

Monitoring Coastal Forest of Pakistan using Advanced Remote Sensing Techniques

An Application of APSCO Data Sharing Service Platform

20-24 October 2025 Presented by

Dr. Atif Shahzad
Project Manager-APSCO Project Mangrove Watch from Space

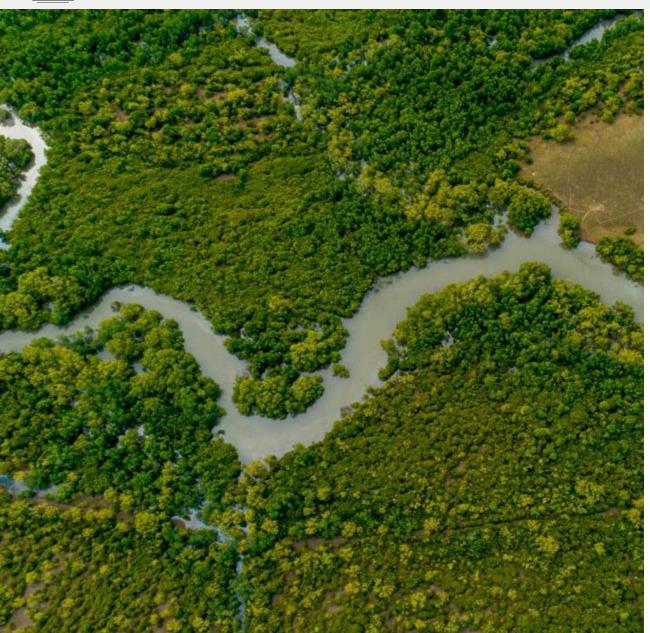






COASTAL FOREST IN PAKISTAN





Mangroves are a remarkably diverse and important ecosystem that works in tandem with other marine ecosystems including sea grass beds and coral reefs all of which are essential not only for the health of our ocean, coasts and the biodiversity that they support, but for the wellbeing of humans.

> Leticia Carvalho, Head of Marine and Freshwater (UNEP)



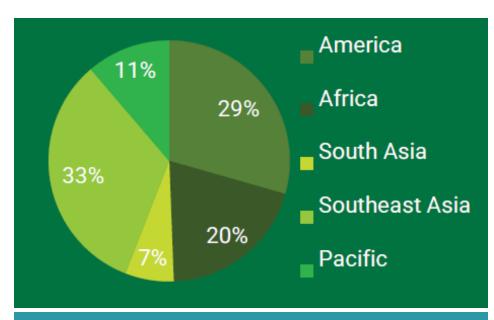
GLOBAL DISTRIBUTION OF MANGROVES



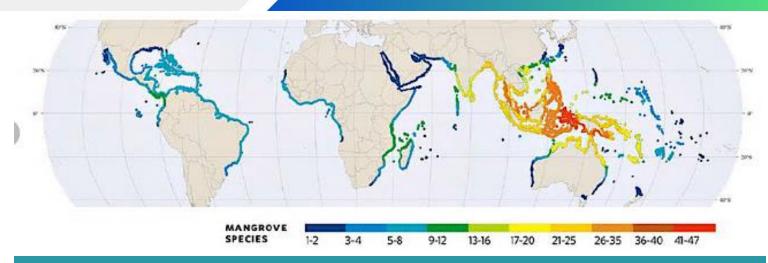
33% percent of Mangroves around the world lies in Southeast Asia Region.

Pakistan falls in 3-4 species category among the world.

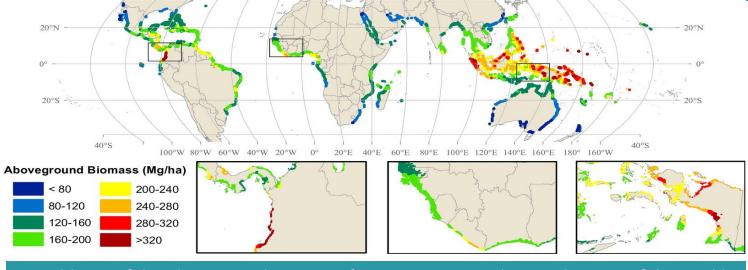
The Biomass of Mangroves in Pakistan ranges from 80 to 120 Mg/ha.



Distribution of Mangroves along the Globe



World map of the mangrove distribution zones and the number of mangrove species along each region (Deltares, 2014).



World map of the Aboveground Biomass of Mangrove Forest along each region of the World



Monitoring Costal Forest of Pakistan using Advanced Remote Sensing Techniques



Activities

1

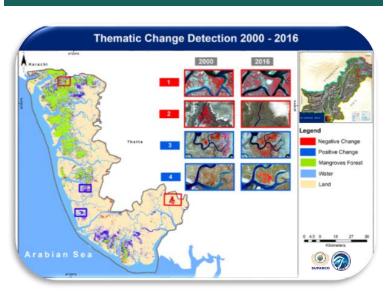
To carry out temporal analysis of deforestation/afforestation in coastal mangrove forest using high resolution satellite data

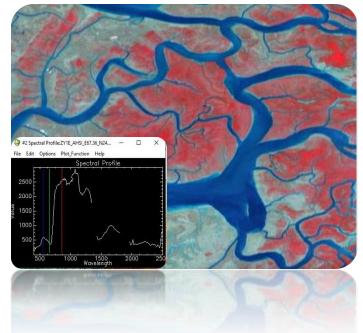
2

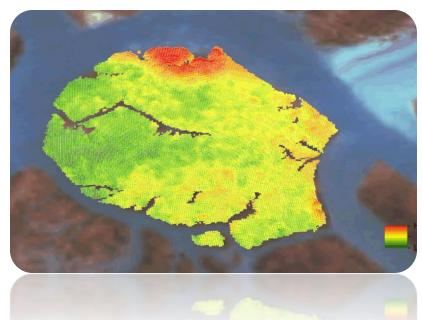
To discriminate mangroves species using hyperspectral satellite data

3

To develop canopy height / 3-D model of mangrove forests using point cloud data from elevation datasets







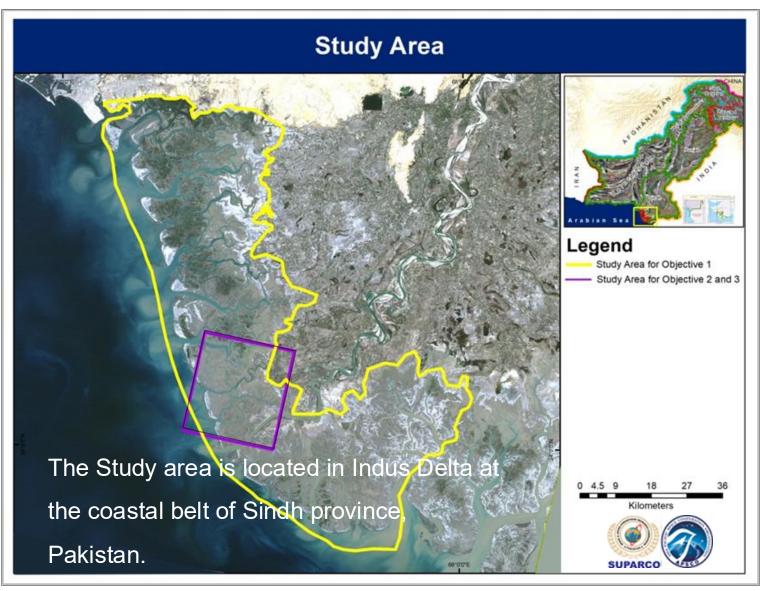


Monitoring Costal Forest of Pakistan using Advanced Remote Sensing Techniques



Study Area

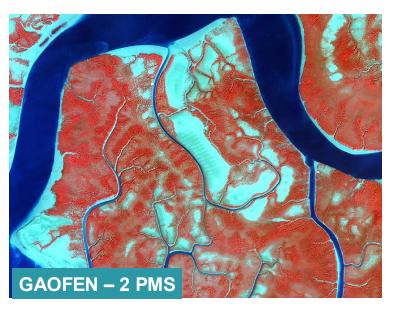






Activity 01 : Temporal Analysis Satellite Datasets from DSSP

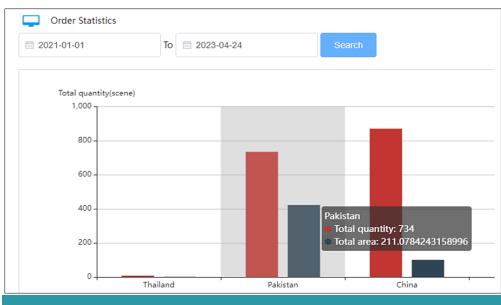












Order Statistics of Pakistan from APSCO's DSSP during study

Satellites	Period	Bands	No. of Scenes	Spatial Resolution
GF-2 PMS	2016-2021	Pan Multispectral	346	1m 4m
GF-1 PMS	2016-2021	Pan Multispectral	347	2m 8m
GF-1 WFV	2016-2021	Multispectral	41	16m
		Total	734	

 During study over 734 scenes were downloaded from DSSP



Activity 01

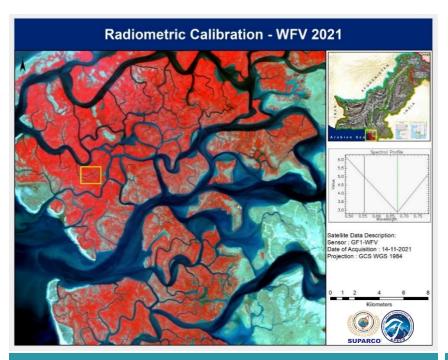
To carry out temporal analysis of deforestation/afforestation in coastal mangrove forest using high resolution satellite data



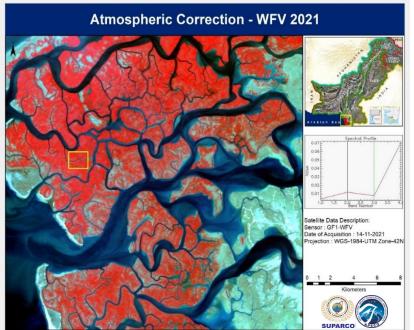
Activity 01 : Temporal Analysis Satellite Datasets



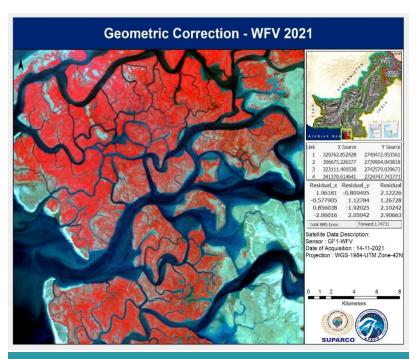
Preprocessing of Satellite Datasets







Atmospheric Correction



Geometric Correction

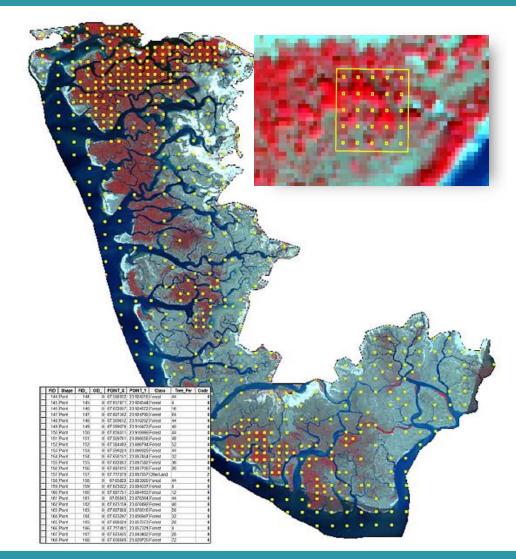


Activity 01 : Temporal Analysis Processing of Satellite Datasets



Development of Training-Validation dataset

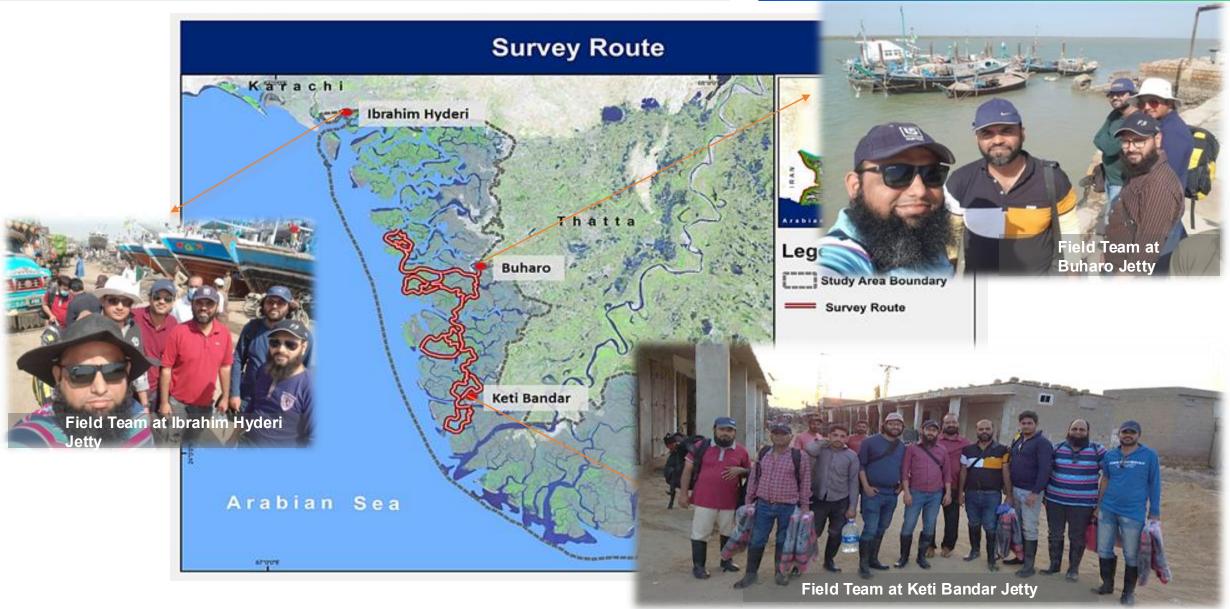
- Two stage systematic sampling technique was used in this study to develop training-validation datasets for mapping mangrove forest in the study area
- A sampling distance of 3 km was used for sample points located in land and water. However a sampling distance of 1.5 km was used for sample points located under forest area
- In this way, the final training-validation layer of each year contain approximately 400 points
- The training-validation layers for 2016 2021 were visually interpreted using high resolution satellite imagery (GF1-PMS and GF2-PMS) into four classes i.e. Wet Land, Grass Land, Other Land and Forest Land
- The training-validation layer for the year 2000 was visually interpreted using Google earth software due to absence of high resolution imagery from DSSP platform for the year 2000





Activity 01 : Temporal Analysis Field Measurement Phase - I







Activity 01 : Temporal Analysis Field Measurement Phase - I



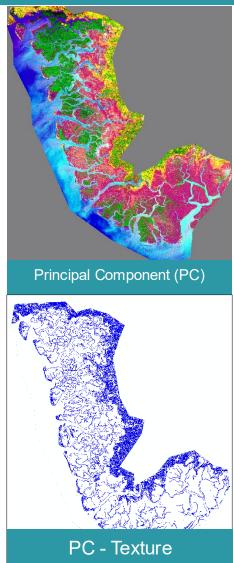


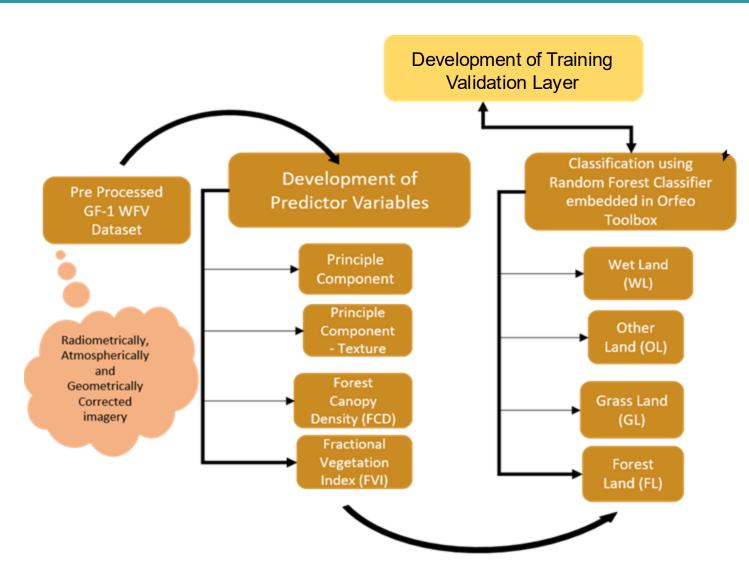


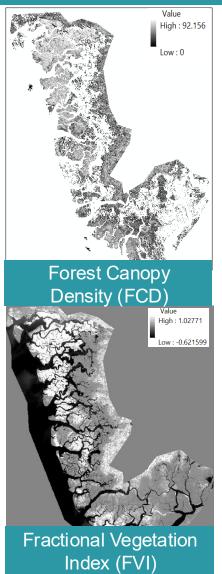
Activity 01 : Temporal Analysis Machine Learning Technique Workflow



Principle Component (PC), PC – Texture, Forest Canopy Density (FCD) and Fractional Vegetation Index (FVI) were developed and used as predictor variables for Thematic Mapping using Machine Learning





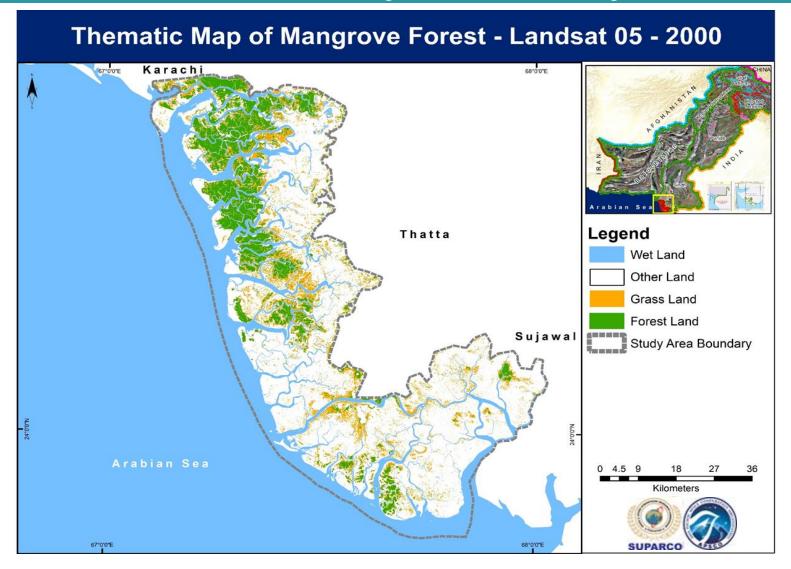




Activity 01 : Temporal Analysis Thematic Maps 2000



Image Classification using Machine Learning Technique



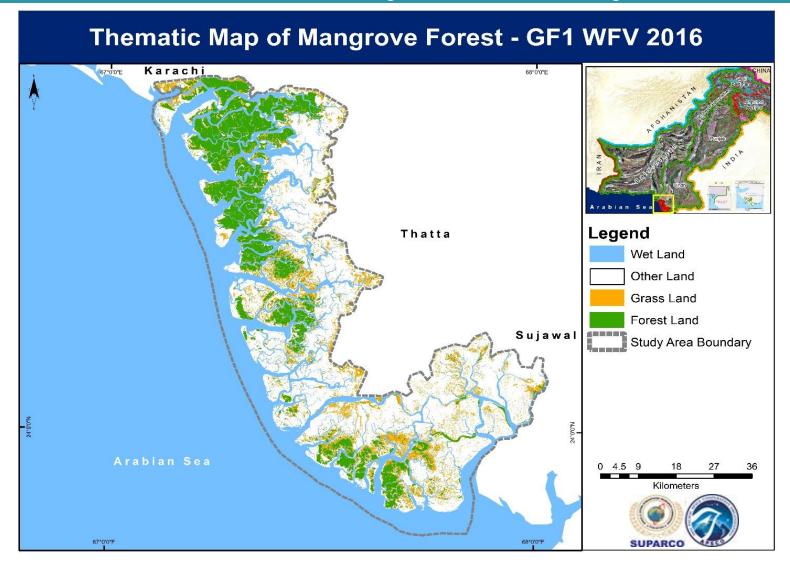
Class Values	Wet Land	Other Land	Grass Land	Forest Land	UA	Total
Wet Land	32	1	0	1	94.12	34
Other Land	12	58	1	4	77.33	75
Grass Land	2	6	1	11	5	20
Forest Land	1	1	0	44	95.65	46
Total	47	66	2	60		175
PA	68.09	87.88	50	73.33		
OA						
Карра						0.67



Activity 01 : Temporal Analysis Thematic Maps 2016



Image Classification using Machine Learning Technique



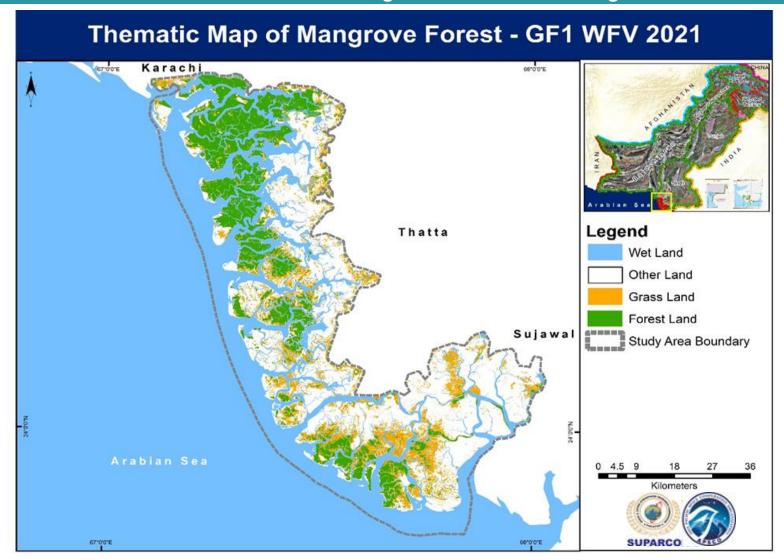
Class Values	Wet Land	Other Land	Grass Land	Forest Land	UA	Total
Wet Land	34	5	1	1	82.93	41
Other Land	3	28	2	2	80	35
Grass Land	0	5	15	1	71.43	21
Forest Land	0	4	1	58	92.06	63
Total	37	42	19	62		160
PA	91.89	66.67	78.95	93.55		
OA					84.37	
Карра						0.77



Activity 01 : Temporal Analysis Thematic Maps 2021



Image Classification using Machine Learning Technique



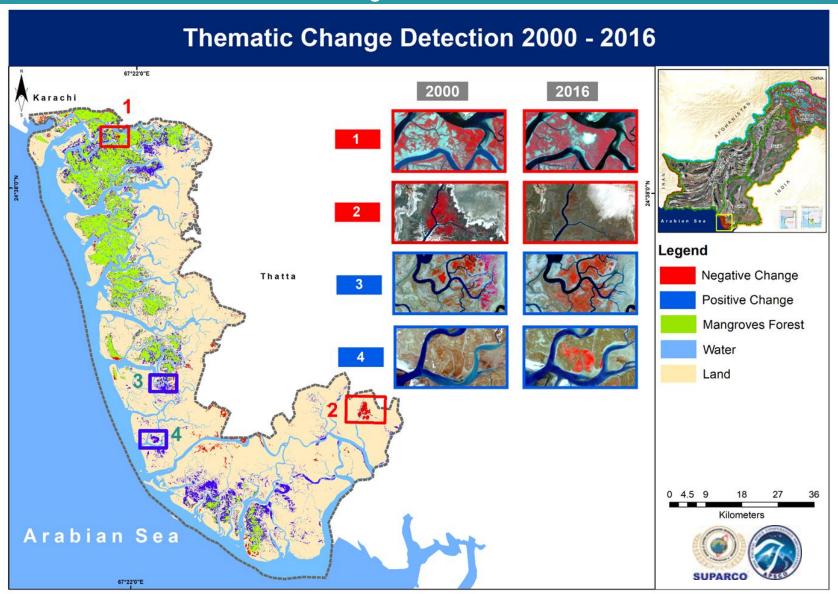
Class Values	Wet Land	Other Land	Grass Land	Forest Land	UA	Total
Wet Land	31	4	1	0	86.11	36
Other Land	2	29	3	2	80.56	36
Grass Land	0	1	30	0	96.77	31
Forest Land	0	3	4	50	87.72	57
Total	33	37	38	52		160
PA	93.94	78.38	78.95	96.15		
OA					87.50	
Карра						0.83



Activity 01 : Temporal Analysis Thematic Change Detection



Thematic Change Detection 2000 - 2016

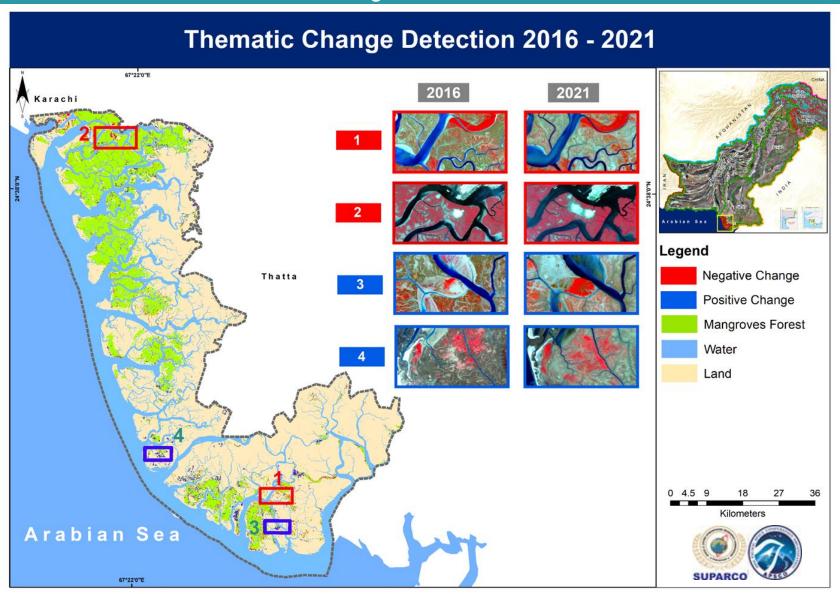




Activity 01 : Temporal Analysis Thematic Change Detection



Thematic Change Detection 2016 - 2021

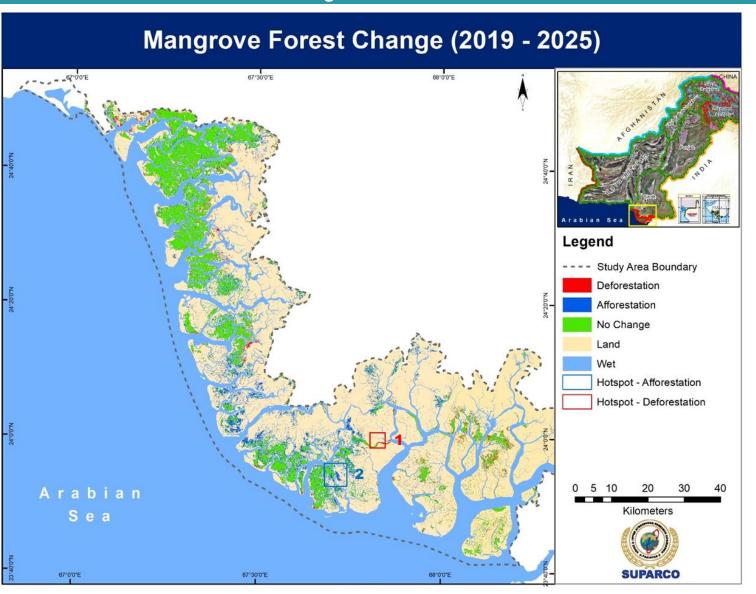




Activity 01 : Temporal Analysis Thematic Change Detection



Thematic Change Detection 2019 - 2025





Activity 02

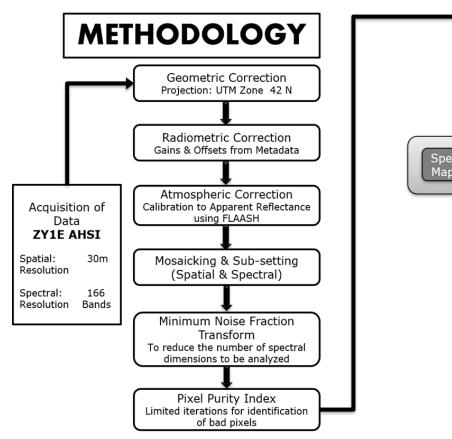
To discriminate Mangroves species using Hyperspectral
Satellite data

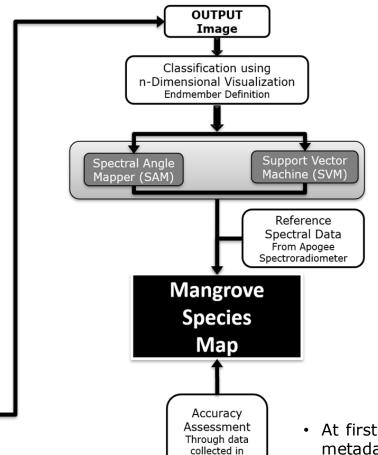


Activity 02 : Mangroves Specie discrimination using Hyperspectral data

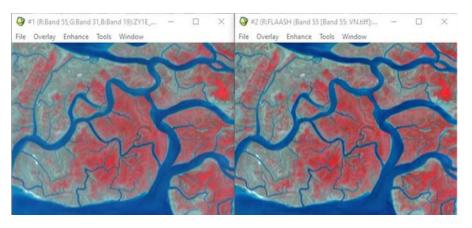


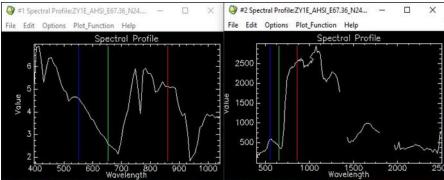
Methodological flow of Mangrove Specie Discrimination study





Field Survey





- At first, using the post-launch gain and offset values provided in the metadata, we apply radiometric calibration methods to transform digital numbers to spectral radiance or exoatmospheric reflectance (reflectance above the atmosphere)
- Later the images were corrected atmospherically (bottom-ofatmosphere reflectance) using FLAASH available within the ENVI software.



Activity 02 : Mangroves Specie discrimination using Hyperspectral data



Pre-analysis of Hyperspectral data

Minimum Noise Fraction (MNF)

The minimum noise fraction (MNF) transform was used to determine the inherent dimensionality of image data to segregate noise in the data and to reduce the computational requirements for subsequent processing.

Pixel Purity Index

The Pixel-Purity-Index (PPI) is a means of finding the most "spectrally pure," or extreme, pixels in Hyperspectral images

In this step 13 hands were selected.

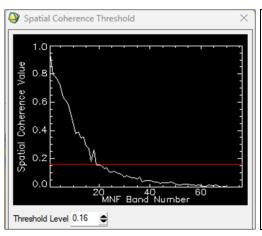
In this step, 13 bands were selected from ZY-1E Hyperspectral which are spatially coherent based on the calculation of spatial coherence after numerous iterations n-D Visualization
n-D Visualizer is used
to locate, identify, and
cluster the purest
pixels and the most
extreme spectral

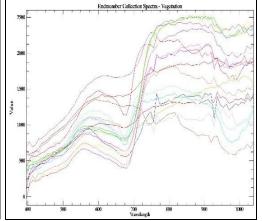
responses in a

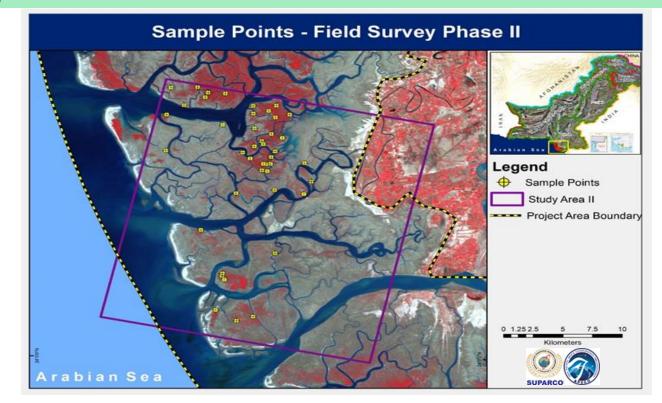
dataset

Ground Validation using Random Sampling Points in each class of SAM output

Ground validation is an important step in remote sensing data analysis to assess the accuracy of classified results. In the case of SAM (Spectral Angle Mapper) classification, ground validation was carried out using random sampling points in each class of the SAM classified output









Activity 02 : Field Survey Phase 2



Collection of spectral signatures using handheld Spectro-radiometer in the Ground

	·
Spectral Range	300-1000 nm
Wavelength	2.0 nm
Cosine Response	80° zenith angle: positive & negative 4%
Detector	2048 pixel; 14 by 200 um microelement array
Linear Range	0 to 2.1 absorbance units (<0.5%)
Detector Integration (Exposure Range)	4 msec to 60 sec (syn-optic multi-channel)
Wavelength Repeatability	Less than 0.05 nm
Wavelength Stability	Less than 0.001 nm per C
Dynamic Range	1 to 4096 counts (+ve & -ve 0.5%)

Total Irradiance was recorded using Spectroradiometer in the wavelength range of (300 nm-1000 nm) in the skyward direction using cosine correction head. The total irradiance helps in eliminating the atmospheric effects from the data



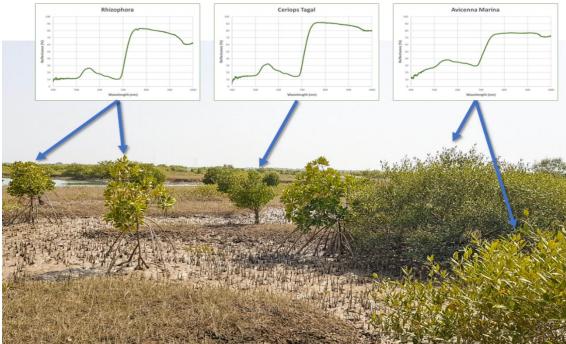
The collection of field spectral data is essential for accurate remote sensing-based classification of mangrove species. The study area was selected in the Indus Delta, Karachi, which is known for its rich mangrove vegetation. The field data collection was carried out during the peak growth period of the mangrove vegetation in the region









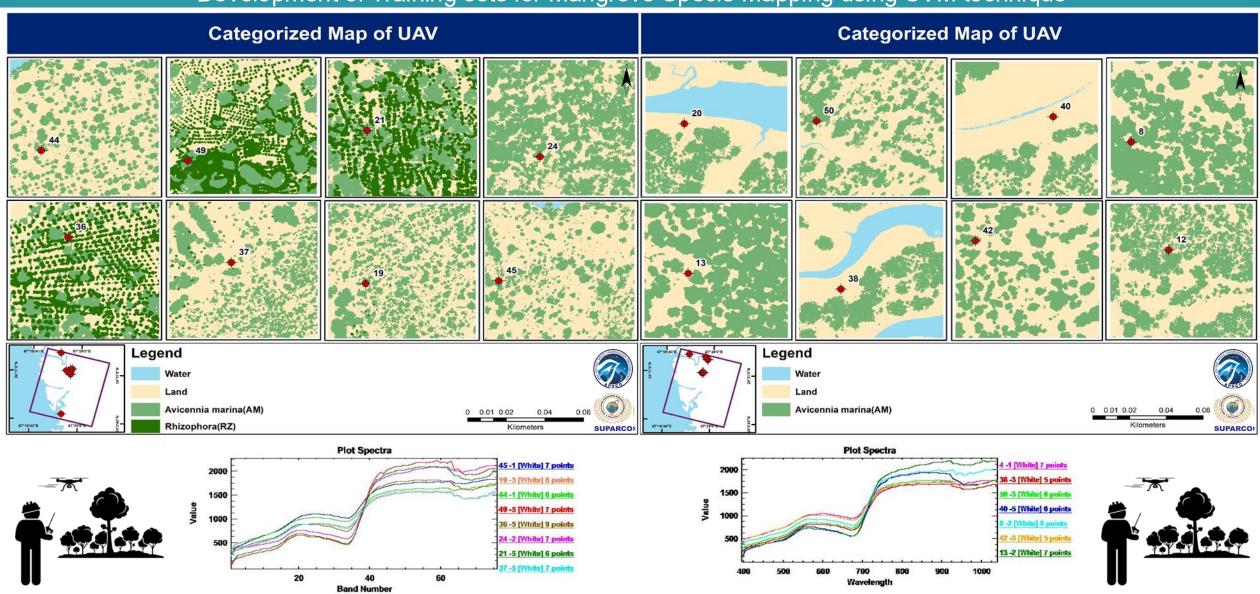




Activity 02 : Mangroves Specie discrimination using Hyperspectral data



Development of Training sets for Mangrove Specie Mapping using SVM technique





Activity 02 : Mangroves Specie discrimination using Hyperspectral data

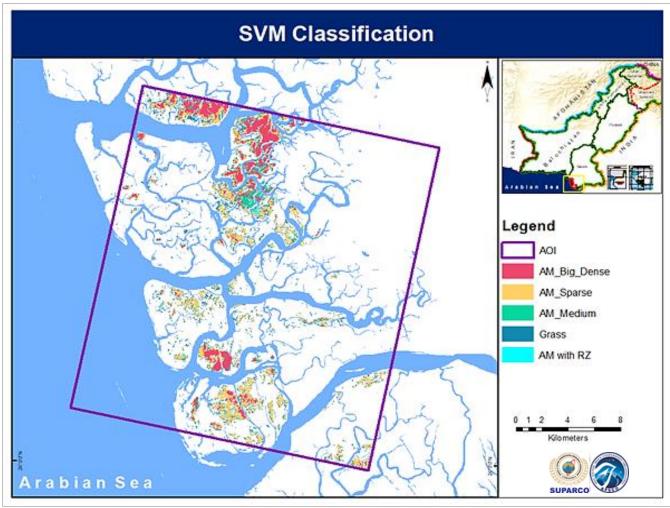


Mangrove Specie Discrimination Using Satellite Datasets

The SVM classification was performed using ENVI's built-in SVM algorithm, which uses a training dataset to identify the spectral signature of each class and create a decision boundary. The SVM algorithm classifies each pixel in the image based on its spectral signature and its location relative to the decision boundary

- In this study, we demonstrated the potential of ZY-1E hyperspectral data and the SVM algorithm for mapping mangrove species in the Indus delta
- The SVM model achieved an overall accuracy of 93.902 % and a kappa coefficient of 0.93 for mangrove species mapping in the Indus delta
- The results show that the SVM algorithm and the selected MNF bands were effective in distinguishing between the mangrove species

	Overall Accuracy					93.90	2	
Class Value	1	2	3	4	5	Tot al	UA %	Карра
Unclas	0	0	0	0	0	0		
1	42	1	0	1	1	45	93.33	
2	0	21	1	0	0	22	95.45	
3	0	0	0	0	0	0	0	
4	0	0	0	9	0	9	100	
5	1	0	0	0	5	6	83.33	
Total	43	22	1	10	6	82		
PA %	97.67	95.45	0	90	83.33			
Карра								0.93





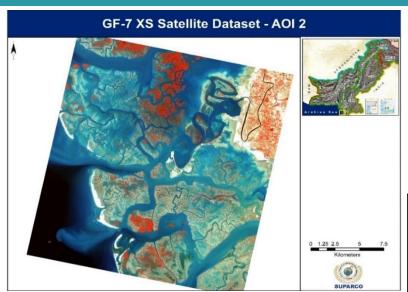
Activity 03

To develop canopy height / 3-D model of mangrove forests using point cloud data from elevation datasets



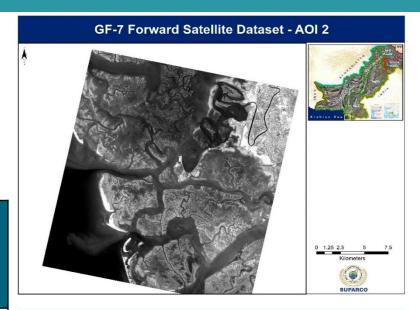


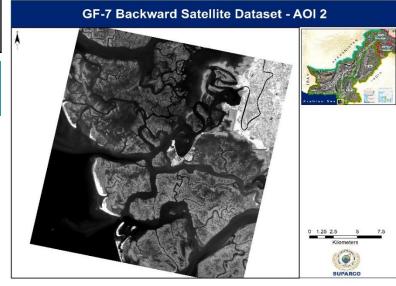
Satellite Data sets – GF-7

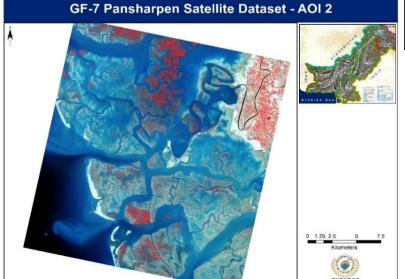


Satellites	View	Spatial Resolution	Stereo Angle	Specifica tions
Gaofen-7	Forward	0.80 m	~6∘ to	Stereo
	Backward	0.60 m	~28∘	Pair

Satellite data specifications for Mapping CHM





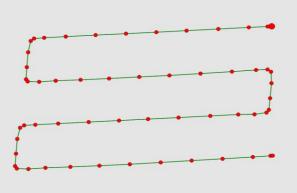






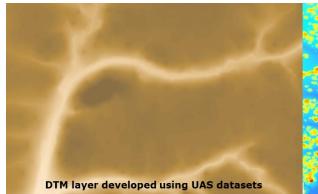
Methodological flow for development of CHM using UAS dataset

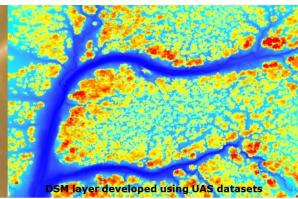




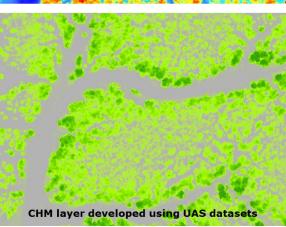












• The altitude in this flight planning was 50-150m. The overlap was 70%, with a side lap of approximately 50%.

DGPS and RTK systems used in Field
Measurements Phase-2

The UAS was equipped with GPS and

information about images. For precise

Inertial Measurement Unit (IMU) to

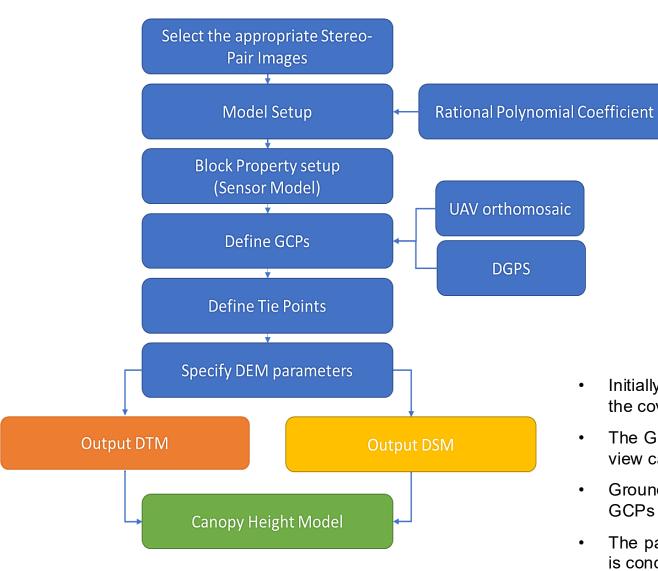
provide direct georeferencing

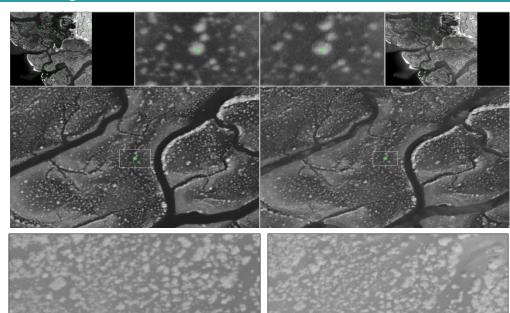
geoinformation, RTK were used





Methodological flow for development of CHM using Satellite datasets





Forward

Initially, selection of the stereo-pair images is a fundamental step for both matching the coverage area and the accuracy

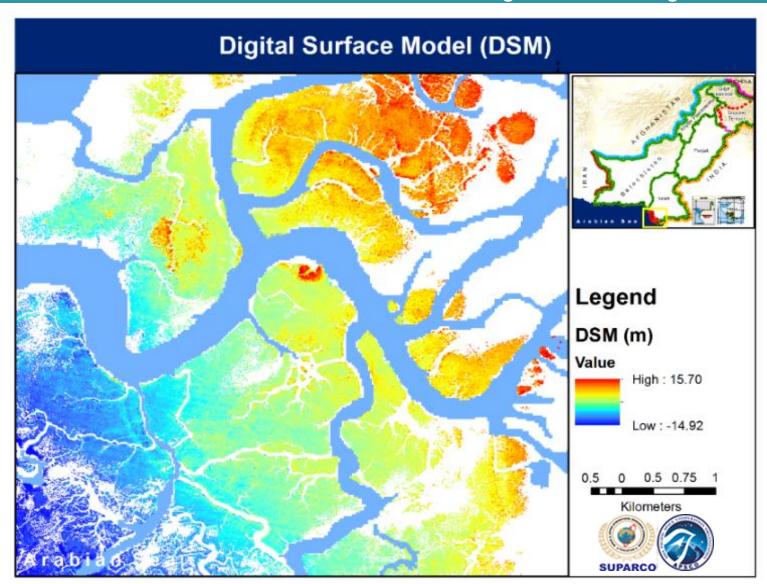
Backward

- The GF-7 data is equipped with a dual-line-array stereo camera comprising a front-view camera and a rear-view camera with -5 and 28 degree view angle
- Ground Control Points (GCPs) were determined from UAS ortho mosiacs and GCPs collected during ground survey
- The parameters of the output DEM are set up, the final step of extracting the DSM is conducted. To extract the DTM from the DSM raster filtering was applied





DSM generation using Satellite datasets

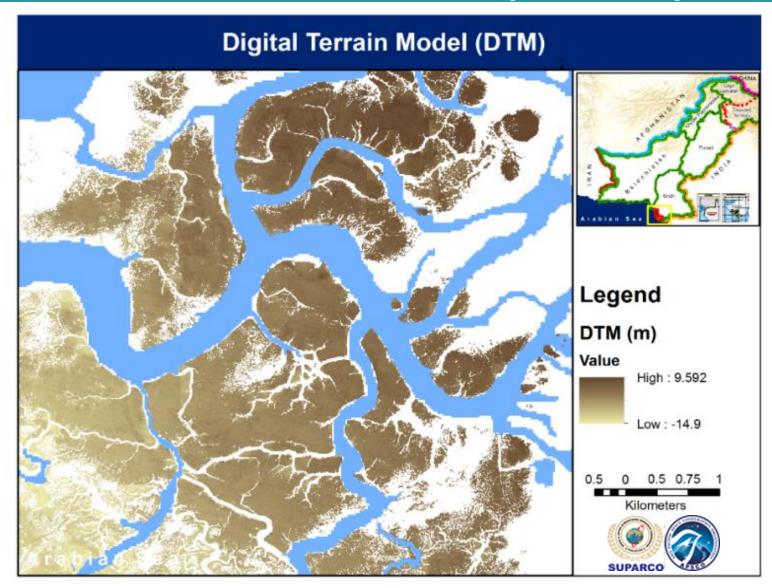


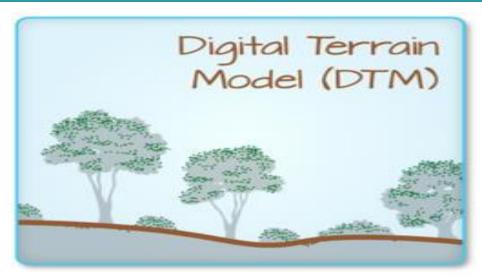






DTM generation using Satellite datasets

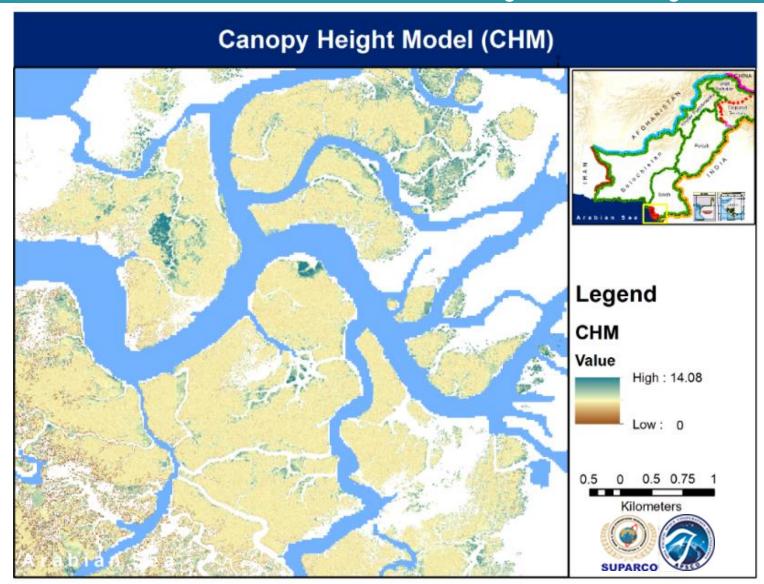




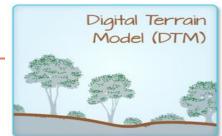


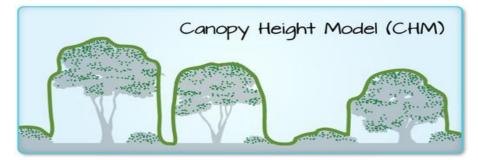


CHM generation using Satellite datasets





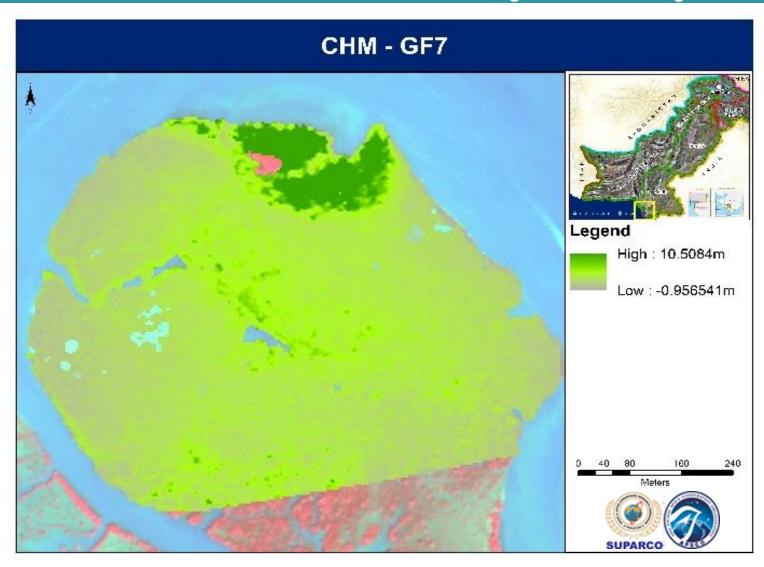








CHM generation using Satellite datasets



lable						
□ - 唱 ·] - = - = 50 ⊠ @ ×					
ccuracy of	GF7					
Shape	UAS	GF7	Diff			
Point	0.918098	1.708	0.789902			
Point	1.0235	1.793	0.7695			
Point	1.4356	2.19426	0.75866			
Point	1.9473	2.698	0.7507			
Point	1.0484	1.788	0.7396			
Point	0.9356	1.659	0.7234			
Point	1.3978	2.10525	0.70745			
Point	2.3537	3.06	0.7063			
Point	1.1531	1.855	0.7019			
Point	1.2265	1.919	0.6925			
Point	0.701698	1.392	0.690302			

S.	Description	Value
No		
1	Number of Points	315
2	Mean value of discrepancies	1.83m
3	Standard deviation of	1.48 m
	discrepancies	
4	Maximum Deviation	4.4m
5	Minimum Deviation	1.2m



Conclusion



The study integrates multi-source satellite data and advanced remote sensing analysis to achieve a comprehensive understanding of mangrove ecosystem dynamics, structure, and species composition.

The analysis quantified the spatial and temporal changes in mangrove forest extent with the high-resolution GF data allowing for the precise detection of smaller-scale restoration/degradation events that occurred between 2016 and 2021. This multi-sensor time series is a validated method for long-term ecological monitoring.

The rich spectral information from the ZY1E satellite data, particularly in the narrow spectral bands, allowed for accurate discrimination of dominant mangrove species within the study area. This capability is crucial for species-specific conservation and management.

The CHM provided essential structural parameters (e.g., maximum and mean canopy height), which can be directly related to Above-Ground Biomass (AGB) and carbon stock estimates, thus establishing a cost-effective method for periodic monitoring of mangrove forest structure.



Conclusion



In summary, the fusion of multi-platform remote sensing data—combining the historical depth of Landsat, the recent advent of high resolution GF1/2, the structural detail of GF-7 point clouds, and the species specificity of ZY1E hyperspectral imagery—offers a powerful, integrated framework for comprehensive and detailed mangrove ecosystem assessment to support conservation and management efforts at country level.

The APSCO Data Sharing Service Platform (DSSP), is an important component of regional space cooperation, specifically designed to provide Earth observation data and services to its member states.



Thank You...!

