPS data

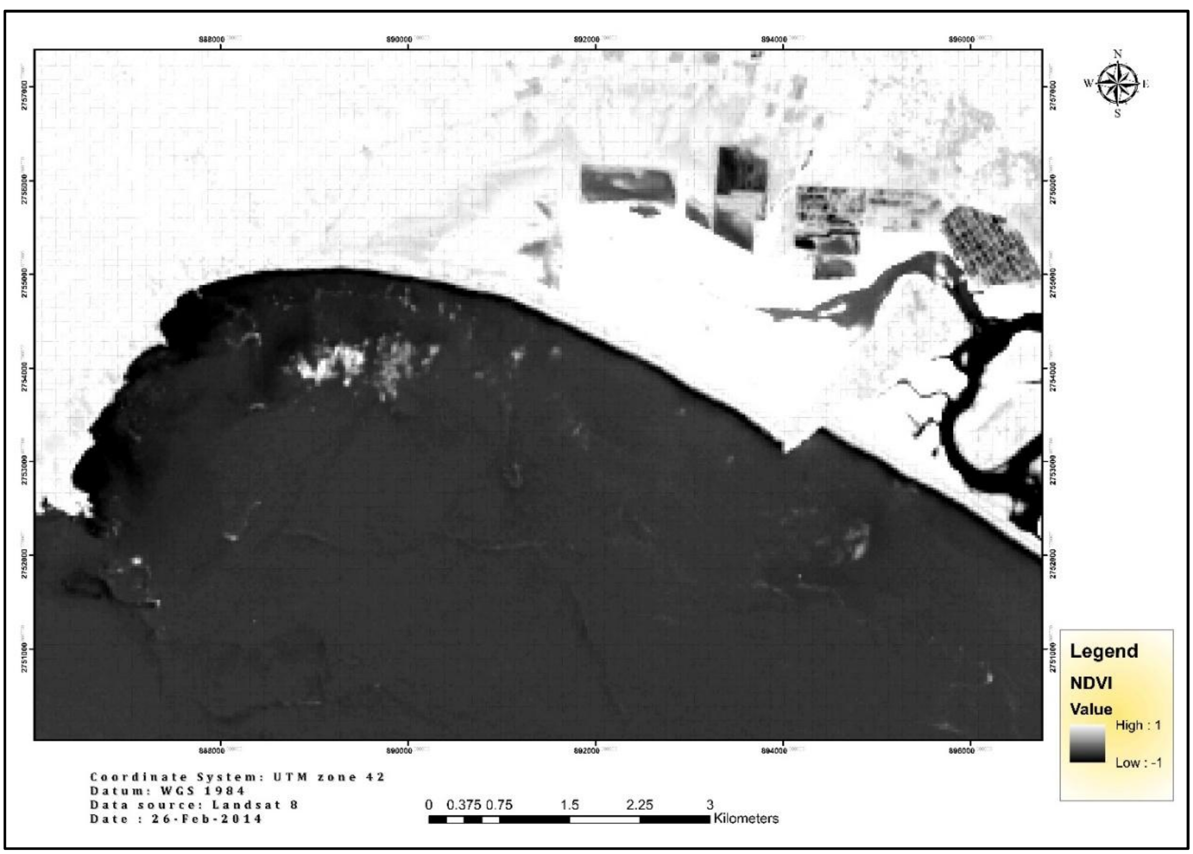


Figure 3 Landsat 8 NDVI

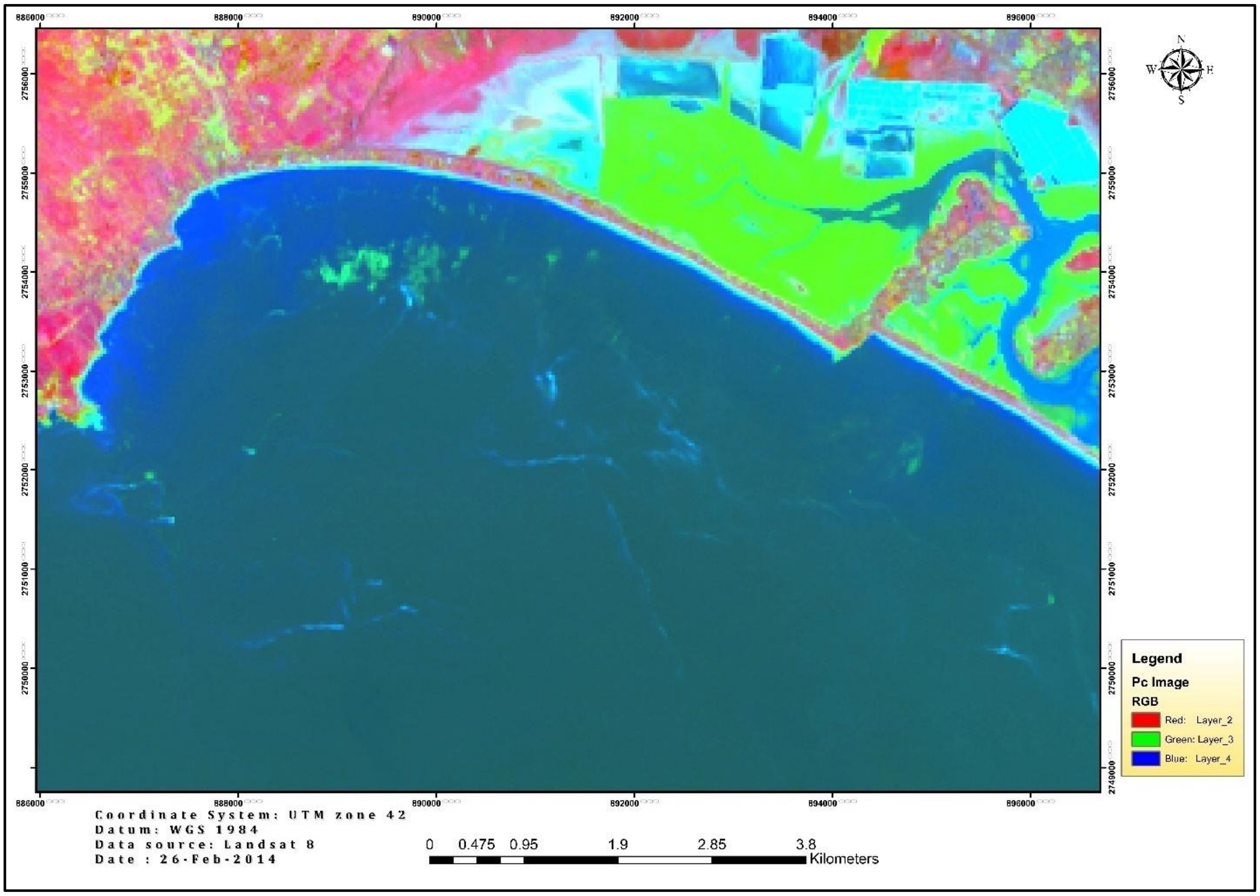


Figure 4 Principal Component Analysis (Landsat 8)

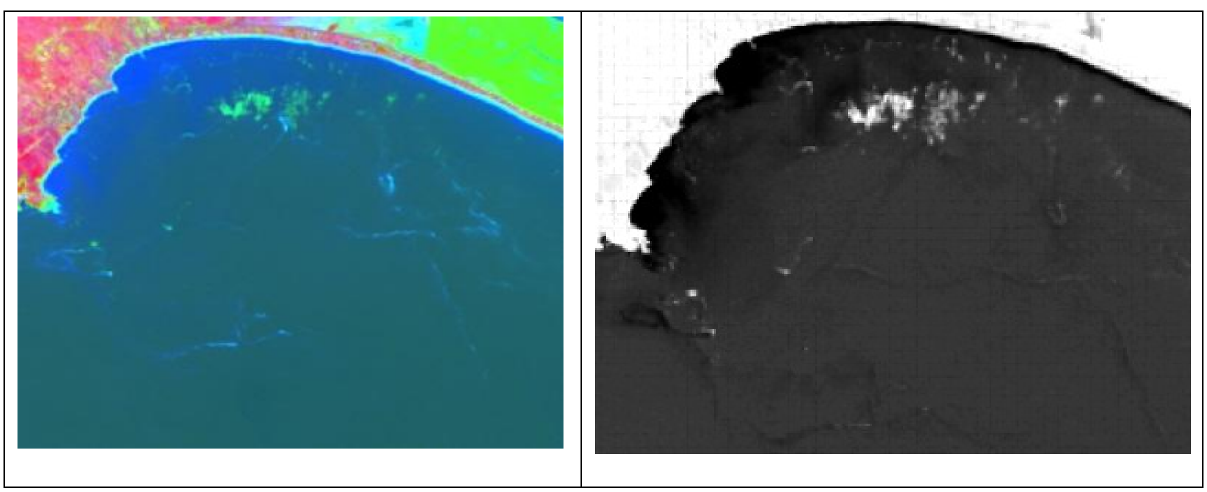
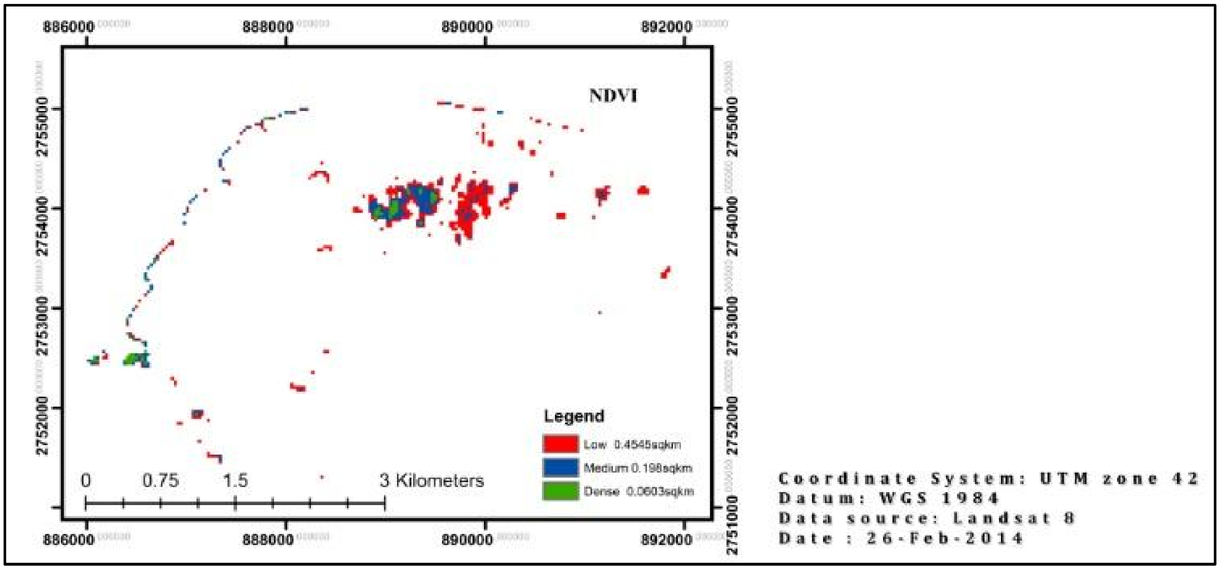


Figure 5 Landsat 8 PCA (Left) and NDVI (Right)



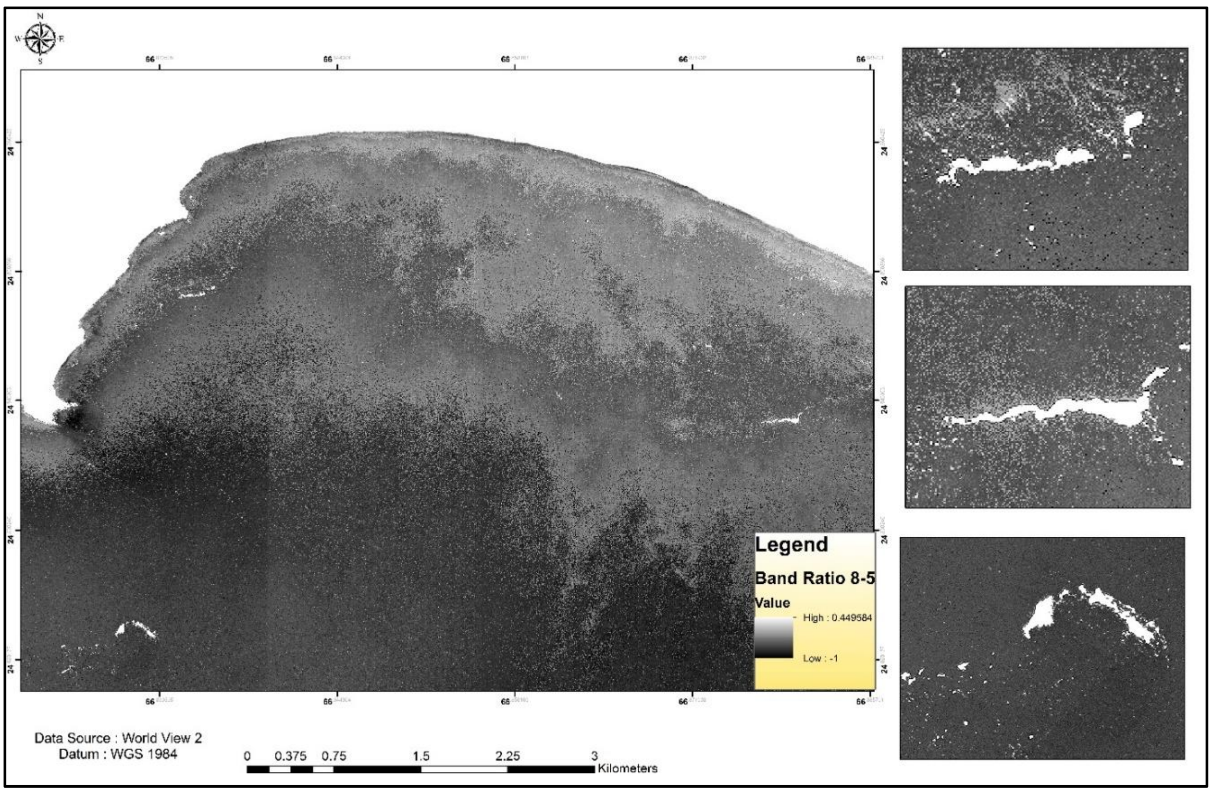


Figure 6 Area Estimation of Landsat 8 NDVI

Figure 7 NDVI 2

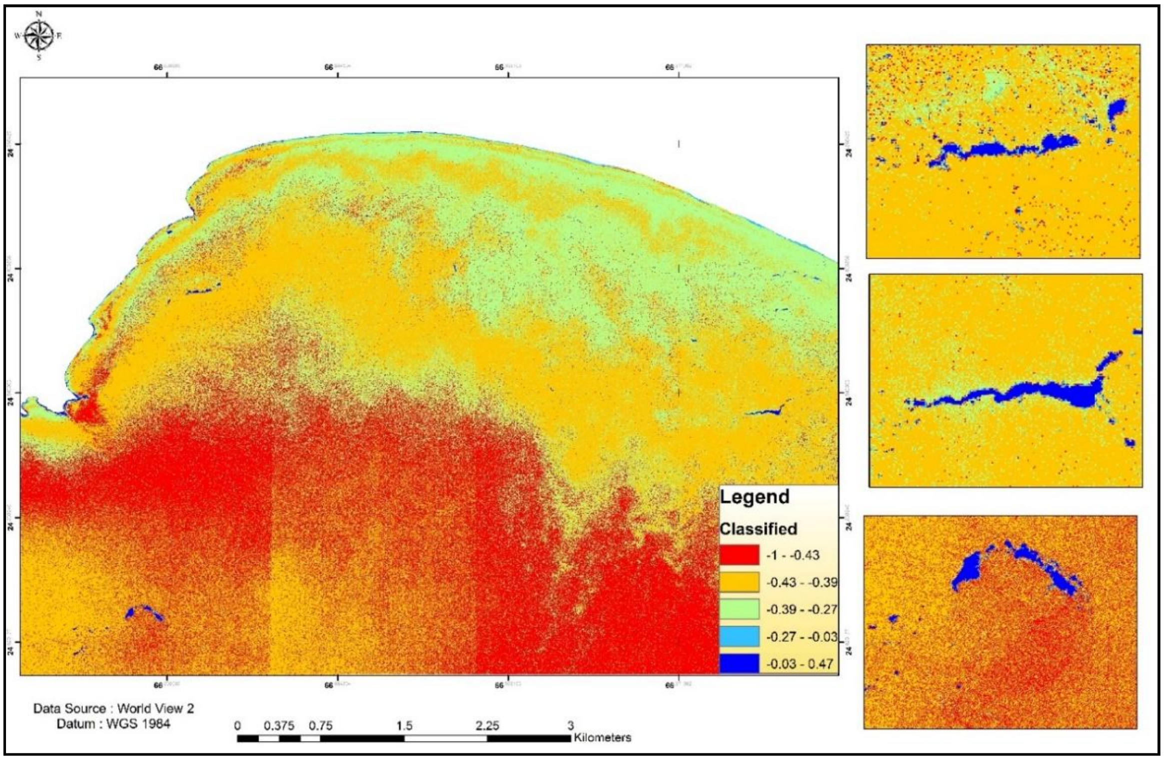


Figure 8 Classified image of NDVI 2

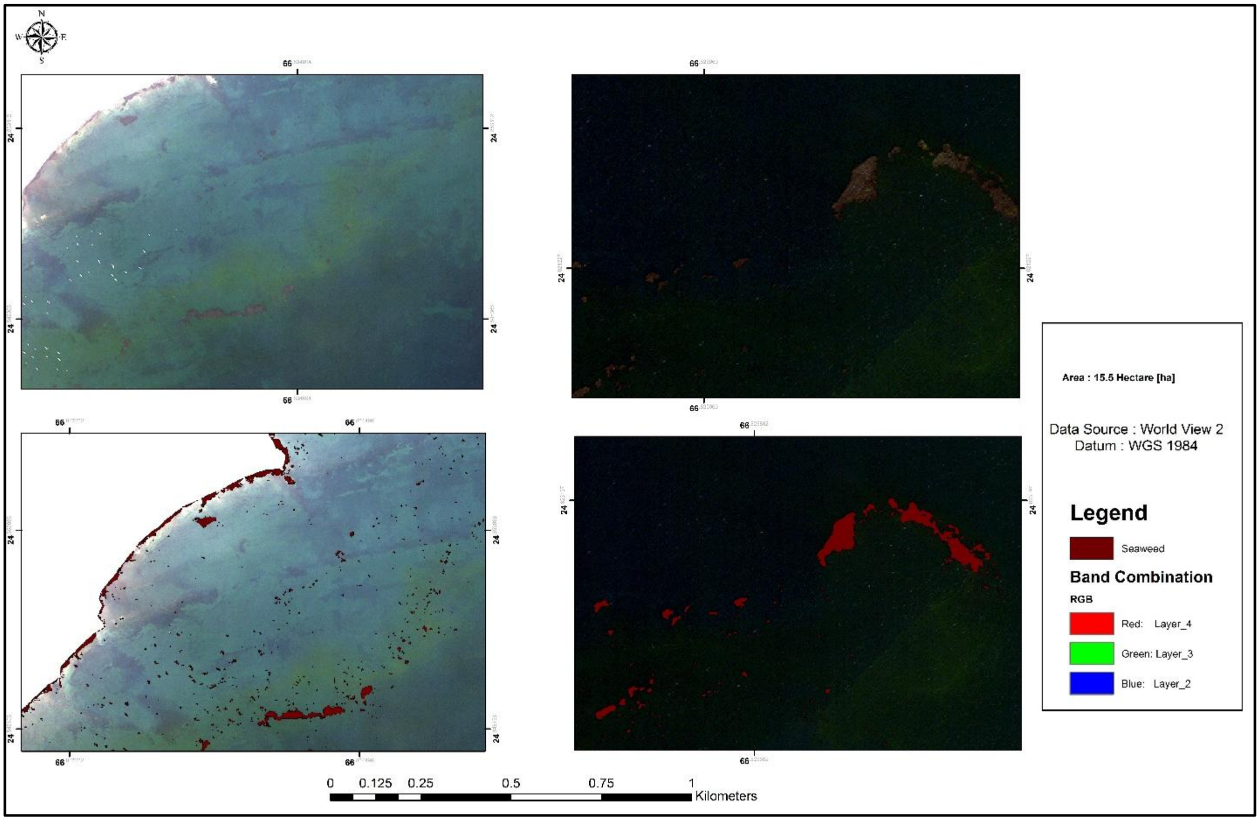


Figure 9 Area Estimation of NDVI 2

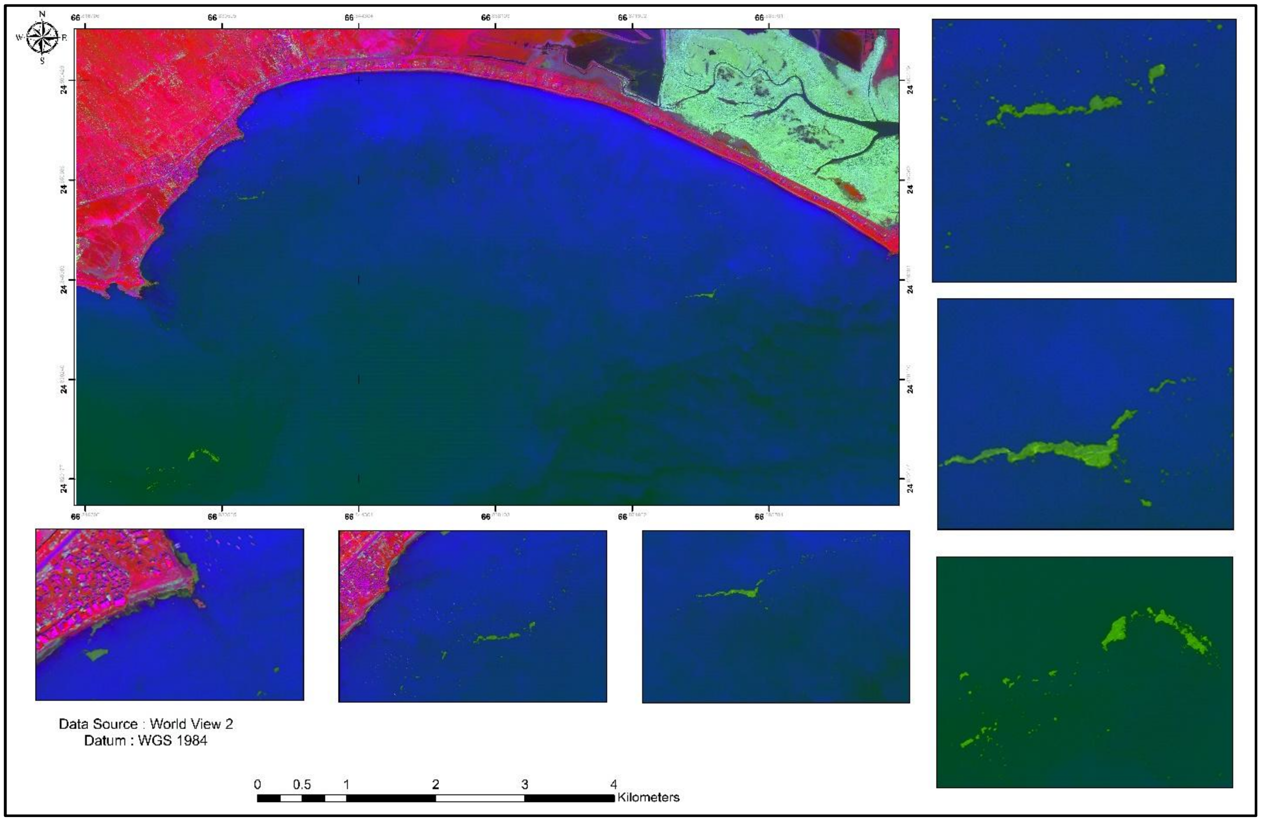


Figure 10 PCA of Worlview-2 Image

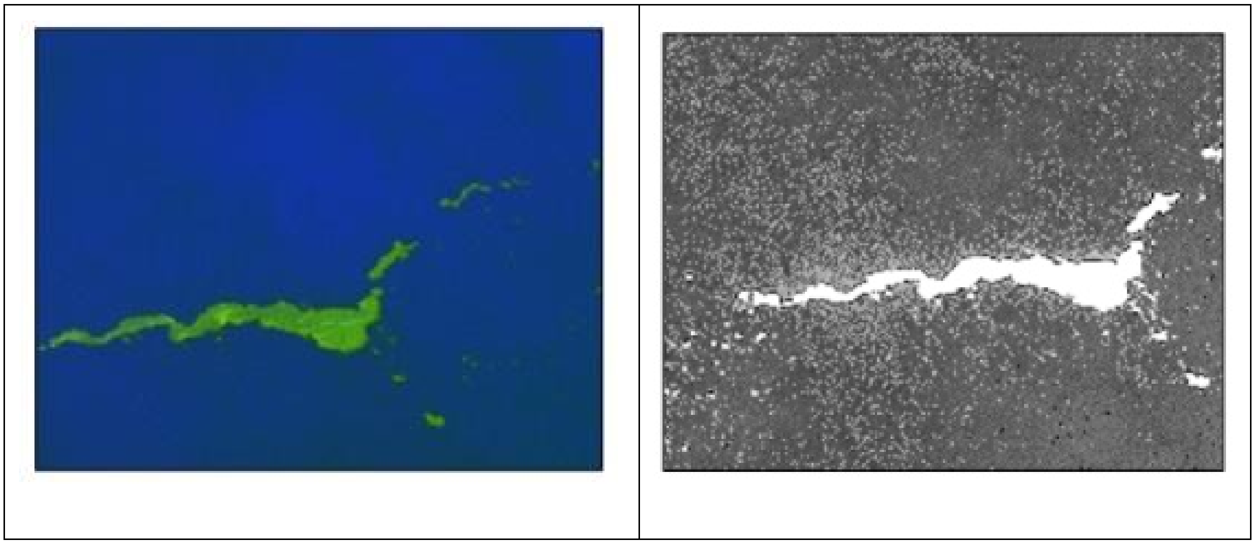


Figure 11 WV-2 PCA (Left) and NDVI 2 (Right)