Green Growth Consultants

BALOCHISTAN CARBON OFFSET PROJECT

Deliverable II Technical Feasibility Study

JUNE 30, 2025

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List of Abbreviations

AGB	Aboveground Biomass
ARR	Afforestation, Reforestation, and Revegetation
BPPPA	Balochistan Public Private Partnership Authority
EPA	Environmental Protection Agency
ESIA	Environmental and Social Impact Assessment
GCC	Global Carbon Council
GEE	Google Earth Engine
IEE	Initial Environmental Examination
IFM	Improved Forest Management
IUCN	International Union for Conservation of Nature
JV	Joint Venture
KPI	Key Performance Indicator
LULC	Land Use Land Cover
MSI	Multispectral Instrument
MOCC&EC	Ministry of Climate Change & Environmental Coordination
NbS	Nature-based Solutions
NDMA	National Disaster Management Authority
NGO	Non-Governmental Organizations
OA	Overall Accuracy
PPP	Public-Private Partnership
REDD	Reducing Emissions from Deforestation and Forest Degradation
SOP	Standard Operating Procedure
WWF	World Wide Fund for Nature

Executive Summary

The Balochistan Carbon Offset Project, focusing on environmental resilience through mangrove conservation and regeneration, envisions a Balochistan province that harnesses the potential of its vast and diverse natural resources, especially those stored within mangroves. To enhance environmental resilience and inculcate socio-economic upliftment, Balochistan province aims to regenerate and conserve its mangroves and leverage the global carbon markets to generate revenue and multiple co-benefits. Mangroves are a critical ecosystem that not only provide natural resources, but also protects the coastal communities from natural disasters. To ensure regeneration, conservation and environmental resilience, action is required to sustain the services of this ecosystem and also enhance carbon sequestration leading to carbon offset markets through Nature-based Solution (NbS), a leading category in the global carbon markets. The proposed feasibility study which will be undertaken by Green Growth Consultants (GGC) with Joint Venture (JV) partner Haidermota & Co. (HMCO) will address Balochistan's immense potential in carbon offset initiatives. Commissioned by the Balochistan Public Private Partnership Authority (BPPPA), it aims to establish a viable project focused on Nature-Based Solutions (NbS) and leveraging the potential of the global carbon market.

This document encapsulates the Technical Feasibility Report detailing the potential of environmental resilience across mangrove sites in the province and identify a viable way forward to realize this potential. The report provides a detailed assessment of 06 proposed sites: Sonmiani Khor, Kalmat Khor, Sahidi Khor, Sawar Khor, Shabi and Ankara Creek and Jiwani Khor, analyzing Land Use and Land Cover Change (LULC) and carbon sequestration potential which informs the proposed project design for the intervention. The report also assesses the vulnerabilities and drivers of land-use change across the sites and analyzes the potential to develop environmental resilience. The report then studies past projects for mangrove restoration and conservation, potential challenges, and devises specific mitigation strategies and interventions that present the potential for environmental resilience and socio-economic upliftment, reversing and/or halting degradation of mangroves. The report also devises a stakeholder identification and relevance section to identify critical players and partners to ensure a data-driven and collaborative approach. An overview and introduction to carbon markets, its standards and methodologies is also provided to understand the global carbon market landscape within which this project will be strategically positioned. On the basis of this assessment and an analysis of the socio-economic situation of the region, baseline carbon assessment is conducted, and carbon sequestration potential of the project is calculated. The results have been discussed in detail to guide an informed decision making and investment opportunity.

INTRODUCTION

Balochistan, Pakistan's largest province, is endowed with vast and diverse natural resources, landscapes and ecosystems, including rangelands, juniper forests, and mangrove areas. However, they are significantly under threat due to climate change and anthropogenic factors. Th province is also experiencing declining socio-economic indicators and challenges such as poverty and inflation. Environmental degradation has exacerbated the vulnerability of the province.

To enhance environmental resilience and inculcate socio-economic upliftment, Balochistan province aims to regenerate and conserve its mangroves and leverage the global carbon markets to generate revenue and multiple co-benefits. Mangroves are a critical ecosystem that not only provide natural resources, but also protects the coastal communities from natural disasters. To ensure regeneration, conservation and environmental resilience, action is required to sustain the services of this ecosystem and also enhance carbon sequestration leading to carbon offset markets through Nature-based Solution (NbS), a leading category in the global carbon markets. The proposed feasibility study will aim to address Balochistan's immense potential in carbon offset initiatives. Commissioned by the Balochistan Public Private Partnership Authority (BPPPA), it aims to establish a viable project focused on Nature-Based Solutions (NbS) and leveraging the potential of the global carbon market.

The aim of this report is to deliver a comprehensive Technical Feasibility detailing the potential of environmental resilience across mangrove sites in the province and identify a viable way forward to realize this potential. It also aims to pave a path for mangrove restoration projects by leveraging the opportunities offered by the global carbon markets to not only achieve socio-economic well-being but also unlock avenues of climate finance for revenue generation to support the execution of these projects. The project proposes mangrove restoration in the Lasbela and Gwadar district including mangroves of the Sonmiani Khor, Kalmat Khor, Sahidi Khor, Sawar Khor, Shabi and Ankara Creek and Jiwani Khor. It encapsulates primary and secondary collection of data on features of mangrove forests, developing a detailed inventory. The research also focuses on the vulnerabilities of the mangrove forests, challenges in implementation of restoration projects and measures taken to sustain them. On the basis of this assessment and an analysis of the socio-economic situation of the region, baseline carbon assessment is conducted, and carbon sequestration potential of the project is calculated. The results have been discussed in detail to guide an informed decision making and investment opportunity.

SECTION 1. PROJECT OVERVIEW

The Balochistan Carbon Offset Project is aimed at identifying avenues to conserve and regenerate mangroves across the province. Coastal pockets in Gwadar and Lasbela possess significant sites which have been identified as the location for this plantation. The project aims to leverage the potential of these sites and its mangroves to work towards environmental resilience through the international carbon markets, generating revenue and unlocking multiple co-benefits for its citizens. Mangroves are significant ecosystems that not only sequester emissions, but their diverse ecosystem can also benefit the socio-economic landscape, providing green jobs and resources for livelihood through community participation in plantation of forests.[1] ecosystems provide vital ecosystem services, including coastal protection, carbon sequestration, and fisheries support. Mangroves act as natural barriers, safeguarding shorelines from storm surges, tidal waves, and erosion, thereby protecting human settlements and biodiversity.

Figure 1 identifies the coastal region of Balochistan province further identifying the position of Miani (Sonmiani Khor), Kalmat Khor, Sahidi Khor, Sawar Khor, Shabi and Ankara Creek and Jiwani Khor on the Balochistan coast.

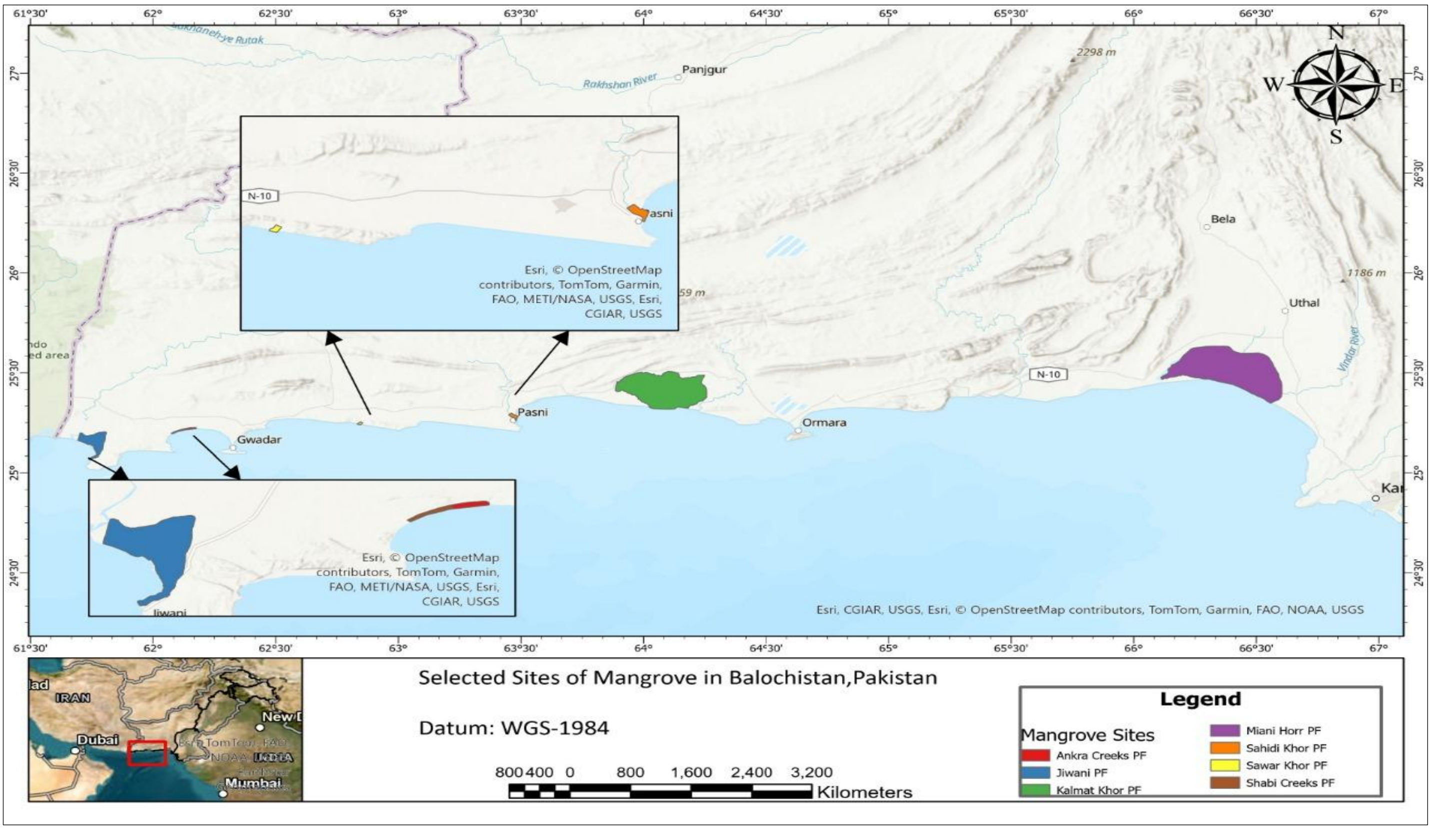


Figure 1 Map of Pilot Area (Demonstrating Different Sites of Protected Mangrove Areas in Balochistan)

1 Rasool, F., Tunio, S., Hasnain, S., & Ahmad, E. (2002). Mangrove conservation along the coast of Sonmiani, Balochistan, Pakistan. *Trees*, 16(3), 213-217. https://doi.org/10.1007/s00468-001-0151-5

The potential project sites lie on the coast of Balochistan province in the districts of Lasbela and Gwadar, and cover the following area:

Forest Area	District	Area (Ha)
Sonmiani Khor	Lasbela	82,503
Kalmat Khor	Gwadar	55,869
Sahidi Khor	Gwadar	617
Sawar Khor	Gwadar	200.5
Shabi & Ankara Creeks	Gwadar	707
Jiwani	Gwadar	8,062
Total		**147,958.5**

Despite their importance, Pakistan's mangrove ecosystems have suffered severe degradation over the past 50 years due to freshwater diversion for agriculture, industrial and urban water pollution, and overfishing.[8] These challenges are exacerbated by national policies prioritizing agriculture and industrial development over coastal conservation, neglecting the essential ecological functions of mangroves. This has not only stressed the fragile ecosystem, but also led to increased climate vulnerability and adverse impacts on local livelihoods. The proposed project aims to inculcate sustainable change and leverage the potential of mangroves to sequester emissions, while unlocking revenue through carbon credits, and pave the way towards environmental resilience and socio-economic upliftment across the identified project sites:

1. Sonmiani Khor

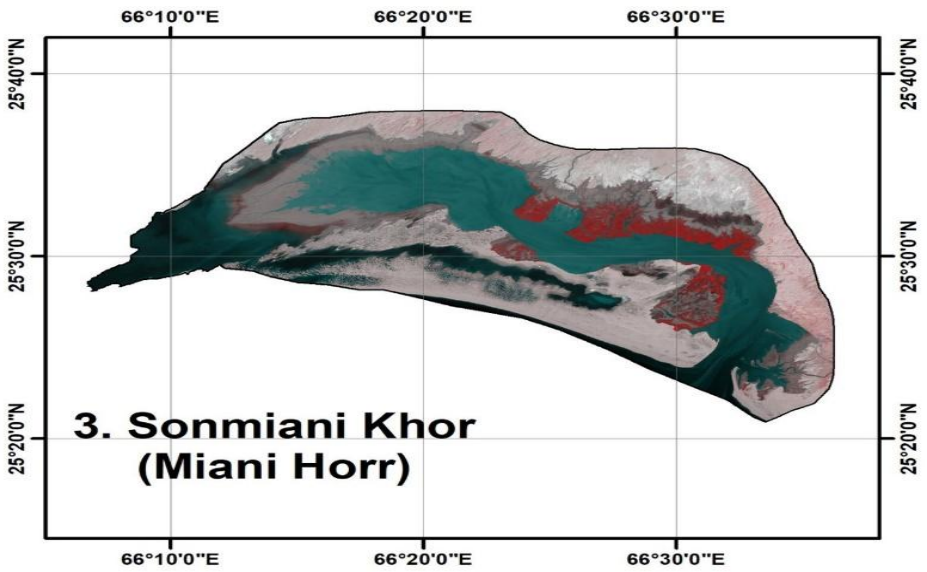


Figure 2 Sonmiani Khor

Located in Lasbela District, Balochistan, Sonmiani Khor, also known as Miani Hor, stretches 95 km from Karachi[2]. The climatic conditions are arid sub-tropical where the summers are very hot, and winters are mild. Sonmiani Khor is a state-owned area with a minor area under the ownership of the Forest Department of Balochistan.

1. Shabi and Ankara Creeks

Shabi and Ankara Creeks are present on the west of Gwadar city with sub-tropical weather and an average temperature of 25.3 degrees °C with slight annual variation.

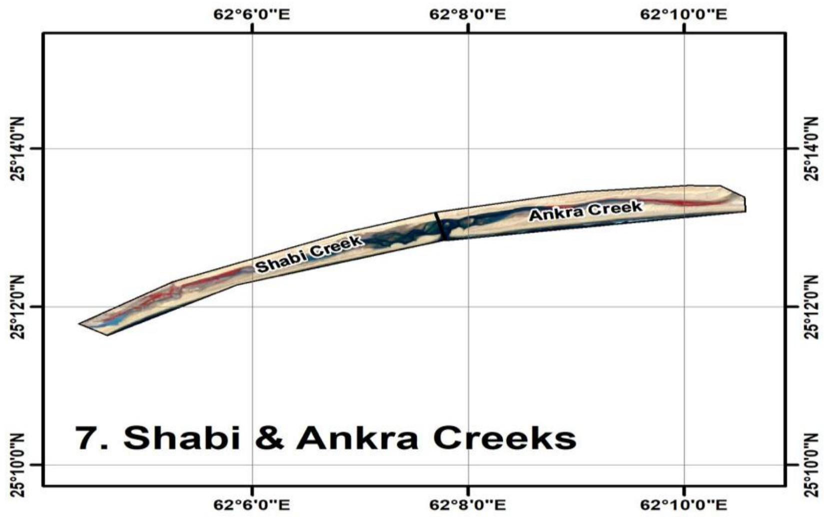


Figure 3 Shabi and Ankara Creeks

2. Jiwani Khor

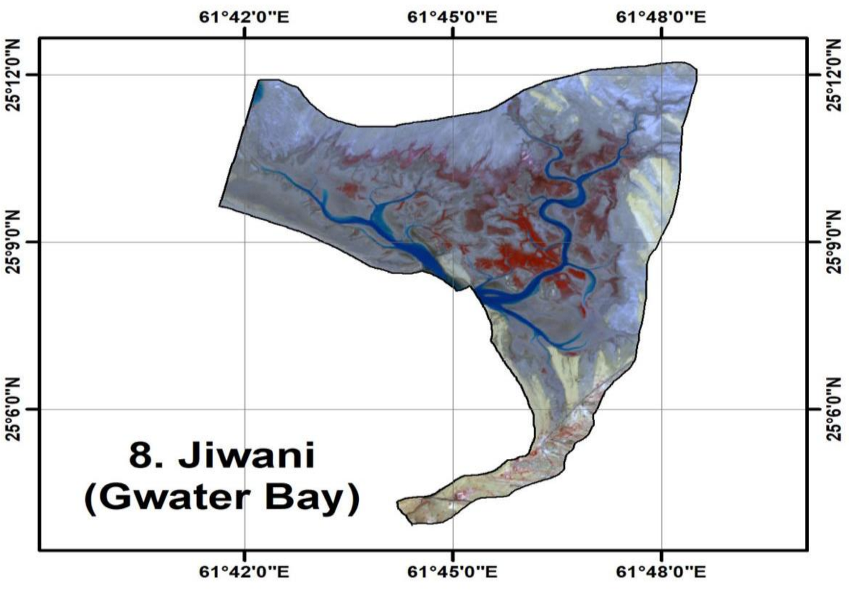


Figure 4 Jiwani Khor

2 Mukhtar, I. and Hannan, A., 2012. Constrains on mangrove forests and conservation projects in Pakistan. *Journal of Coastal Conservation*, *16*, pp.51-62.

Jiwani Khor, also known as Gwater Bay, is a tidal creek in Gwadar, Balochistan, and is located near Bandri and Okar village in the Gwatar Bay that lies 515 km from Karachi[3]. The mangrove forests of Balochistan constitute 3% of Pakistan's total mangrove cover [4], with Gwater Bay accounting for 8%.

3. Kalmat Khor

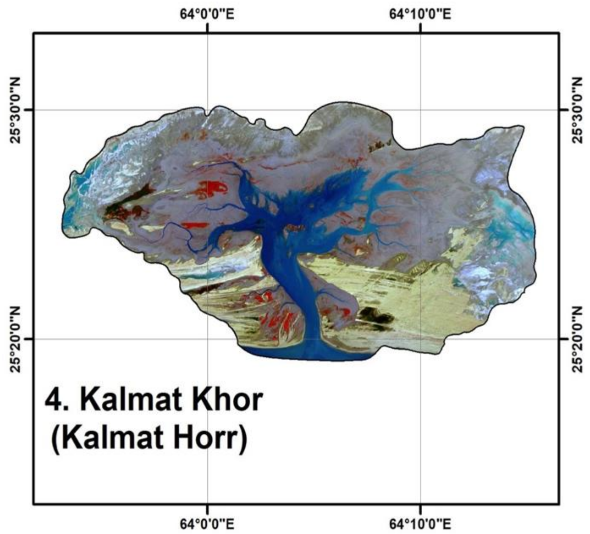


Figure 5 Kalmat Khot

Located in Gwadar district, Balochistan, Kalmat Khor has a maximum width of 27km and lies 315 km from Karachi[5]. The mangrove forests of Balochistan constitute 3% of Pakistan's total mangrove cover [6], with Kalmat Khor accounting for 21%. It achieves its full form at high tide and is essential to sustain life for the arid desert around. The Makran Coast Ridge cuts off the lagoon from the mainland and the mangroves in Kalmat Khor have been observed to show continuous growth.[7]

4. Sahidi Khor and Sawar Khor

Located in Gwadar district, Sawar and Sahidi Khor sites are recently identified due to which there is a lack of secondary data available. The Sawar Khor occurs in the shape of narrow patches and both the sites are located between Shabi and Ankara Creeks and Kalmat Khor (Figure 2).

3 Mukhtar, I., & Hannan, A. (2012). Constrains on mangrove forests and conservation projects in Pakistan. *Journal of Coastal Conservation*, *16*, 51-62.

4 Rafique, M.U.H.A.M.M.A.D., 2018. A review on the status, ecological importance, vulnerabilities, and conservation strategies for the Mangrove ecosystems of Pakistan. Pak. J. Bot, 50(4), pp.1645-1659.

5 Mukhtar, I. and Hannan, A., 2012. Constrains on mangrove forests and conservation projects in Pakistan. *Journal of Coastal Conservation*, *16*, pp.51-62.

6 Rafique, M.U.H.A.M.M.A.D., 2018. A review on the status, ecological importance, vulnerabilities, and conservation strategies for the Mangrove ecosystems of Pakistan. Pak. J. Bot, 50(4), pp.1645-1659.

7 Abbas, S., Qamer, F. M., Ali, G., Tripathi, N. K., Shehzad, K., Saleem, R., & Gilani, H. (2013). An assessment of status and distribution of mangrove forest cover in Pakistan. *Journal of Biodiversity and Environmental Sciences*, *3*(6), 64-78.

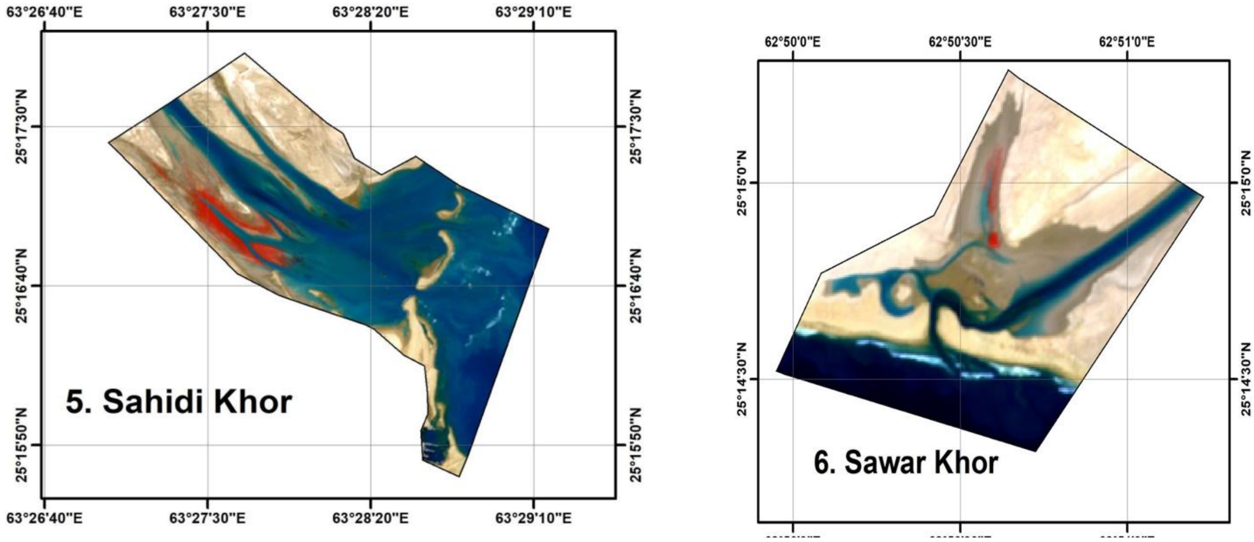


Figure 6 Sahidi Khor and Sawar Khor

SECTION 2. PROJECT SITE ASSESSMENT AND FOREST INVENTORY

This section encapsulates a comprehensive Land Use and Land Cover Change Classification of mangrove forests in Balochistan province by monitoring land use and cover changes in mangrove spatial patterns, particularly for the selected mangrove forest on the coastline of the province: Jiwani Khor, Sonmiani Khor, Sahidi Khor, Kalmat Khor, Sawar Khor, and Shabi and Ankara Creeks.

Approach

The continuous monitoring and mapping of this precious marine plant may not be very efficient and cost-effective using traditional means and 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 temporal and spatial scales. Remote sensing techniques and tools play a vital role in monitoring and mapping of the highly vulnerable mangrove ecosystem. Habitat inventory and change detection (Land use land cover, area estimation) can be done by using remote sensing[8]. A Comprehensive Land use/land cover study is desirable to manage and monitor mangrove resources with medium and high-resolution satellite data using RS techniques. Mangrove extent needs to be monitored to check gain and loss in area and changes in time to indicate resilience to sea level rise.[9]

The advent of Google Earth Engine (GEE), a cloud-based geospatial platform, now enables high-resolution, machine learning–driven LULC classification over large spatial extents with reduced computational overhead. Recent studies have demonstrated the utility of GEE in mapping mangrove dynamics and change detection in coastal environments.[10][11][12] By integrating multispectral satellite imagery with advanced classification algorithms, GEE facilitates robust, real-time monitoring of critical ecosystems like mangroves.

This study focuses on the LULC classification of mangrove areas in Balochistan using GEE to assess spatial distribution, restoration potential, and degradation patterns. By combining remote sensing data with ecological insights, this research aims to provide a scientifically grounded foundation for conservation planning, community-based restoration, and policy-level decision-making.

The study area spans various locations within the Makran coastal belt, including:

8 Kuenzer, Claudia, et al. "Remote sensing of mangrove ecosystems: A review." Remote Sensing 3.5 (2011): 878-928.

9 Duncan, Clare, et al. "Satellite remote sensing to monitor mangrove forest resilience and resistance to sea level rise." Methods in Ecology and Evolution 9.8 (2018): 1837-1852.

10 Giri, C., Long, J., Tieszen, L., et al. (2011). Distribution and dynamics of mangrove forests of the world using Earth observation satellite data. Global Ecology and Biogeography, 20(1), 154–159.

11 Fatoyinbo, L., Lagomasino, D., Fatoyinbo, T., et al. (2018). Mapping coastal wetlands of West Africa using Sentinel-1 and Google Earth Engine. Remote Sensing of Environment, 216, 370–385.

12 Zald, H.S.J., Dunn, C.J., et al. (2020). Mapping forest disturbance and change using machine learning in Google Earth Engine. Remote Sensing, 12(1), 23

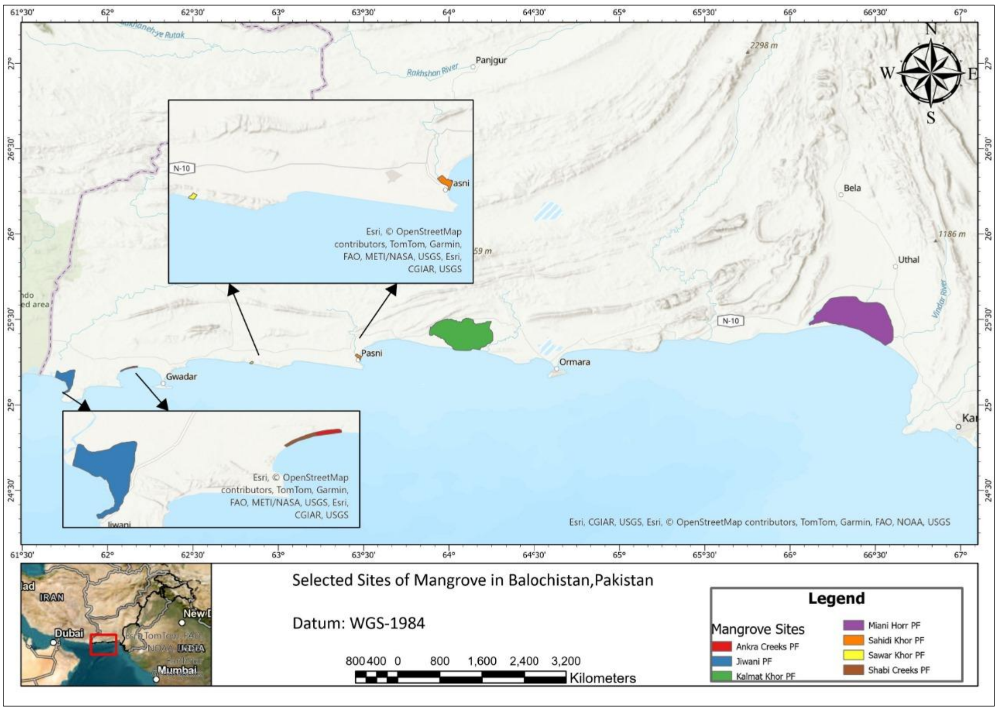


Figure 7 Map of Pilot Area (Demonstrating Different Sites of Protected Mangrove Areas in Balochistan)

Methodology

The methodology adopted for this analysis is outlined in Figure 8. Sentinel-2 images are acquired and pre-processed using Google Earth Engine (GEE). Training data is developed for four classes: mangrove, potential area, water, and other land. A supervised image classifier extracts the classes and accuracy assessment is applied based on the training data. The results are converted into vector format for area estimation, followed by classification and mapping of the estimated areas.

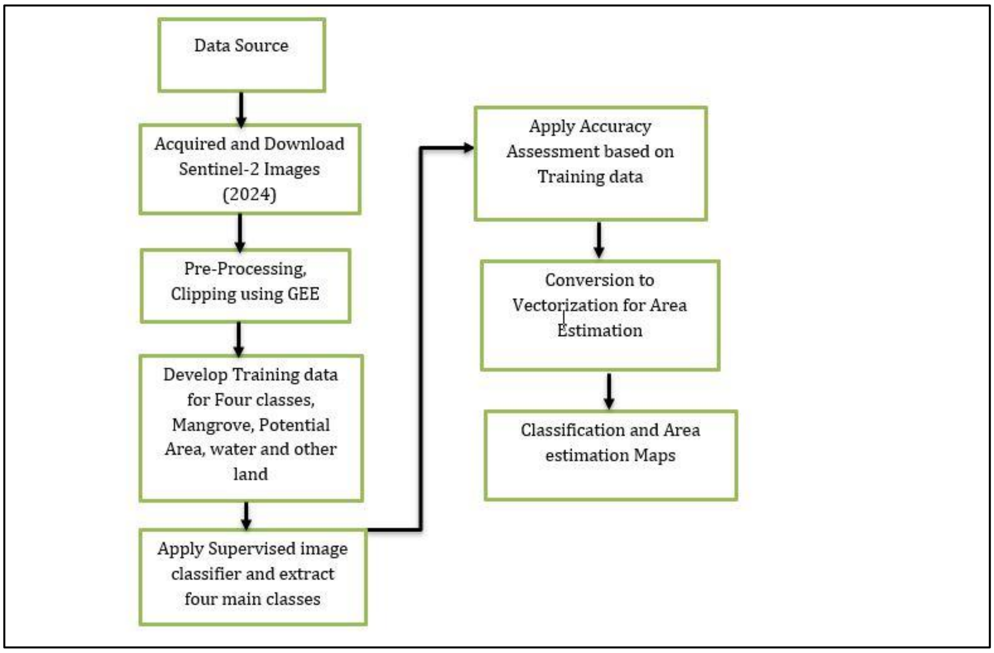


Figure 8 Methodology Flow Chart

The following is a technical assessment conducted for this project:

Land Use and Land Cover Classification

The land use and land cover mapping were carried out using a supervised classification method that employs the maximum likelihood classifier algorithm within Google Earth Engine (GEE). Understanding land use/land cover (LULC) changes is crucial for various fields that rely on Earth observations. This includes urban and regional planning, environmental vulnerability and impact assessments, monitoring natural disasters and hazards, and estimating soil erosion and salinity, among others. A quantitative assessment and prediction of LULC dynamics serve as effective tools for managing and comprehending landscape transformations. Mapping LULC changes is recognized as a vital component for a wide range of activities and applications, including land use planning and strategies for mitigating global warming.

Sentinel 2 Image Data

The Multispectral Instrument (MSI) on the Sentinel-2 satellite is a high-resolution multispectral imaging sensor with a spatial resolution of 10 m for visible and near-infrared bands. This study utilized Sentinel-2 Level 2A SR Low tide months, i.e., December images were used. Data acquisition and preprocessing were performed using the GEE cloud platform.

Google Earth Engine (GEE)

This advanced analytical platform facilitates the in-depth examination of satellite imagery and a variety of geospatial data, yielding essential insights into the health, distribution, and resilience of mangrove ecosystems. Recent advancements in the application of machine-learning algorithms to remotely sensed imagery have garnered significant attention in the context of Land Use/Land Cover (LULC) mapping. Within this domain, machine-learning techniques can be distinctly categorized into two primary subtypes: supervised techniques, which rely on labeled training data to classify new observations, and unsupervised techniques, which identify patterns and structures in data without predefined labels.

In this study, the area of interest was systematically divided into several thematic classes, which include Mangrove Forest, Water Bodies, Potential Blank Area, and Other Land. This classification not only enhances our understanding of the ecological dynamics at play but also aids in the effective management and conservation of these critical ecosystems. The integration of these sophisticated analytical tools allows for more accurate monitoring and assessment of environmental changes over time, ensuring informed decision-making for the protection of mangrove habitats.

Accuracy Assessment

The confusion matrix (Table 1) serves as a valuable method for evaluating the accuracy of image classifications. In this study, the confusion matrix was computed utilizing the online programming capabilities of the Google Earth Engine (GEE) cloud platform. Subsequently, the overall accuracy (OA) and Kappa coefficient were calculated as shown in table-1. These metrics provide a comprehensive reflection of the results' accuracy, encapsulating the effectiveness of the classification outcomes.

Table 1 Accuracy Assessment

Confusion Matrix with Accuracies					
Actual/Predicted	Mangrove	Water	Potential Blank Area	Other Land	**Producer's Accuracy**
Mangrove	32	0	0	0	1
Water	0	33	1	0	0.970588235
Potential Blank Area	0	0	63	0	1
Other Land	0	0	0	60	1
User's Accuracy	1	1	0.984375	1	

Overall Accuracy (OA) = Sum of Diagonal Elements of the Confusion Matrix / Sum of All Elements in the Confusion Matrix (Congalton, R. G. 1991)

$$\text{OA}= \frac{32+33+63+60}{189} = 0.9947$$

Kappa Coefficient (k) = (P_o - P_e) / (1 - P_e) (Congalton, R. G. 1991)
Where:

P_o = Observed agreement (same as Overall Accuracy)

P_e = Expected agreement by chance

To calculate P_e:

P_e = Σ[(Row Total for Class i × Column Total for Class i) / (Total Number of Predictions)²]

$$K=0.9927$$

Reference:

Congalton, R. G. (1991). *A review of assessing the accuracy of classifications of remotely sensed data*. Remote Sensing of Environment, **37**(1), 35–46.
https://doi.org/10.1016/0034-4257(91)90048-

Technical Assessment of Project Site(s)

1. Sonmiani Khor

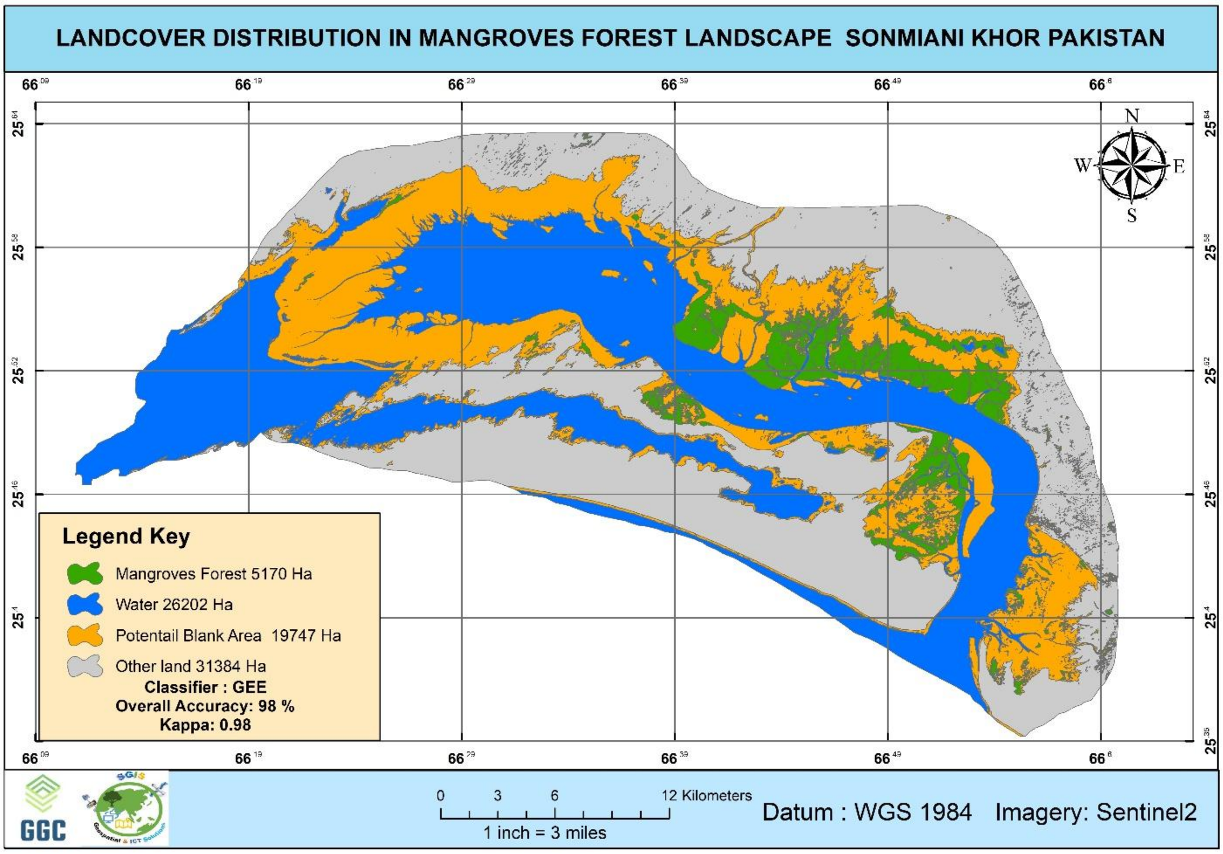


Figure 9 Landcover Distribution in Mangrove Forest Landscape in Sonmiani Khor

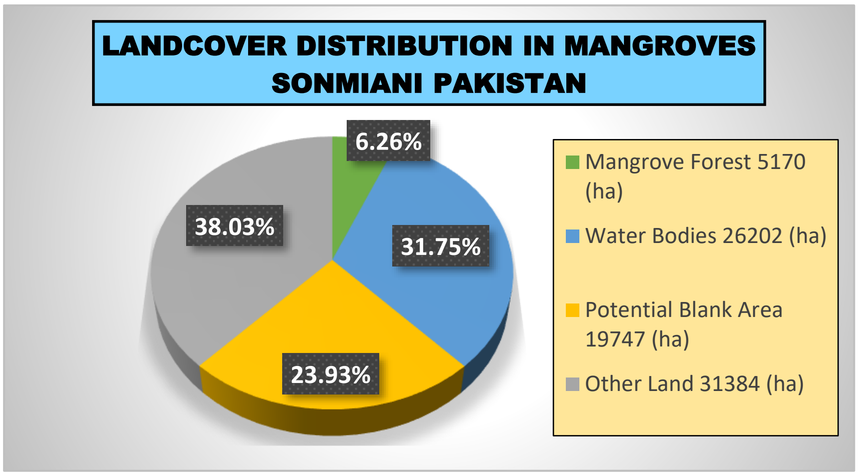


Figure 10 Landcover Distribution in Sonmiani Khor

Figure 10 demonstrated Sonmiani Khor's land cover analysis covering a total area of 82,503 hectares, and primarily depicts the impact of land uses that do not involve vegetation. As per the LULC assessment, **mangrove forests** in the location cover **5,170 ha (6.26%)**. Despite its limited coverage, the mangrove forest is ecologically crucial as it offers critical coastal protection from erosion and storm surges. Additionally, it ensures carbon sequestration that is beneficial for climate policies and carbon credit potential and acts as a nursery for marine life, benefiting local fisheries. **Water bodies** encompass **26,202 hectares (31.75%),** almost one-third of the region, including tidal flats, lagoons, and creeks. This suggests a high marine biodiversity suitable for sustainable fisheries and aquaculture. **Potential blank area** consists of **19,747 hectares (23.93%)**. This area likely includes barren saline land, mudflats, or degraded zones. **Other land** covers **31,384 hectares** (**38.03%),** and likely includes areas with dunes, rocky terrain, sparse vegetation, or human-altered landscapes. The findings are summarized and depicted below:

Table 2 LULC Standard Classes of Sonmiani Khor

Land Cover Type	Area (ha)	Percentage of Total (%)
Mangrove Forest	5,170	6.26%
Water Bodies	26,202	31.75%
Potential Blank Area	19,747	23.93%
Other Land	31,384	38.03%
Total Area	82,503	100%

2. Jiwani Khor

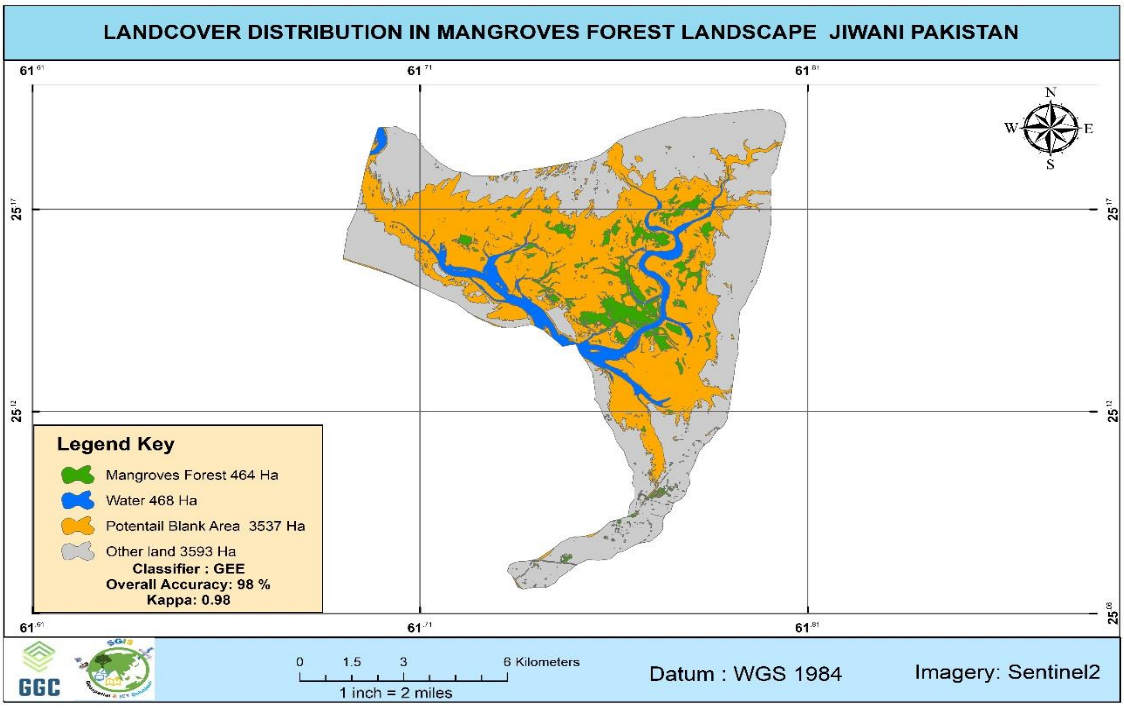


Figure 11 Landcover Distribution in Mangrove Cover Landscape in Jiwani

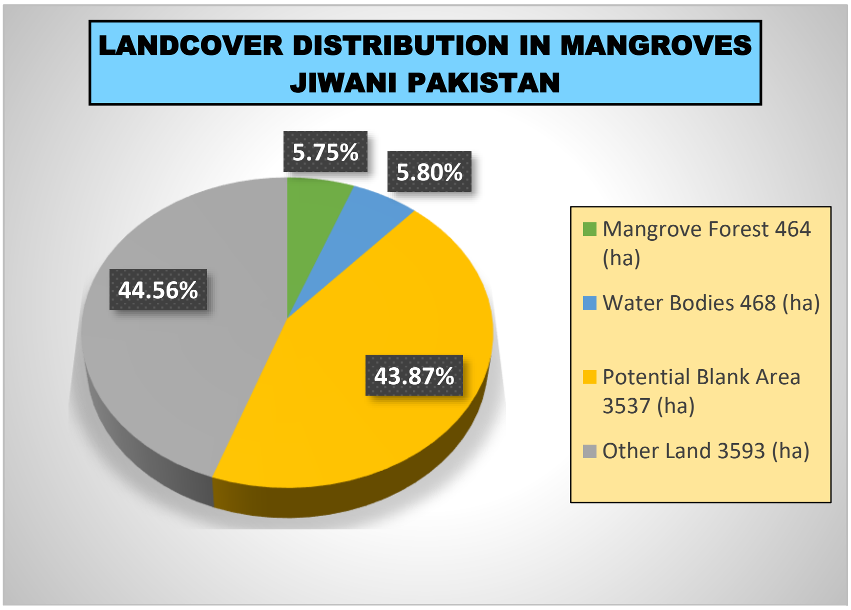


Figure 12 Landcover Distribution in Mangroves in Jiwani

The land cover analysis of the Jiwani mangrove region (Figure 11), covering a total area of 8062 ha, demonstrated a landscape with limited vegetative cover and a high proportion of altered or unproductive land. In terms of **mangrove forests**, they cover **464 ha (5.75%)** and play a crucial role as ecological keystones. These forests provide essential functions such as buffering storm surges, preventing erosion, supporting marine species, sequestering carbon, and improving water quality. **Water bodies** span **468 ha (5.80%)** of the region and include tidal channels, estuaries, lagoons, and shallow coastal waters. These areas are vital for fisheries, salinity regulation, and maintaining ecosystem connectivity with mangroves.
A significant portion of the region, **3,537 ha or 43.87%,** is categorized as a **potential blank area**, consisting of salt flats, barren land, or unused terrain. **3,593 ha (44.56%)** is **other land**, encompassing various terrains such as sandy areas, rocky terrain, sparse vegetation, and settlements. The findings are summarized and depicted below:

Table 3 LULC Standard Classes of Jiwani

Class	**Area (ha)**	**Percentage (%)**
Mangrove Forest	464	5.75%
Water Bodies	468	5.80%
Potential Blank Area	3,537	43.87%
Other Land	3,593	44.56%
Total Area	8,062	100%

3. Sahidi Forest

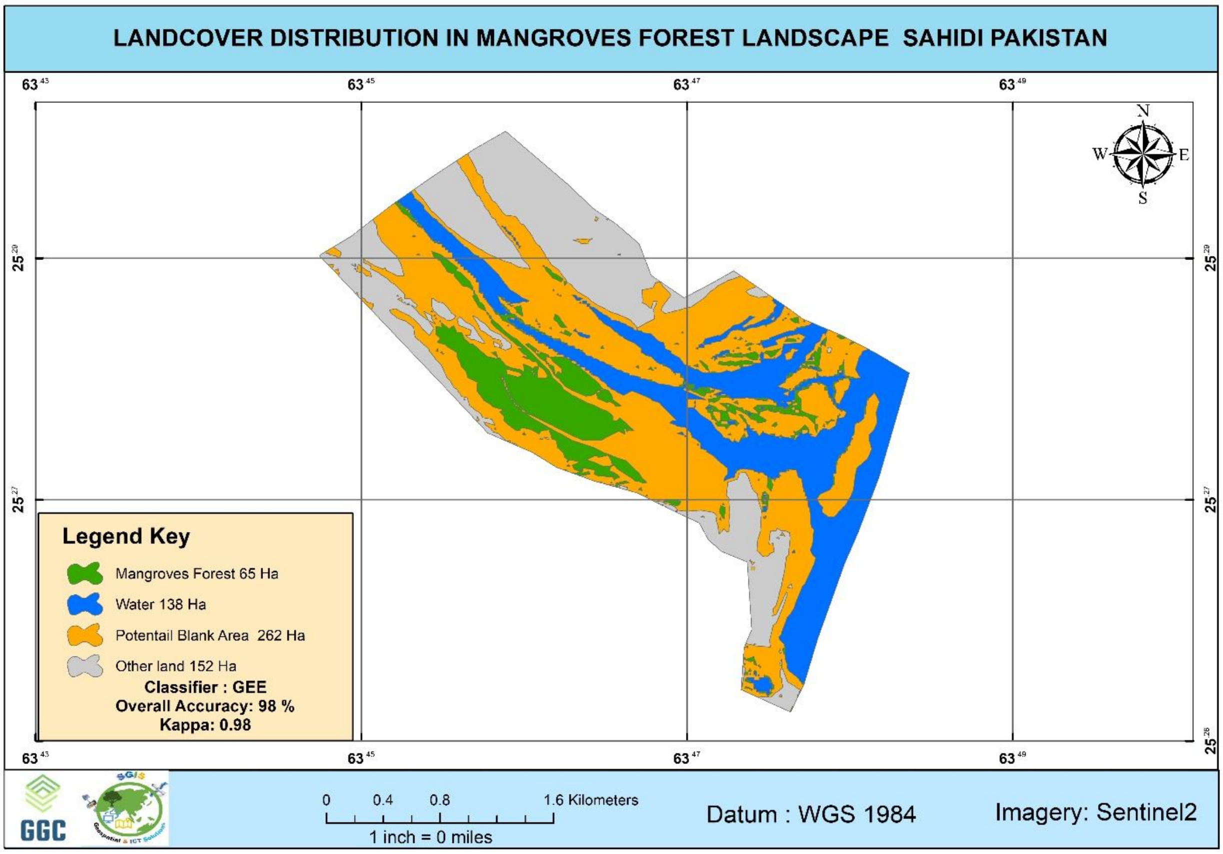


Figure 13 Landcover Distribution in Mangrove Forest Landscape in Sahidi Khor

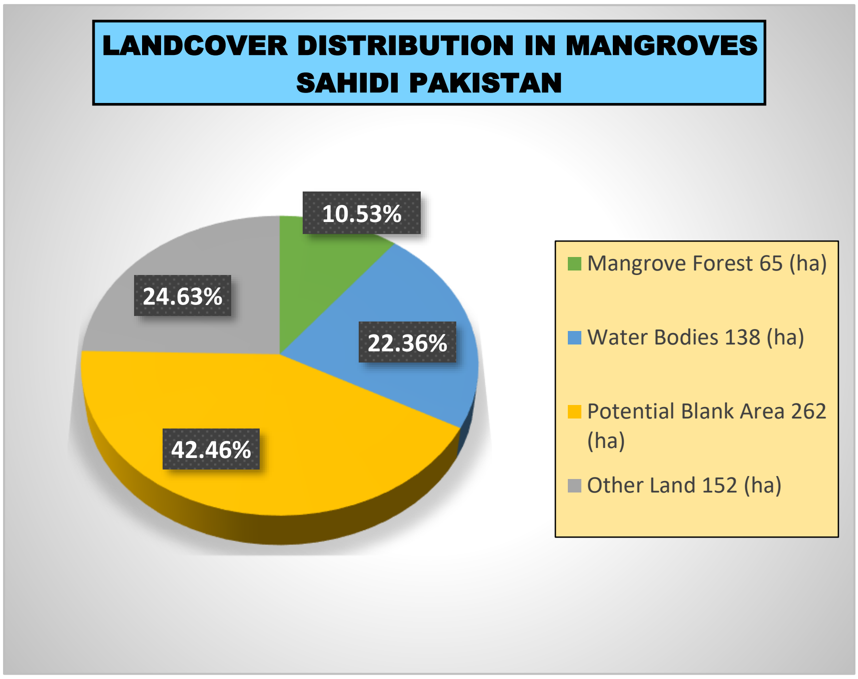


Figure 14 Landcover Distribution in Mangroves in Sahidi Khor

The land cover analysis of the Sahidi mangrove region, covering a total area of 617 hectares, demonstrates a high rate of potential blank area for a fruitful regeneration of mangroves forest. **Mangrove forests** span **65 ha (10.53%)**. While small in size, they are still crucial for the ecosystem and provision of a habitat for coastal biodiversity, prevents erosion, and acts as a valuable carbon sink. **Water bodies** cover **138 ha (22.36%)** and are essential for fisheries, aquaculture, and natural drainage. Mapping seasonal variations using satellite imagery can provide valuable insights for managing these vital hydrological features. The **potential blank area** occupies **282 ha (42.46%),** and offers immense potential for mangrove reforestation, wetland restoration, and more. **Other land**, totaling **152 ha (24.63%),** includes various environments like sandy land and sparse vegetation. The findings are summarized and depicted below:

Table 4 LULC Standard Classes of Sahidi

Land Cover Type	Area (ha)	Percentage of Total (%)
Mangrove Forest	65	10.53%
Water Bodies	138	22.36%
Potential Blank Area	282	42.46%
Other Land	152	24.63%
Total Area	617	100%

4. Kalmat Khor

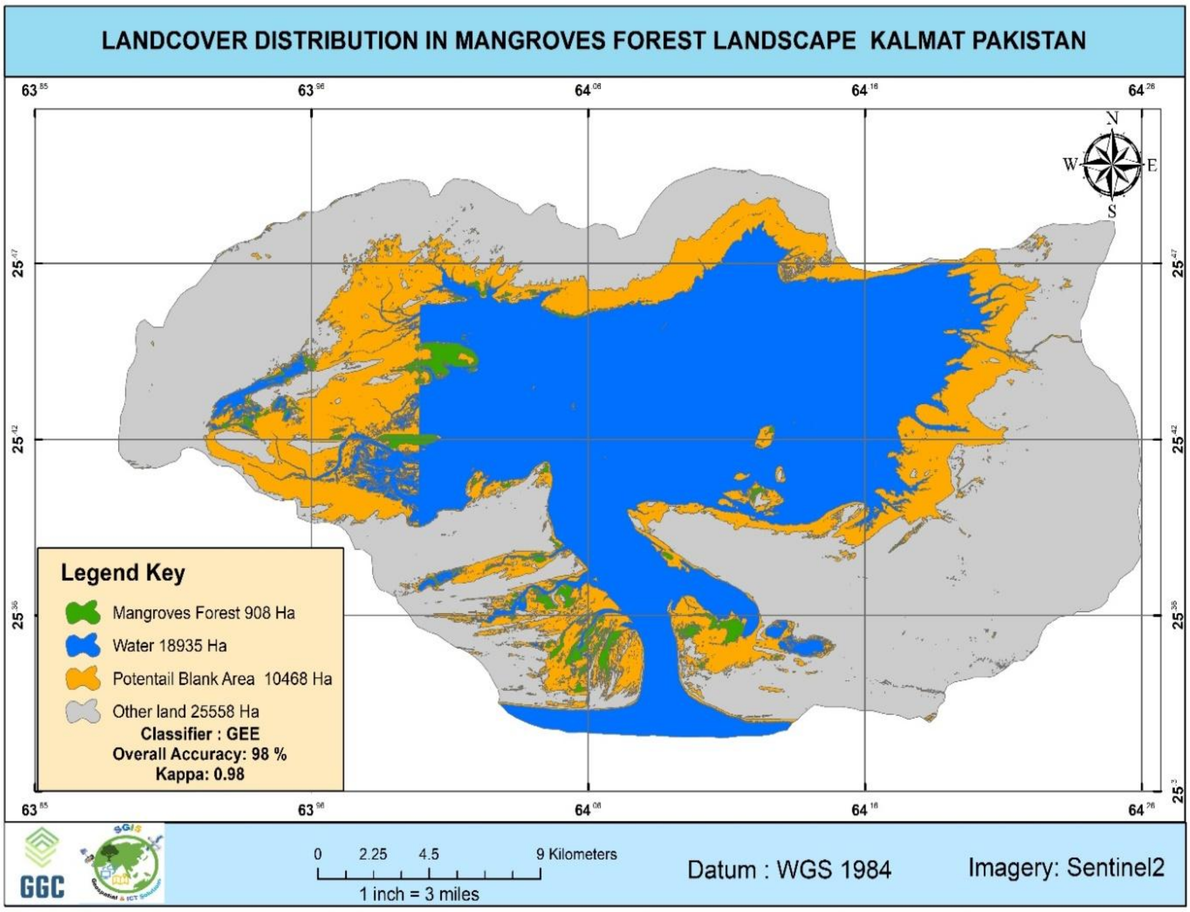


Figure 15 Landcover Distribution in Mangroves Forest Landscape in Kalmat Khor

The land cover analysis of the Kalmat region, covering a total area of 55,869 hectares, reveals a landscape predominantly influenced by non-vegetative land uses. Only **908 ha (1.625%)** of land are covered by **mangrove forests** in Kalmat. This insufficient coverage is alarming, considering the significant role that mangroves play in shoreline stabilization, habitat provision, and carbon sequestration. In comparison to the vast stretches of water bodies and open spaces, the limited presence of mangroves underscores the pressing need for immediate conservation and expansion initiatives in the region. **water bodies** cover a significant portion of Kalmat, accounting for **18,935 ha (33.89%).** This strong hydrological presence is likely attributed to the coastal or estuarine characteristics of the region, which foster a diverse range of aquatic species and support livelihoods dependent on water resources. **The potential blank area** covers **10,468 ha (18.73%)** of the region. This space presents a valuable opportunity for restoration, afforestation, or sustainable development projects. These areas provide a chance for environmental intervention and climate-resilient land use strategies. **Other land** occupies **25,558 ha (45.74**%), the largest category makes up 51.64% of the total. This sizable percentage indicates extensive human activity, arid regions, or the presence of infrastructure development. The findings are summarized and depicted below:

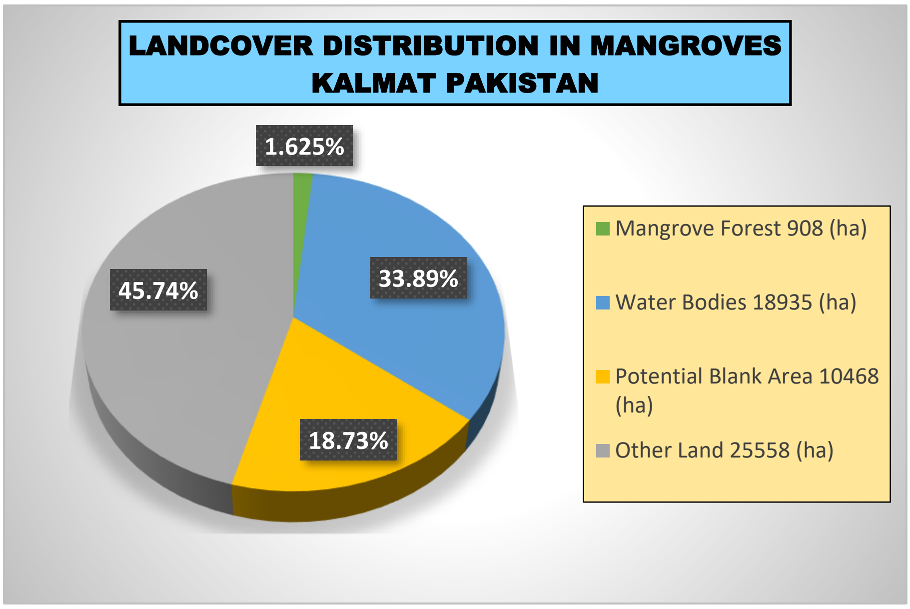


Figure 16 Landcover Distribution in Kalmat Khor

Table 5 LULC Standard Classes of Kalmat Khor

Land Cover Type	Area (ha)	Percentage of Total (%)
Mangrove Forest	908	1.625%
Water Bodies	18935	33.89%
Potential Blank Area	10468	18.73%
Other Land	25558	45.74%
Total area	55869	100%

5. Shabi and Ankara Creeks

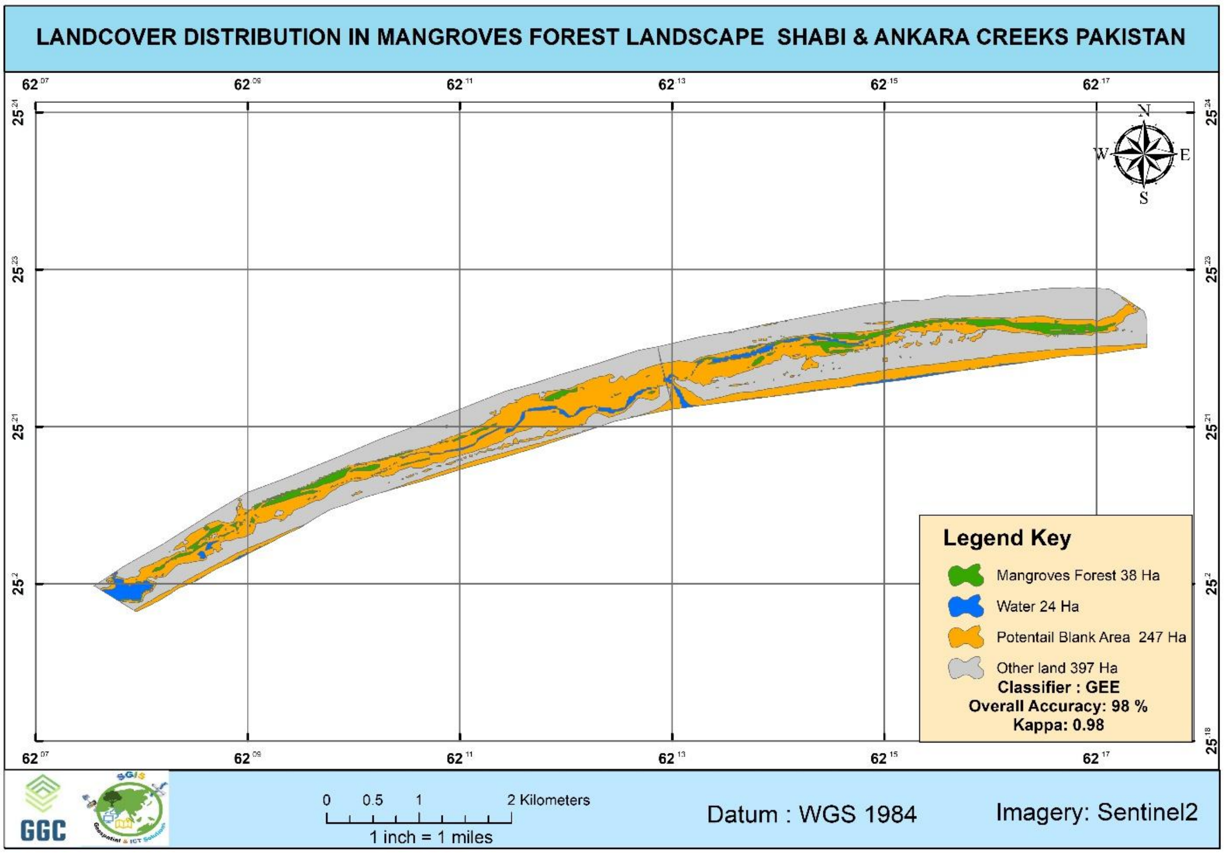


Figure 17 Landcover Distribution in Mangroves Forest Landscape of Shabi & Ankara Creeks

GIS-based spatial analysis of the 707-hectare Shabi and Ankara region of the mangrove forest reveals critical insights. **Mangrove forest**s encompass **38 ha (5.37%)**. They are strategically situated in ecologically sensitive zones, primarily near tidal inlets or along the sheltered banks of creeks. Despite their relatively small size, they play a significant role in ecological productivity, protection against coastal erosion, and support for fish spawning. **Water**

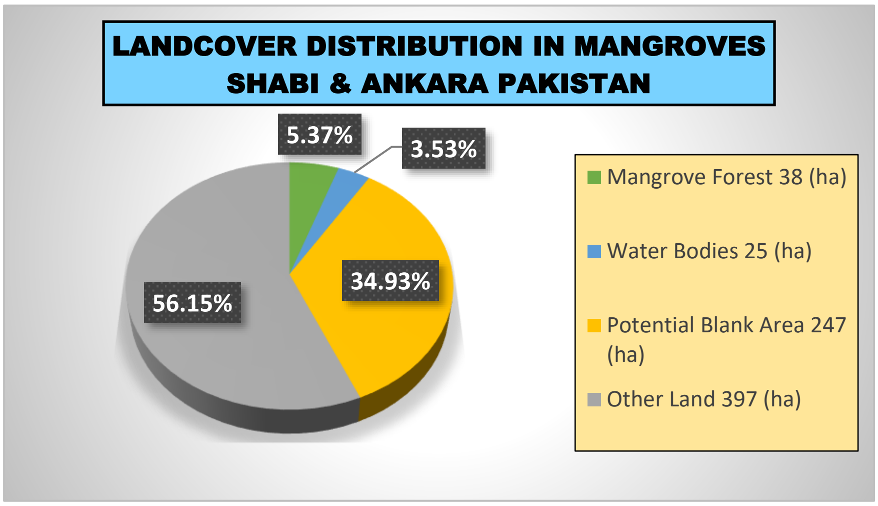


Figure 18 Landcover Distribution in Mangroves Shabi & Ankara Creeks

bodies cover **25 ha (3.53%)**. This category includes creek channels, seasonal waterlogged areas, and lagoons. Although their extent is limited, these water bodies are crucial for maintaining hydrological balance and ensuring tidal connectivity. A substantial portion, measuring **247 ha (34.93%),** is classified as a **potential blank area**. This area is likely composed of saline or degraded land, tidal mudflats, or exposed sediment zones. It presents opportunities for mangrove reforestation, wetland restoration, and carbon sequestration initiatives. The majority of the land, totaling **397 hectares (56.15**%), is categorized as **other land**. This classification typically includes sandy or gravelly surfaces, areas with sparse vegetation, and minor infrastructure or natural dunes. The findings are summarized and depicted below:

Table 6 LULC Standard Classes of Shabi & Ankara Creeks

Land Cover Type	**Area (ha)**	**Percentage of Total (%)**
Mangrove Forest	38	5.37%
Water Bodies	25	3.53%
Potential Blank Area	247	34.93%
Other Land	397	56.15%
Total Area	707	100%

6. Sawar Forest

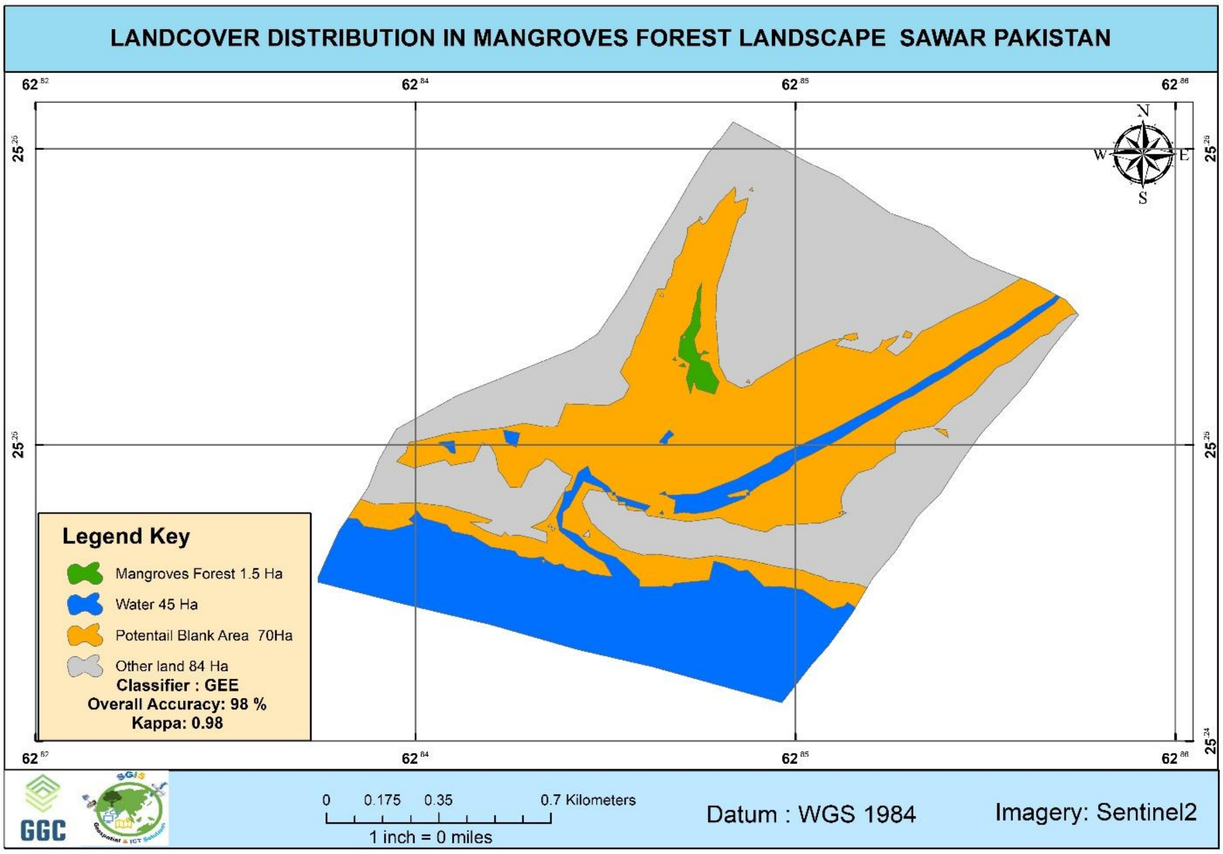


Figure 19 Landcover Distribution in Mangroves Forest Landscape in Sawar Khor

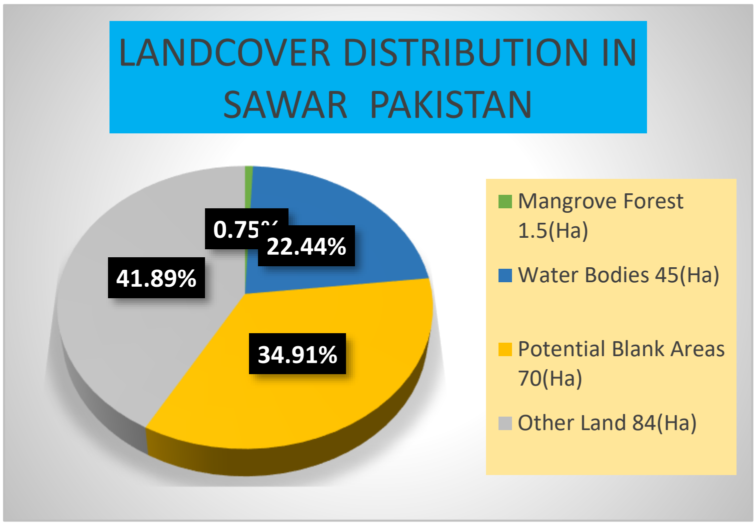


Figure 20 Landcover Distribution in Sawar Khor

Mangrove forest covers 1.5 hectares (**1.09%**) though small, plays a crucial role in the ecosystem. It indicates limited tidal influence, most likely near sheltered creek mouths or estuarine margins. Despite its size, this patch is essential for coastal biodiversity, sediment stabilization, and carbon sequestration. It is considered a priority conservation zone and is well-suited for mangrove enrichment planting or assisted natural regeneration through community-based or climate resilience programs. **Water bodies** comprise **45 ha (32.72%)**,spanning almost 40% of the total area, the water bodies in this region are thought to be a mix of tidal creeks, saline lagoons, and seasonal water channels. This suggests a highly dynamic hydrological zone that may experience tidal fluctuations or seasonal flooding. These areas play a vital role in supporting diverse aquatic ecosystems and offer promising opportunities for activities such as blue carbon storage, aquaculture, and wetland restoration. **Potential blank area** spans **70 ha (5.09%).** This category likely consists of saline flats, degraded scrublands, or unproductive coastal patches. Although currently underutilized, this area holds significant potential for ecological restoration through initiatives such as expansion of community managed green-belts. **Other land** spans **84 ha (61.09%)** This category likely consists of a variety of landscapes such as barren ground, sandy terrain, rocky outcrops, and limited human activity. Although not currently ecologically active, these areas should undergo detailed analysis through advanced remote sensing or on-site investigations to assess their potential for rehabilitation, sustainable land utilization, or development planning.

Table 7 LULC Standard Classes of Sawar Khor

Land Cover Type	**Area (ha)**	**Percentage of Total (%)**
Mangrove Forest	1.5	0.75%
Water Bodies	45	22.44%
Potential Blank Area	70	34.91%
Other Land	84	41.89%
Total Area	200.5	100%

Environmental Paradigms Across Mangrove Ecosystems

The following table demonstrated the various study areas identified and how they may be feasible in terms of their environmental value:

Table 8 Environmental Paradigm of Mangroves

Paradigm	zones	Implication/Action
Lack of Understory	Likely in Sawar, Shabi & Ankara due to small mangrove patches and possible overuse	Requires enrichment planting with community help
Inundation Classifications	Kalmat and Sonmiani have extensive water bodies, supporting complex tidal zones	Use DEM + water body overlays for site-specific planting
Salinity Tolerance & Biomass	Kalmat, with large blank and water areas, can support zoned reforestation	Apply salinity mapping + species selection for restoration
Nutrient, Growth, Herbivory	Jiwani and Sahidi have low mangrove cover and moderate blank areas	Likely degraded; CSR/community monitoring for grazing & nutrient balance needed
Geomorphological Classification	Varied land types in Sonmiani and Kalmat suggest diverse geomorphology	Use slope, soil, and tidal models to guide restoration planning

Findings

The encapsulated assessment for the Land Use Land Cover (LULC) classification of the mangrove sites across Balochistan's coast has revealed critical information pertaining to the current status of these vital ecosystems, presenting a significant opportunity for the province to capitalize on. The assessment reveals the presence of **34,351 ha** of potential land that may be utilized for afforestation efforts to work towards regeneration of mangroves (Figure 22).

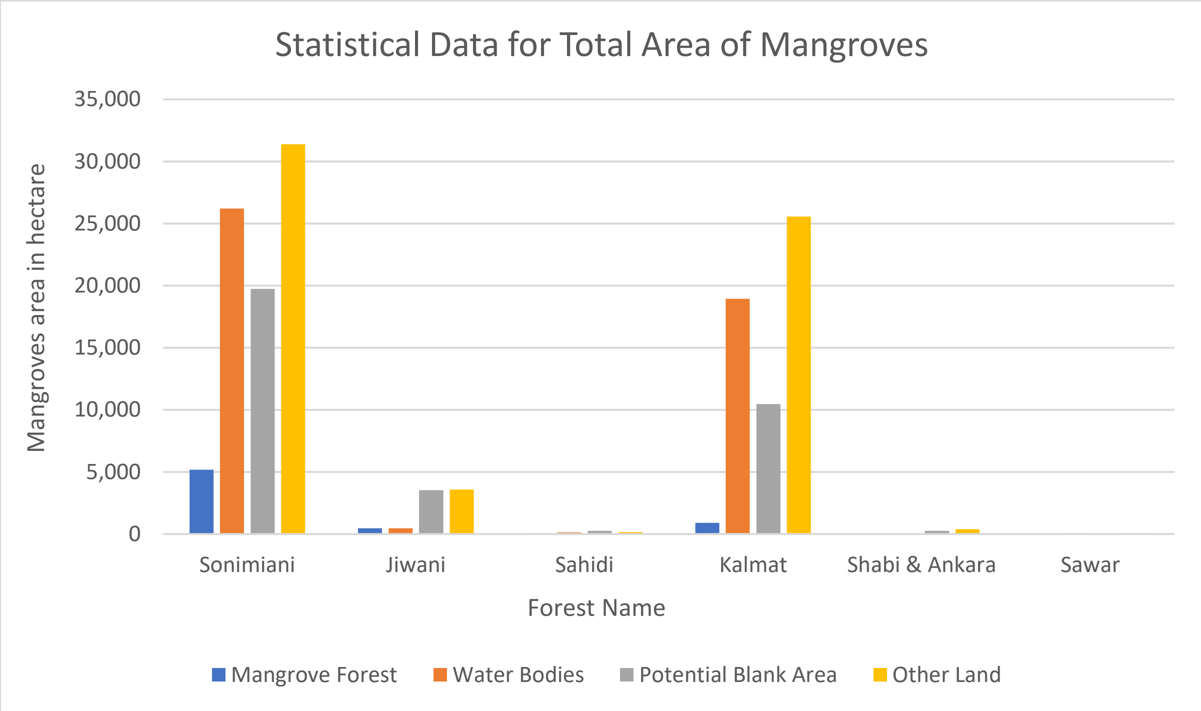


Figure 21 Total Area of Mangrove Sites

The findings of this study convey the recognition and assessment of mangrove ecosystems in six coastal regions through the use of machine learning in the classification of land use and land cover (LULC) using Google Earth Engine. Figure 22 indicates significant variation in land cover types. Report suggested that Miani Hor (Sonmiani) and Kalmat Khor shows the highest mangrove with extensive water channels/bodies.it can be said that Sonmiani has the largest mangrove area, measuring 5,170 hectares, along with a potential blank area of 19,747 hectares, making it ideal for large-scale restoration efforts. Kalmat also shows promise, with 908 hectares of mangroves and over 10,000 hectares of suitable blank area, supported by adjacent water bodies of 18,935 hectares. These findings emphasize the need to protect and restore mangrove ecosystems in Balochistan. Regions like Jiwani and Sahidi, despite limited mangrove coverage, present significant restoration opportunities due to suitable blank land. Conversely, areas such as Shabi, Ankara, and Sawar are experiencing critical mangrove depletion, demanding immediate conservation action.

SECTION 3. CARBON SEQUESTRATION ASSESSMENT

This section encapsulates the carbon sequestration estimation across the identified project sites to assess the viability and projected impacts of this intervention.

Methodology

The methodology employed for this analysis is outlined in Figure 22:

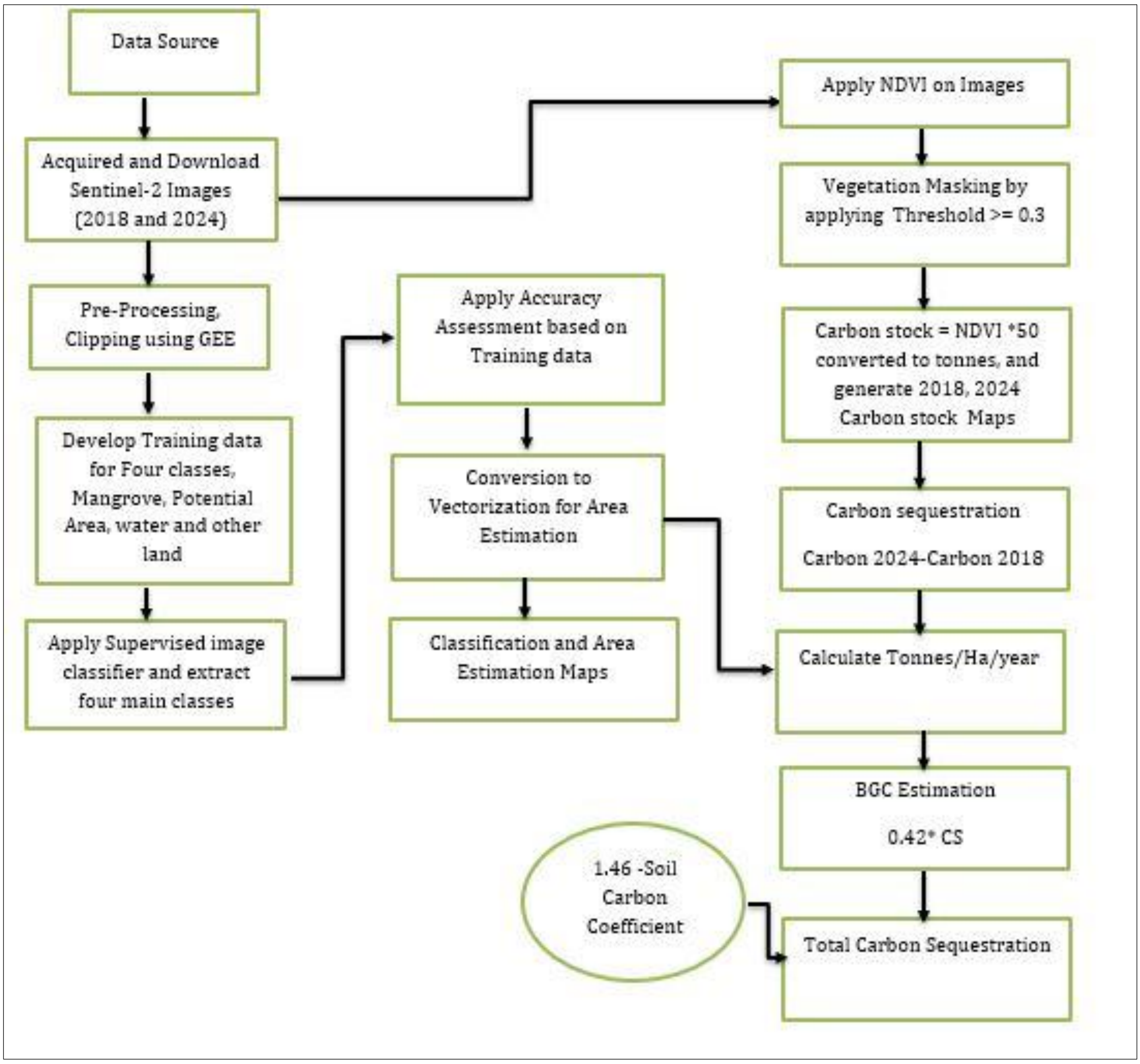


Figure 22 Carbon Sequestration Methodology

Carbon Stock Estimation

The linear relationship between NDVI and carbon stock (e.g., Carbon Stock = NDVI × 50) is based on empirical models developed through regression analyses in various studies.

Carbon Sequestration Estimation

The Intergovernmental Panel on Climate Change (IPCC) provides detailed methodologies for estimating GHG emissions and removals from land use, including forest carbon stock changes.

Key Equations for Biomass Carbon Stock:

$$\Delta C=(Ct2-Ct1)\Delta C=(C\ t2\ -C\ t1\ )$$

Where $Ct1$ and $Ct2$ are carbon stocks at times 1 and 2.

Total Carbon Sequestration[13] [14] [15] [16] [17]

To estimate total carbon sequestration, three factors are needed:

1) Tonnes/ha/year

2) Below Ground Carbon (BGC)= 0.42 Suggested by IPCC Guidelines

3) Soil carbon (Constant value)=1.46 which was suggested by VERA-VM0033 Methodology for Tidal Wetland and Seagrass Restoration, v2.1

Total Carbon sequestration= Tonnes/ha/year+BGC+Soil carbon (IPCC-2006)

Tonnes/ha/year is calculated by multiplying the forest area, which was calculated from classification, by carbon sequestration

Tonnes/ha/year= forest area (ha)*carbon sequestration

Table 9 Framework for estimation of Carbon Sequestration

Component	Our Approach	IPCC / REDD+ Guidance
NDVI as biomass proxy	Carbon = NDVI × 50	Acceptable under Tier 1/2 with local calibration
Sequestration calculation	Carbon_t2 - Carbon_t1	Matches IPCC Equation 2.3

13 Situmorang, J. P., Sugianto, & Darusman. (2016). Estimation of Carbon Stock Stands using EVI and NDVI Vegetation Index in Production Forest of Lembah Seulawah Sub-District, Aceh, Indonesia. *Aceh International Journal of Science and Technology*, 5(3), 126-139

14 UNFCCC. (2009). *Methodological guidance for activities relating to REDD+*. Decision 4/CP.15. https://unfccc.int

15 IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use (AFOLU)*.

16 IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

17 **GOFC-GOLD (2016)**. *A sourcebook of methods and procedures for monitoring and reporting REDD+ activities*. (https://verra.org/methodologies/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-1/ https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Vegetation threshold	NDVI ≥ 0.3	Aligns with REDD+ remote sensing guidelines
Area-weighted summation	NDVI × pixelArea	Consistent with IPCC GHG estimation
Time-series comparison	2018 vs. 2024	Standard practice in REDD+/IPCC
BGC Coefficient	0.42	IPCC guidelines for national Greenhouse Gas inventories
Soil carbon	1.46	VM0033 Methodology for Tidal Wetland and Seagrass Restoration, v2.1
Total Carbon Sequestration	Tonnes/ha/year +BGC+Soil carbon	Climate Change (IPCC 2006) Guidelines https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Assessing the Sites

The analysis of six different forest sites using NDVI and AGB-based satellite imagery reveals a total annual carbon sequestration of approximately 106.19 tonnes/ha/year across a combined forest area of 6,646.50 hectares. The figures below demonstrate the carbon stock and sequestration across the key project sites:

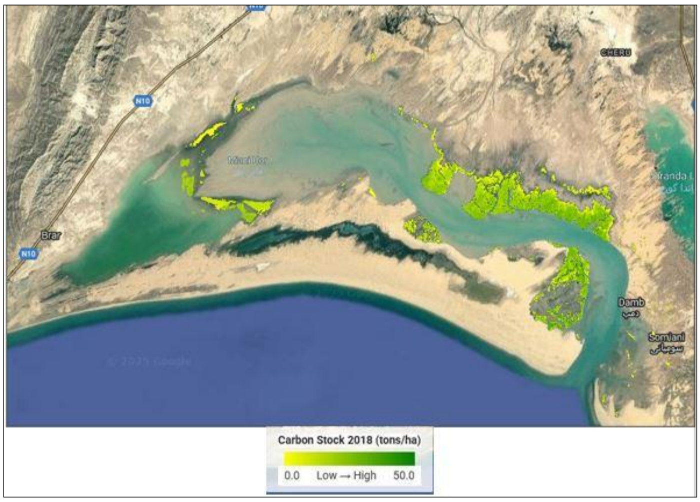


Figure 23 Carbon Stock at Miani Khor- 2018

Figure 24 Carbon Stock at Miani Khor- 2024

Figure 25 Carbon Sequestration at Sonmiani Khor

Figures 23 and 24 show temporal changes in carbon stock within the Miani Hor coastal wetland. These maps compare carbon stock levels between the years 2018 and 2024, values ranging from 0 to 50 tons/ha. Dark color areas show carbon-rich areas, whereas light color areas show less carbon areas likely influenced by ecological changes, human activities, or conservation interventions. Notable differences between the two years may indicate degradation or restoration of vegetated habitats such as mangroves, which are known for their high carbon storage capacity. Figure 25 shows carbon sequestration potential across the Miani hor, measured in tons per hectare per year. Zones with higher sequestration rates are indicated in green, while lower-performing zones appear in This information provides critical understanding into the spatial variability of carbon commitment, helping to identify significant zones for ecosystem protection and restoration.

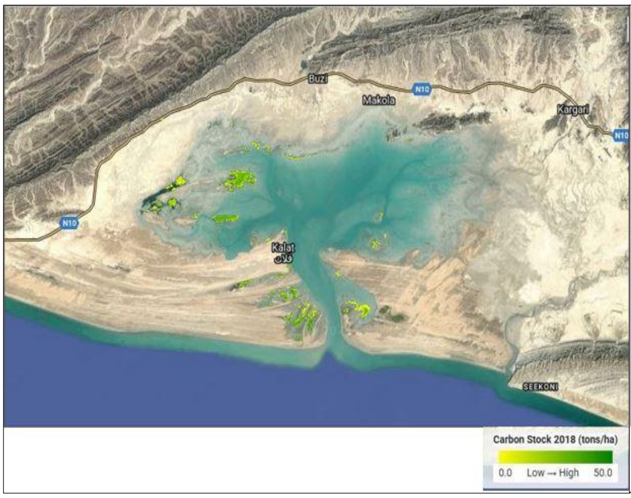


Figure 26 Carbon Stock at Kalmat Khor-2018

Figure 27 Carbon Stock at Kalmat Khor-2024

Figure 28 Carbon Sequestration at Kalmat Khor

Figures 26 and 27 depict the carbon stock assessment for Kalmat Khor between the years 2018 and 2024. Green-to-yellow color gradient indicates the relative density of carbon stored in vegetated habitats, such as mangrove forests and salt marshes, with green areas representing higher carbon storage. These Carbon stock maps show changes in carbon-storing vegetation. These changes could result from natural processes, anthropogenic activities, or other climate factors. This Comparative analysis is essential for evaluating the long-term sustainability of blue carbon ecosystems in Kalmat Khor and for measuring the impact of conservation or degradation over time. Figure 28 represents the carbon sequestration potential measured in tons per hectare per year. It uses a color-coded scale ranging from red (low sequestration) to green (high sequestration)**.** Green zones show regions with high annual carbon uptake, typically areas dominated by dense, healthy mangroves or marsh vegetation**.** Red zones show low or negligible sequestration potential, possibly due to degraded habitats, bare soils, or water bodies with minimal vegetation.

Figure 29 Carbon Stock at Jiwani-2018

Figure 2 Carbon Stock at Jiwani-2024

Figure 31 Carbon Sequestration at Jiwani Khor

Figures 29 and 30 show carbon stock levels for the years 2018 and 2024, respectively. The comparison between these two years reveals a clear increase in carbon stock over time, as indicated by the expansion of green areas in the 2024 map. This suggests an improvement in vegetation cover or restoration efforts contributing to greater carbon storage in the region. Figure 31 illustrates the spatial distribution of carbon sequestration in the Jiwani coastal region. highlighting areas with varying sequestration capacity using a gradient from low (red) to high (dark green). The occurrence of green tones specifies that the region has a substantial volume to capture and store atmospheric carbon, likely due to the presence of coastal ecosystems such as mangroves.

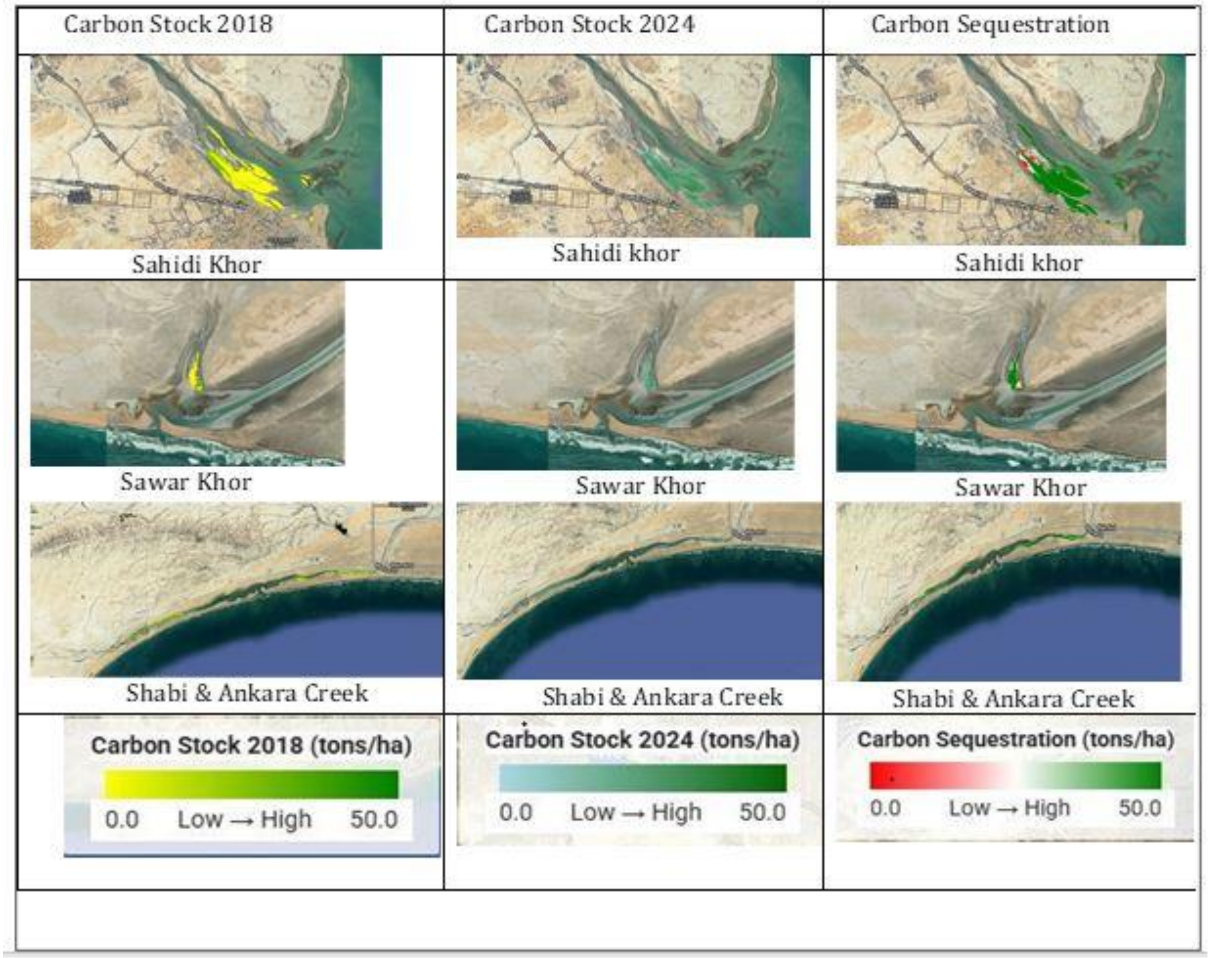


Figure 32 Carbon Estimation at Other Sites

Figure 32 presents a detailed comparison of carbon stock in 2018 and 2024 along with carbon sequestration potential across three specific coastal sites: Sahidi Khor, Sawar Khor, and Shabi & Ankara Creek. In the Sahidi Khor carbon stock 2018 area shows moderate carbon stock values, represented by yellow shades with patches of green. This suggests the presence of vegetation contributing to carbon storage, but not at its full potential. In 2024, there is a visible increase in green coverage compared to 2018, indicating significant growth in vegetation and improved carbon storage. The density of green suggests higher biomass accumulation. Carbon sequestration in the Sahidi Khor shows high carbon sequestration potential. The area appears to be highly productive in capturing and storing atmospheric carbon, likely due to mangrove restoration or natural regeneration.

Sarwar Khor shows limited carbon stock, with sparse yellow areas indicating low biomass density and reduced carbon storage capacity, but in 2024 reveals a noticeable improvement, with increased green zones suggesting enhancement in vegetation cover and carbon accumulation over time. The green shading suggests a moderate to high sequestration potential in Sawar Khor. The increase in vegetation between 2018 and 2024 reflects a positive ecological trend supporting carbon capture.

Shabi and Ankara creeks show minimal carbon stock in 2018, with large areas devoid of color, indicating negligible or no vegetation cover. There is a marked transformation in vegetation cover, with extensive green zones suggesting a significant rise in carbon storage by 2024. The area is now considered a high level of carbon sequestration, shown in strong green shades and this indicates the successful establishment of vegetation or restoration activities, turning the site into a valuable carbon sink.

Table 10, and figure 33 and 34, summarize and present the carbon estimation for identified sites:

Table 10 Carbon Estimation for Identified Sites

S.No	Site Name	Site Area (Ha)	Forest Area (Ha)	Carbon Stock 2018 (Tonnes)	Carbon Stock 2024 (Tonnes)	Carbon Sequestration (2024 Cstock-2018Cstock)	Tonnes/Ha/Year	BGC = 0.42x CS	Soil Carbon = 1.46Tons/Ha	Total Carbon Sequestration/Ha/Year
1	Miani Horr	82503	5170.00	80183.60	114559.71	34376.11	6.65	2.79	1.46	10.90
2	Jiwani	8062	464.00	4675.71	6608.44	1932.73	4.17	1.75	1.46	7.37
3	Kalmat	55869	908.00	15020.85	21416.47	6395.62	7.04	2.96	1.46	11.46
4	Sawar Khor	200.5	1.50	9.82	33.00	23.18	15.45	6.49	1.46	23.40
5	Sahidi Khor	617	65.00	-378.55	1291.57	1670.12	25.69	10.79	1.46	37.95
6	Shabi/ Ankara Creeks	707	38.00	500.00	865.18	365.18	9.61	4.04	1.46	15.11
G.Total		**147958.5**	**6646.50**	**100011.43**	**144774.37**	**44762.94**				**106.19**

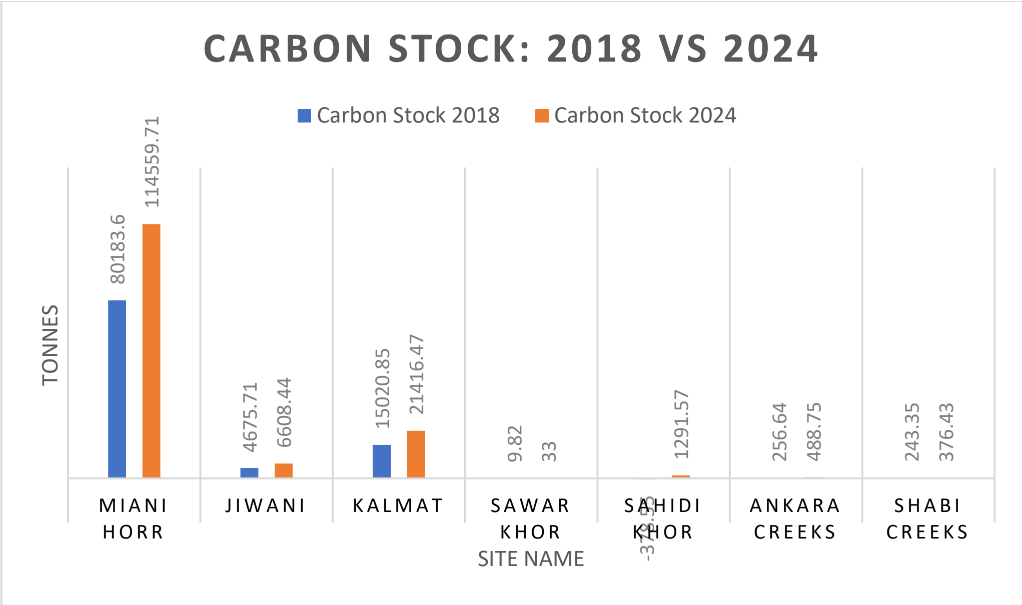


Figure 33 Carbon Stock Graph

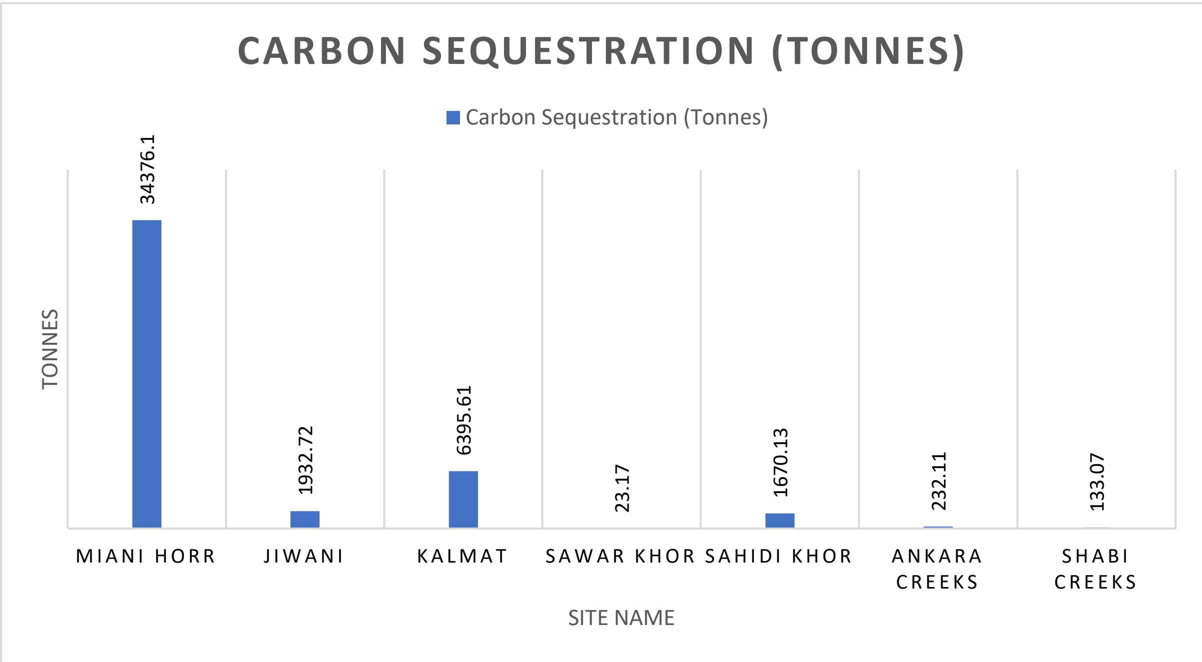


Figure 34 Carbon Sequestration Graph

The Way Forward

The presence of a large "Potential Blank Area" in Kalmat and Sonmiani indicates untapped restoration potential, which could significantly boost carbon sequestration afforestation or reforestation efforts are implemented. The analysis of six different forest sites using NDVI and AGB-based satellite imagery reveals a total annual carbon sequestration of approximately 106.19 tonnes/ha/year across a combined forest area of 6,646.50 hectares.

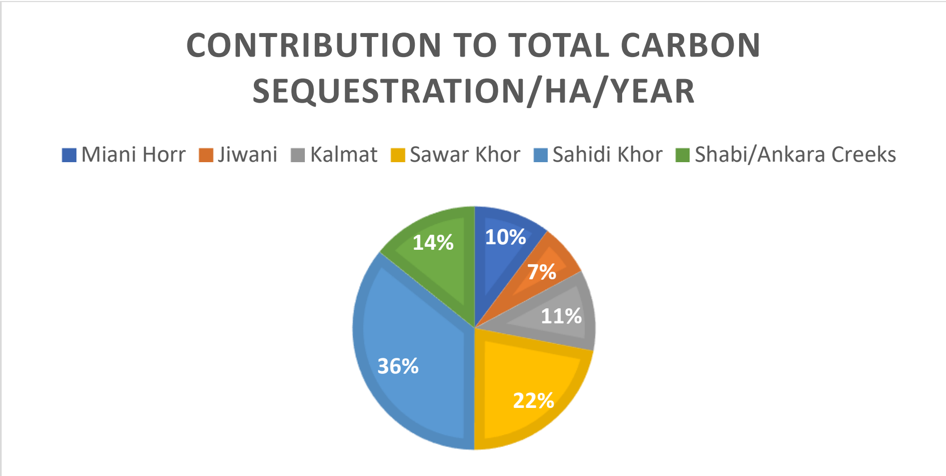


Figure 35 Total Carbon Sequestration Graph

Figure 35 presents the site vise contribution to total carbon sequestration per hectare per year, demonstrating the significance of Sahidi Khor, followed by Sawar Khor. The site with the highest carbon sequestration per hectare per year is Sawar Khor, with 23.40 t/ha/year, despite having a small forest area (1.5 ha), indicating its high biomass productivity and carbon density. Conversely, larger sites like Miani Hor and Kalmat, while contributing significantly to total carbon sequestration due to their size, have lower per-hectare rates (10.90 and 11.46 t/ha/year, respectively)

SECTION 4. POTENTIAL PROJECT DESIGN

This section builds upon the LULC of the identified project sites and identifies a potential project design to ensure efficient, inclusive, localized and data-driven efforts.

The proposed project design aims to deliver a data-driven, informed and localized project design for Balochistan province to develop in order to not only generate environmental resilience and regeneration, but to develop a robust carbon market project. The project duration will span 30 years, inclusive of a 20 year crediting period and a 10 year renewal buffer. The planting activities for a total area of **34,351 ha** will be done within 2 years in Phase 1 and Phase 2. Phase 1 (Year 1) will encompass plantation in Sonmiani spanning 19,747 ha. Phase 2 (Year 2) will include plantation across the other sites, Kalmat Khor, Jiwani Khor, Sahidi Khor, Sawar Khor, and Shabi and Ankara Creeks, spanning an area of 14,604 ha. The species that will be utilized are *Avicennia Marina, Ceriops tagal and Rhizophora mucronata*.

Proposed Project Design

Project Period

The project duration will span 30 years, inclusive of a 20 year crediting period and a 10 year renewal buffer. The planting activities for a total area of **34,351 ha** will be done within 2 years in Phase 1 and Phase 2. Phase 1 (Year 1) will encompass plantation in Sonmiani spanning 19,747 ha. Phase 2 (Year 2) will include plantation across the other sites, Kalmat Khor, Jiwani Khor, Sahidi Khor, Sawar Khor, and Shabi and Ankara Creeks, spanning an area of 14,604 ha.

Planting Phase(s)

A Mangrove Plantation Plan spanning 2 years is proposed. In this 1st year, 19,747 ha across Sonmiani Khor is to be utilized for plantation, due to its accessible terrain and ecological readiness as established in Sections 2 and 3. In this phase, proponents will focus on all operational and plantation related, nursery, and community mobilization efforts across a large and high-potential site. The key target will be to establish a centralized nursery and logistics hub in Sonmiani, accompanies by a full ecological zonation and develop a comprehensive micro-site planting strategy. This is to be followed by plantation across the other sites, notably, spanning 14,604 ha.

Phase(s)	Site(s)	Area (ha)	Priorities(s)
Phase 1	Sonmiani Khor	19,747 ha	o Prioritize operational, plantation and nursery, and community mobilization related efforts o Establish centralized nursery and logistics hub in Sonmiani o Based on activities such as ecological zonation and micro-site planting

			strategy development, identification of monitoring plots and baseline data collection, plantation will begin o Initiate MRV system in Sonmiani o Capacitate and train labor
Phase 2	Kalmat Khor, Jiwani Khor, Sahidi Khor, Sawar Khor, and Shabi and Ankara Creeks	14,604 ha	o Leverage trained workforce, centralized nursery, and planting equipment based on Sonmiani to begin Phase 2 o Develop mobile nurseries near sites, if required o Expand MRV system to other sites, preceded by Sonmiani o Tailor planting windows, species, and community engagement on lessons learned from Phase 1, if any o Consolidate MRV and carbon credit issuance process

Planting Time

The project will begin planting in the months of August or September, leveraging the optimal moisture and reduced salinity stress due to monsoon season. From February to April, a secondary window for maintenance and replanting is expected. The tidal schedule will also be monitored, with planting occurring during low tide season when the ground is exposed but moist. Propagules/saplings will be planted by hand about 5-10 cm deep into the ground to ensure optimal growth.

Planting Design and Species

The species identified for plantations are *Avicennia Marina, Ceriops tagal and Rhizophora mucronata*:

Species	Type	Plantation Site(s)	Qualities
Avicennia marina	Primary species	**All sites** (baseline species)	Highly salinity-tolerant, fast-growing, native to Balochistan
Ceriops tagal	Secondary species (salinity-adapted)	Supplementary in high salinity areas	Tolerant to 35–45 ppt; enhances biodiversity
Rhizophora mucronata	Only in specific low-energy tidal creeks	**Only in Sonmiani**	Sensitive to salinity >30 ppt and wave energy; high biomass; planted in calm, sheltered zones

The planting design for the identified species proposes the following spacing and density:

Species	Spacing and Density
Avicennia Marina and Ceriops	2m x 2m (2,500 plants/ha)
Rhizophora	2.5m x 2.5m (1,600 plants/ha) due to a larger canopy

Propagules/saplings will be planted by hand about 5-10 cm deep into the ground to ensure optimal growth. 2,000–2,500 saplings per hectare will be required, which amount to **~70–90 million saplings** (includes 15% buffer for replanting and mortality) for 34,000 ha. Planting area per year across 2 years is identified below:

Year	Area to Plant (ha)	Cumulative Total (ha)
Year 1	19,747	5,000
Year 2	14,604	11,000
Year 3	0	18,000
Year 4	0	25,000
Year 5	0	31,000
Year 6	0	**34,351**

Nursery Development Plan

To develop the nursery, collection of propagules from existing mangrove stands will be done in April to May. A centralized nursery is to be established in Sonmiani during Phase 1 and centralized nurseries will also be established near other planting sites in collaboration with local communities.

To develop the nurseries. Raised beds will be utilized and brackish water will be used for irrigation. Propagules are expected to grow be until ~30–50 cm in ~3–4 weeks. The stocking plan proposes ~2,000–2,500 saplings per hectare and distinct nursery plots will be maintained for the species: *Avicennia Marina, Ceriops tagal and Rhizophora mucronata*.

Expected Emission Sequestration

Across the project sites, Table 11 denotes the total carbon sequestration per year, denoting the potential of the identified sites to leverage this project:

Table 11 Carbon Sequestration Per Site

S.No	Site Name	Site Area (Ha)	Forest Area (Ha)	Carbon Stock 2018 (Tonnes)	Carbon Stock 2024 (Tonnes)	Carbon Sequestration (2024 Cstock-2018Cstock)	Tonnes/Ha/Year	BGC = 0.42x CS	Soil Carbon = 1.46Tons/Ha	Total Carbon Sequestration/Ha/Year
1	Miani Horr	82503	5170.00	80183.60	114559.71	34376.11	6.65	2.79	1.46	10.90
2	Jiwani	8062	464.00	4675.71	6608.44	1932.73	4.17	1.75	1.46	7.37
3	Kalmat	55869	908.00	15020.85	21416.47	6395.62	7.04	2.96	1.46	11.46
4	Sawar Khor	200.5	1.50	9.82	33.00	23.18	15.45	6.49	1.46	23.40
5	Sahidi Khor	617	65.00	-378.55	1291.57	1670.12	25.69	10.79	1.46	37.95
6	Shabi/ Ankara Creeks	707	38.00	500.00	865.18	365.18	9.61	4.04	1.46	15.11
G.Total		**147958.5**	**6646.50**	**100011.43**	**144774.37**	**44762.94**				**106.19**

Building upon the identified project design plan, the project expects a cumulative estimated sequestration of **8,787,615 tCO2e**, attained through 02 plantation years and maintenance until 30 years as denoted in Table 12.

Table 12 Potential Emission Sequestration Over Project Duration

Year	Area to Plant (ha)	Cumulative Total (ha)	Area Maintained (ha)	Annual Estimated Sequestration (tCO2e)	Cumulative Estimated Sequestration (tCO2e)
	A	B	C	D	E
Year 1	19,747	5,000	0		-
Year 2	14,604	11,000	5,000	48,050	48,050
Year 3	0	18,000	11,000	105,710	153,760
Year 4	0	25,000	18,000	172,980	326,740
Year 5	0	31,000	25,000	240,250	566,990
Year 6	0	34,351	31,000	297,910	864,900
Year 7	0	34,351	34,000	330,113	1,195,013
Year 8	0	34,351	34,000	330,113	1,525,126

Year 9	0	34,351	34,000	330,113	1,855,239
Year 10	0	34,351	34,000	330,113	2,185,352
Year 11	0	34,351	34,000	330,113	2,515,466
Year 12	0	34,351	34,000	330,113	2,845,579
Year 13	0	34,351	34,000	330,113	3,175,692
Year 14	0	34,351	34,000	330,113	3,505,805
Year 15	0	34,351	34,000	330,113	3,835,918
Year 16	0	34,351	34,000	330,113	4,166,031
Year 17	0	34,351	34,000	330,113	4,496,144
Year 18	0	34,351	34,000	330,113	4,826,257
Year 19	0	34,351	34,000	330,113	5,156,370
Year 20	0	34,351	34,000	330,113	5,486,484
Year 21	0	34,351	34,000	330,113	5,816,597
Year 22	0	34,351	34,000	330,113	6,146,710
Year 23	0	34,351	34,000	330,113	6,476,823
Year 24	0	34,351	34,000	330,113	6,806,936
Year 25	0	34,351	34,000	330,113	7,137,049
Year 26	0	34,351	34,000	330,113	7,467,162
Year 27	0	34,351	34,000	330,113	7,797,275
Year 28	0	34,351	34,000	330,113	8,127,388
Year 29	0	34,351	34,000	330,113	8,457,502
Year 30	0	34,351	34,000	330,113	8,787,615
	34,351			**8,787,615**	

SECTION 5. POTENTIAL AND VULNERABILITIES OF MANGROVE SITES IN GWADAR AND LASBELA

This section discusses the vulnerabilities, drivers and causes of degradation across mangrove sites in the province of Balochistan. It also identifies the potential of mangroves to ensure and enhance environmental resilience.

Vulnerabilities of Mangrove Forest in Gwadar and Lasbela

Over the past 50 years, coastal mangrove ecosystems in Pakistan have been seriously degraded as a result of freshwater diversion for agriculture, industrial and urban water pollution, and over-fishing.[18] Anthropogenic factors, couples with natural factors, have increased the vulnerability of mangroves in Balochistan.

The problem is further exacerbated by impacts of climate change such as global warming, sea level rise, intense storms and salinity problem. Some of the natural causes of vulnerability for the mangrove forests of Gwadar and Lasbela are the active mud volcano that is placed on the radar evidenced by past tsunamis that affected the Southern Pakistan. [19] However, anthropogenic activities remain the major threat to the mangroves where cutting trees and forest clearing for the purpose of housing, urbanization, industrialization and agriculture contribute majorly to the loss of mangrove forests. Environmental degradation of mangroves is further accelerated by runoff of fertilizers and pesticides, discharge of industrial effluent and sewage in the coastal waters and oil spills. [20]

Due to the increasing pressure of human requirements and the lack of awareness of conserving ecosystem services, harvesting practices are prominently unsustainable leading to the depletion of these forests. The vulnerabilities of mangrove regions are now visible. The Kalmat Khor has been strained due to overfishing, mangrove deforestation and overall global warming impacting the livelihood of 95% of the population engaged in fishing and 1% in its sale.[21] The impact of exploitation of natural resources in the region can be seen below in Table 2 in the depleted or extinct species number per boat fishing trip.

Table 13 Depletion in Species[22]

Fish Specie	10 Years Back	Present Status
	Number per boat fishing trip	
Paplet	200	10
Mushka	300-400	40-50
Chota Mangra	200	20-30
Ghalo	200	Extinct

18 WWF: Pakistan Mangroves

19 Mangroves for the Future. (n.d.). *Pakistan National Strategy and Action Plan*. Retrieved from https://www.mangrovesforthefuture.org/assets/Repository/Documents/MFF-Pakistan-NSAP2.pdf

20 EnvPK. (n.d.). *Mangroves of Pakistan: Types, importance, and environmental degradation*. EnvPK. Retrieved February 7, 2025, from https://www.envpk.com/mangroves-of-pakistan-types-importance-and-environmental-degradation/

21 WWF-Pakistan. (2005). Technical paper: Knowledge, attitudes, and practices (KAP) survey in Kalmat Khor, Balochistan. WWF-Pakistan. https://www.wwf.org.pk/pdf/tp_kap_kalmat.pdf

22 WWF-Pakistan. (2005). Technical paper: Knowledge, attitudes, and practices (KAP) survey in Kalmat Khor, Balochistan. WWF-Pakistan. https://www.wwf.org.pk/pdf/tp_kap_kalmat.pdf

Kunn	500	100
Sonab	40-50	10
Kaka Torr	100-200	Extinct
Khir Soota	10-15	Extinct
Patin	200	50
Pagaas	6-7	Extinct
Gerk	20-30	Extinct

This significant depletion of species is caused by over-fishing practices by local fisherman along with foreign trawlers and fishermen from Karachi. The practices were also noted to be unsustainable, added by the problems created by harmful fishing gears.[23] Local fishermen rely on traditional equipment that is often outdated, and are left with limited number of catch which affects their livelihood negatively likely to cause extreme poverty. In Jiwani, the deforestation activities by domestic population in nearby human settlements is a major threat to forests.

Drivers and Agents of Land Degradation

The mangroves of Gwadar and Lasbela districts of Balochistan are increasingly under threat due to both natural and anthropogenic factors (Figure 36). As climate change takes hold, sea level rise has led to increase saline water intrusion and coastal erosion, coupled with disastrous natural disasters. Anthropogenic activities have also worsened the situation as communities depend on grazing and exploitation of natural resources, in the forms of fuelwood extraction and overfishing, to sustain livelihoods. To assess the situation, this section divides the factors into macro (global and national factors) and micro (local factors) level categories.

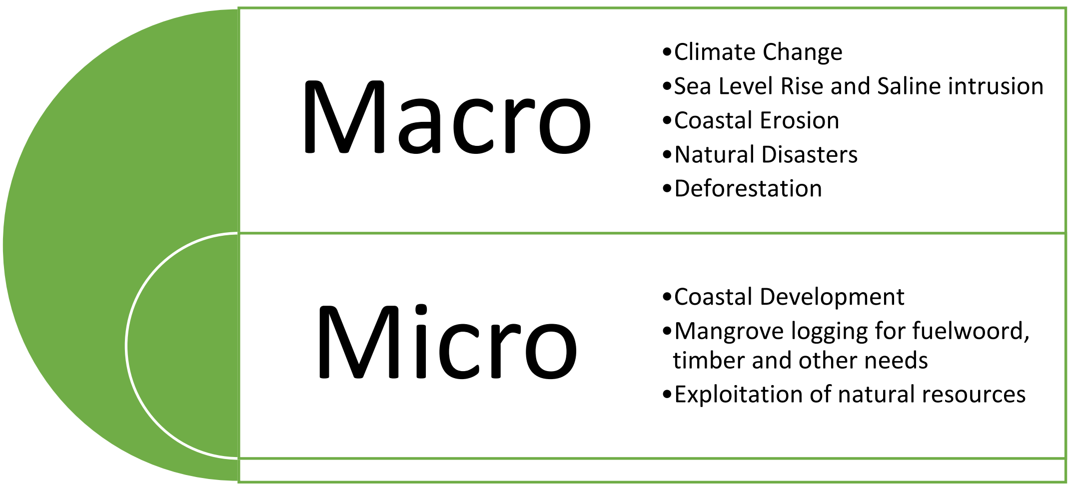


Figure 36 Macro and Micro Drivers

23 Yousuf, F., Shaheen, U., Iqbal, A., Sumbal, A., & Baloch, M. C. (2020). Destructive fishing practices being applied at the coastal areas of Lasbela Balochistan, Pakistan. *Pakistan's Multidisciplinary Journal for Arts & Science*, *1*(01), 55-69.

The table below identifies key causes of mangrove degradation in Balochistan, along with the associated underlying causes:

Macro and Micro Drivers			
Macro (National)	**Underlying Causes**	**Micro (Local)**	**Underlying Causes**
Climate Change	Lack of adaptive capacities and awareness	**Mangrove Logging**	Economic dependance, livelihood security, lack of employment, lack of education and awareness
Sea level Rise and Saline Intrusion	Climate change, lack of adaptive capacity	**Coastal Development**	Population growth, economic and industrial activities, lack of regulation and oversight
Pollution	Population growth, economic and industrial activities, lack of regulation and oversight	**Grazing**	Economic dependance, livelihood security, lack of employment, lack of education and awareness
Natural Disasters	Climate change, lack of adaptive capacity	**Resource Exploitation (over-fishing)**	Economic dependance, unsustainable and outdated fishing practices, illegal fishing and presence of trawlers, lack of employment, lack of education and awareness, lack of oversight

Macro-Level (National) Drivers

Macro level drivers of land degradation refer to broader and structural factors that may impact a certain location, it is the context within which a location exists. Macro-Level driver are as follows:

- Climate Change

Pakistan ranks as the 5th most vulnerable nation to climate change which has significantly impacted global temperature and weather patterns. Sea level rise induced by global warming has severely impacted the coastal areas of Balochistan province. [24] This has also led to sea intrusion and coastal erosion that impacts fragile ecosystems. A study by WWF concluded that while there are about 8 indigenous species of mangroves (*Bruguiera conjugata, Ceriops roxburghiana, Sonneratia caseolaris , Rhizophora apiculata, Rhizophora mucronata, Aegiceras corniculatum, Avicennia marina, and Ceriops tagal*) in Pakistan, the first 4 have gone extinct primarily due to climate change and anthropogenic activities.[25]

The impacts of climate change such as temperature rise, sea level rise, intense storms and salinity problem directly impact ecosystems, further leading to adverse impacts on dependent communities, consequently causing unproductivity for the community in the vicinity.

- Sea Level Rise and Saline Intrusion

Saltwater intrusion is the movement of saline water into freshwater aquifers, which can lead to contamination of drinking water sources and render fertile agricultural land unusable and barren. [26] It is one of the most significant drivers of degradation along the coast of Balochistan, not only engulfing acres of land but further damaging the balance of the ecosystem and depriving access to drinking water.

- Pollution

Environmental degradation across mangroves sites is further accelerated by runoff of fertilizers and pesticides, discharge of industrial effluent and sewage in the coastal waters and oil spills.[27] Additionally, pollution in the form of plastic waste, discarded fishing equipment, industrial waste, and other debris causes significant degradation.[28]

- Natural Disasters

Pakistan ranks 18th out of 191 countries according to the 2019 Inform Risk Index, denoting its increasing susceptibility and risk levels of disasters. Balochistan is also vulnerable to natural

24 Khan, M. R., Ahmad, S. R., & Ahmad, S. (2023). Climate Change Impact on Mangrove Forests in Pakistan. In Disaster Risk Reduction in Agriculture (pp. 277-291). Singapore: Springer Nature Singapore.

25 he Express Tribune. (2020, December 14). Study finds tremendous growth in mangroves. The Express Tribune. https://tribune.com.pk/story/2275495/study-finds-tremendous-growth-in-mangroves

26 Paksistan National Strategy and Action Plan, Mangroves for the Future

27 EnvPK. (n.d.). *Mangroves of Pakistan: Types, importance, and environmental degradation*. EnvPK. Retrieved February 7, 2025, from https://www.envpk.com/mangroves-of-pakistan-types-importance-and-environmental-degradation/

28 PDMA, Balochistan

hazards and disasters such as flooding, cyclones, tsunamis.[29] Some of the natural causes of vulnerability for the mangrove forests of Gwadar and Lasbela are the active mud volcano that is placed on the radar evidenced by past tsunamis that affected the Southern Pakistan.[30]

Micro-Level (Local) Drivers

Micro-Level Drivers refer to specific factors that exist locally and impact land degradation. Micro-Level drivers include:

- Mangrove Logging for Personal and Commercial Use[31]

Cutting down of mangroves for fuelwood and timber for personal use or commercial sale is a key cause of degradation. In Sonmiani Khor three species of mangroves [*Avicennia marina* (*Forssk.) Vierh, Ceriops tagal* (*Perr.) C.B Robinson and Rhizophora mucronata* Lam.] exist naturally, and are used for fuel, construction and fodder.[32] The Sonmiani Bay resides local communities that utilize the mangrove forest for fuel wood, building material and fodder and have the rights for deforestation.[33] Three major villages namely Dam, Sonmiani and Bhira along with a settlement called Baloch Goth rely on the coastal resources for survival and livelihood particularly fisheries and mangroves. Due to the increasing pressure of human requirements and the lack of awareness of conserving ecosystem services, harvesting practices are prominently unsustainable leading to the depletion of these forests. This is further aggravated as alternatives such as kerosene oil or natural gas are either unavailable or too expensive.[34]

- Coastal Development

Coastal development plans and strategies that may involve deforestation and/or reduction of forest cover severely threaten mangroves. A naval base has been proposed to be developed in the Kalmat Khor threatens the biodiversity of the area and raises sustainability concerns.[62]

- Grazing

Grazing for animals and livestock leads to deterioration of mangroves. Camel grazing along the Makran coast, specifically along the mangrove sites of Sonmiani Khor, Kalmat Khor, and Jiwani Khor, has led to damage to biodiversity, directly impacting local fishermen and endangering their sources of income.[35] This also leads to mudflat erosion or presence of sand.[36]

29 https://www.pdma.gob.pk/natural-hazards

30 Mangroves for the Future. (n.d.). *Pakistan National Strategy and Action Plan*. Retrieved from https://www.mangrovesforthefuture.org/assets/Repository/Documents/MFF-Pakistan-NSAP2.pdf

31 Mangrove conservation along the coast of Sonmiani, Balochistan

32 Mangrove conservation along the coast of Sonmiani, Balochistan

33 WWF Pakistan. (2015). *Template for Submission of Scientific Information to Describe Areas Meeting Scientific Criteria for Ecologically or Biologically Significant Marine Areas*. Retrieved from https://www.cbd.int/doc/meetings/mar/ebsaws-2015-02/other/ebsaws-2015-02-template-wwf-pakistan-05-en.pdf

34WWF: Pakistan Mangroves

35 Assessment and impacts of mangroves based camel grazing in coastal Balochistan

36 An assessment of status and disitribution of mangrove forests

- Resource exploitation

The coast of Balochistan hold ecological significance as they are abundant in marine life species, providing sources of livelihoods for 400,000 people in the province. In coastal areas, fisheries account for 70% of local employment.[37] However, over-fishing and unsustainable fishing practices lead to degradation, also impacting mangrove cover.[38] Data denotes the presence of deep-sea trawlers which significantly damage mangroves due to unsustainable and exploitative fishing practices involving instruments such as trawl nets, depleting fish resources and marginalizing local fishermen.[39]

Potential for Developing Environmental Resilience

Mangroves are one of the most productive ecosystems on earth which hold tremendous potential for climate change mitigation and adaptation. Serving as a crucial intersection of marine and terrestrial ecosystems, mangroves hold potential for ecological services such as carbon sequestration, providing habitat to biodiversity and protection from coastal natural disasters. Additionally, these forests also contribute to soil formation, regulate coastal water movements and encourage food chains through facilitating nutrient cycles. Air quality maintenance and biological control along with biodiversity conservation significantly influence the socio-economic factors in the communities living near mangroves heavily reliant on these natural resources.[40] The benefits of this ecosystem were previously disregarded as a hinderance to economic development. However, with awareness and knowledge, the importance of mangrove wetlands is being realized.

Being one of the most productive and unique ecosystems having a porous structure, mangroves facilitate the exchange of matter and energy between coastal and terrestrial environments. They are a great source of timber and firewood along with a safe and enriched habitat for fisheries. Also known for their tourism value, mangroves provide food, fodder and non-wood products as well. Ecologically, the mangrove trees are also considered as the habitat migration corridors and biodiversity hotspots. In a broader spectrum, these wetlands are active in improving the water quality, circulating nutrient cycles and grounds for scientific research. Restoring these forests should be of priority for the government owing to the environmental and socio-economic outcomes of thriving mangroves.

Mangroves provide mechanisms for phyto-and bioremediation mangroves can provide urban resilience and a nature-based solution for adaptation. Different species of mangroves are known to take up heavy metals such as copper, lead, nickel and chromium from polluted water. Phyto-stabilization is another technique that the mangroves are known for that limits the mobility of water pollutants to the roots and rhizosphere and prevents the leaching into

37 World Bank

38 WWF: Pakistan Mangroves

39 WWF Study on Knowledge, Attitudes and Practices of Fisherfolk and mangrove Communities

40 Ali, N., Bashir, S., Umm-i-Kalsoom, Begum, N., & Hussain, T. (2017). Study of variation in surface morphology, chemical composition, crystallinity and hardness of laser irradiated silver in dry and wet environments. Optics & Laser Technology, 91, 1–9. https://doi.org/10.1016/j.optlastec.2017.01.002

groundwater and adjacent areas. Phyto filtration and rhizofiltration are also some of the other mechanisms used by the mangroves to purify water.

In addition to these benefits, mangroves are also known to foster rich microbial diversity. An abundance of organic matter, fluctuating salinity and high redox potential values encourage the colonization of microbes in sediments, various parts of the mangrove trees and water columns. Not only are these microbes responsible for nutrient cycle balance but also take part in bioremediation in events such as oil spills.

Collaborative partnerships are essential in mangrove restoration along with innovative approaches such as rhizosphere engineering through modification of root soil interface.[41] By optimizing interaction in the active zone of the mangrove roots, can significantly improve the health of trees and enhance nutrient cycle leading to a resilient ecosystem. Other than that, this restoration activity can regulate salinity, enrich biodiversity, sequester carbon and stabilize coastal erosion.

Environmental resilience in urban settlements can also be achieved with the help of mangrove restoration. Serving as a buffer zone against coastal natural disasters and nurturing sustainable fisheries and other economic outcome likes honey, traditional medicines and timber, mangroves prevent flooding in urban areas. However, achieving a balance between development and restoration activities requires appreciation of the symbiotic value of the mangroves.[42] Building upon this potential, the following section identifies crucial mitigation strategies and interventions that can be harnessed for environmental resilience in the mangrove sites.

41 Anu, K., Sneha, V. K., Busheera, P., Muhammed, J., & Augustine, A. (2024). Mangroves in environmental engineering: Harnessing the multifunctional potential of Nature's coastal architects for sustainable ecosystem management. *Results in Engineering*, 101765.

42 Ali, N., Bashir, S., Umm-i-Kalsoom, Begum, N., & Hussain, T. (2017). *Study of variation in surface morphology, chemical composition, crystallinity and hardness of laser irradiated silver in dry and wet environments*. *Optics & Laser Technology, 91*, 1–9. https://doi.org/10.1016/j.optlastec.2017.01.002

SECTION 6. MITIGATION STRATEGIES AND INTERVENTIONS

This section identifies crucial interventions and strategies to inculcate sustainable mangrove management while ensuring secure and resilient livelihoods across the project sites.

Interventions and Projects for Mangrove Restoration and Conservation

In the Sonmiani Khor several efforts have been taken to conserve the ecology and biodiversity of the region. An initiative of WWF-Pakistan in collaboration with Karachi University-Department of Botany was started in 1995 and identified potential rehabilitation sites and gaps in conservation activities. Designated as one of the Ramsar sites in Pakistan, migratory bird populations are nestled here. The reproductive biology has been studied for Penaeus indicus in Pakistan in an effort to calculate and justify minimum permissible capture of this fishery. A need to establish a Marine Protected Area has been considered that would conduct study on marine animals and plants to further design conservation action.

The Kalmat Khor communities and the fishermen have taken steps to protect the threatened species in the region. Through the use of safe nets and indigenous fishing practices the fishermen have given up their short-term earnings that are harmful for the fish resources.[43] Continuous over-fishing is avoided and timetables are followed to allow the fish species to revive their population. Checks are kept on fishing from outside trawlers leading to several disputes with local community members. These people have also initiated efforts to conserve mangrove resources with the help of influential members. This strategy also involves keeping checks on outsiders to avoid over-exploitation of mangrove ecosystem services. [44]

As identified by the community members, problems such as lack of drinking water, health facilities, education, transport infrastructure, amenities, coupled with unemployment and decline in fish species are a challenge for the local people. A project by WWF worked on a village development plan which was based on community participation. However, notably, the activity could afford participation from male gender only owing to cultural constraints.

In Jiwani Khor, a WWF-Pakistan initiative has attempted to identify the cause of biodiversity loss in the area. The Mangrove Conservation Project and the Turtle Conservation project have been initiated with community participation as a result of this study. Some of the recommended actions are data collection for turtle biodiversity numbers and prevention of adult turtle exploitation and designation of the area as a protected site. Another suggestion is to establish a hatchery and nursery for green turtle at the junction of Sindh and Balochistan coast. Within the local community it has been proposed that basic facilities and proper infrastructure is provided to the people so that they don't exploit natural

43 WWF-Pakistan. (2005). Technical paper: Knowledge, attitudes, and practices (KAP) survey in Kalmat Khor, Balochistan. WWF-Pakistan. https://www.wwf.org.pk/pdf/tp_kap_kalmat.pdf

44 Baloch, S. M. (2017, April 20). Net loss: How illegal trawling is hurting fishermen and marine life. *The Express Tribune*. Retrieved from https://herald.dawn.com/news/1153726

resources. Furthermore, sustainable utilization of resources must be conveyed to the dwellers for long term conservation of the mangroves and their biodiversity.[45]

Region Specific Mitigation Strategies and Interventions

Building upon the drivers of deforestation and degradation, and assessing a few past interventions in the mangrove sites, this document identifies specific mitigation strategies and interventions that aim to not only promote regeneration and conservation of mangroves and its fragile ecosystem, but also work towards resilient livelihoods through alternative revenue generation, improved awareness and capacities, community led forest management, and sustainable interventions. The methodology to identify potential interventions is as follows:

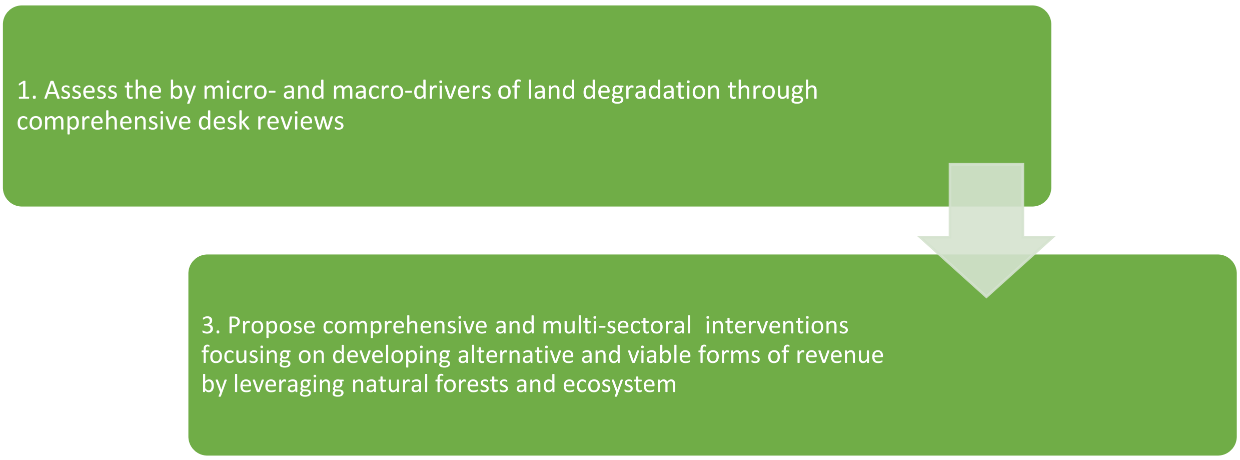


Figure 37 Approach for Identification of Site Level interventions

45 Ramsar Sites Information Service. (n.d.). Ramsar Information Sheet: Indus Delta, Pakistan (Site No. 1066). Ramsar Convention Secretariat. Retrieved February 7, 2025, from https://rsis.ramsar.org/RISapp/files/RISrep/PK1066RIS.pdf

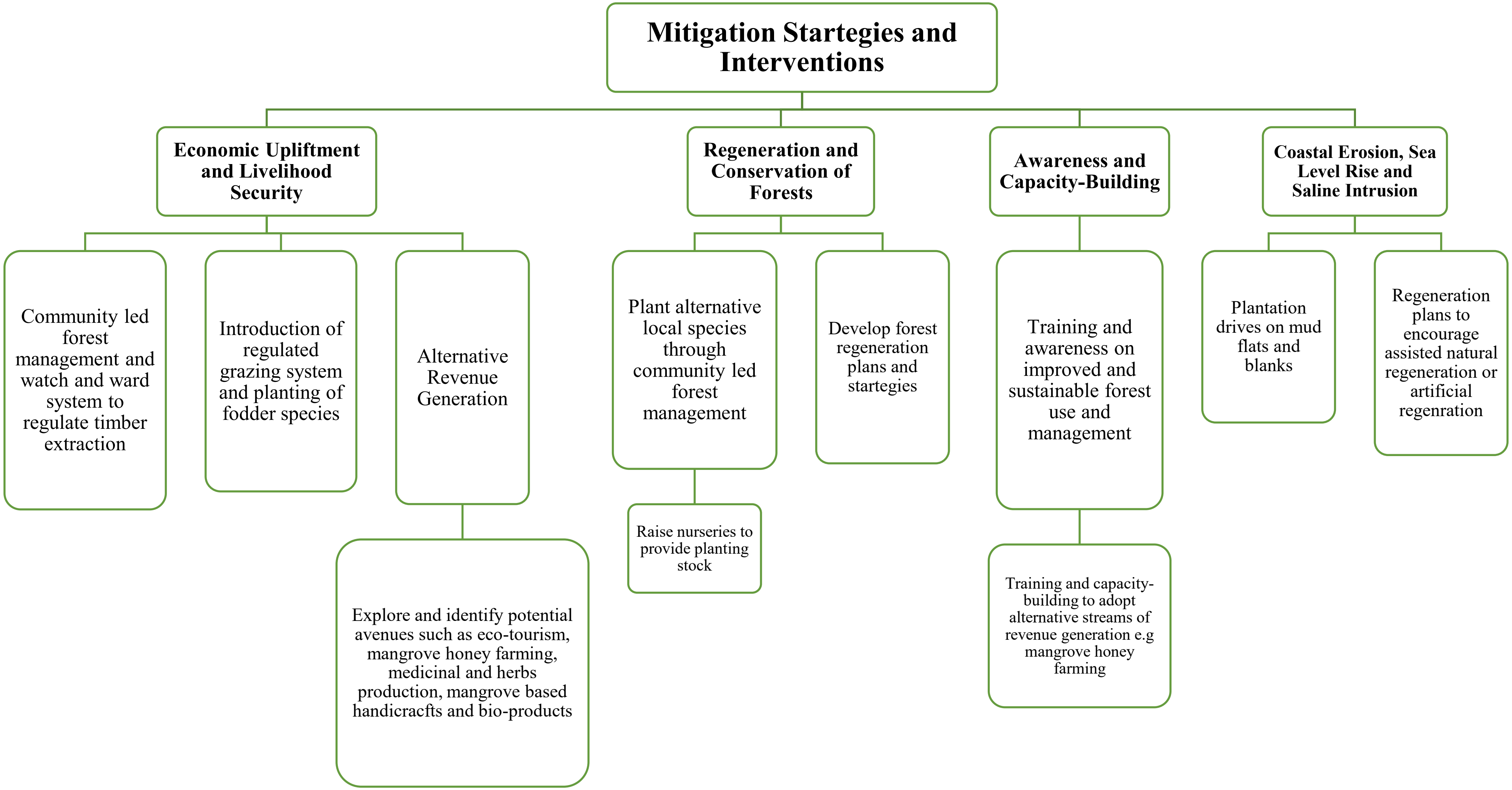


Figure 38 Mitigation Strategies and Interventions

1. Economic Upliftment and Livelihood Security

- Community Forest Management

Collaborative and inclusive forest management is critical as it fosters a sense of ownership and stewardship amongst locals, empowering them to sustainably manage forests and utilize them for their livelihoods. Exploitative extraction for timber, fuelwood and other uses, along with unregulated grazing leads to severe degradation, harming the ecosystem and increasing vulnerability of the coast. A community-based watch and ward system is essential to improve forest management through engagement with locals. It will also improve monitoring and oversight of implementation of regulations and policies pertaining to the mangrove sites.

- Regulated Grazing Plan

Livestock grazing is essential to securing livelihoods of the pastoral community members. However, one of the key factors of degradation is unregulated camel grazing. To tackle this, authorities can develop a structured and regulated grazing plan in consultation with communities, and promote planting efforts to ensure that plantation cover is regenerated.

- Alternative Revenue generations

At present, the primary sources of livelihoods for communities residing near mangrove sites is agriculture and fishing. While mangroves are utilized for this purpose, and also logged for illegal timber extraction and more, there is an absence of alternative strategies that diversify streams of revenue and ensure conservation and regeneration of mangroves.

There are a number of avenues that may be worth exploring and developing in this regard. A key intervention is honey-bee farming to sustainably manage forests while utilizing them for revenue generation. Bee farming allows cultivation of mangrove honey, using nectar of the trees. The intervention has been introduced in mangrove sites across the world to enable locals to earn a living.[46] Locals in the identified sites can also trained to develop honey farm as a mainstream avenue of revenue generation. Other avenues include eco-tourism, which will further enhance the value of Balochistan's coast and allow tourists to engage with mangroves without adversely impacting the ecosystem. This will also allow for the provision of livelihoods for locals.

The use of mangroves for traditional medicinal uses is also an avenue that can be developed. A dominant specie across the project site, Avicennia marina, is often utilized to treat health issues such as skin disease, rheumatism, smallpox, and more.[47] Furthermore, sustainable mangrove harvesting can also lead to the development of cottage industries for handicrafts

46 Honey Bee Farming in Vietnam

47 Avicennia marina medicinal application - Review

and furniture. Boatmaking is an existing craft in coastal areas, which can further be developed into an organized industry.[48]

2. Regeneration and Conservation of Mangroves

- Plantation of Local Alternative Species

Plantation of local mangrove species will ensure regeneration of mangrove sites and ensure sustainable management of mangroves. Community-led drives will ensure fostering of ownership, engaging locals in planting of mangroves across potential areas. To provide for planting stocks, nurseries should be planted and managed in collaboration with locals

- Regeneration Plans and Strategies

The development of a policy-level document identifying avenues for regeneration plans and strategies for mangroves in the sites across Balochistan will ensure coordinated efforts. Additionally, plantation across mud flats will lead to enhancement of mangrove cover, while ensuring resilience against coastal erosion, saline water intrusion and natural disasters.

3. Awareness and Capacity-Building

Awareness and capacity-building on sustainable use and management of forests is crucial to drive regeneration and conservation interventions. This will empower locals, foster ownership, and improve the engagement of communities in relation to forests. With the Balochistan Forest Department as the lead in these efforts, communities can be mobilized as key partners.

- Training

Training and awareness interventions for locals are critical to develop and promote alternative forms of livelihoods. Support from authorities will ensure that identified interventions are adopted across the sites, and a market access is facilitated for local communities to engage with customers and provide a platform for critical products such as mangrove honey and handicrafts.

48 IUCN Balochistan Conservation Strategy

SECTION 7.
CHALLENGES FOR FOREST PROJECTS

This section discusses the challenges that may arise when developing and implementing forest sector projects in Balochistan province.

Large scale mangrove forest plantation is known to have its challenges; however, the identification and realization of challenges is crucial in order to develop a path forward. Capacity building for communities and institutions along with mechanisms to utilize potential opportunities is also required. For example, fishermen that may be aware of the importance of mangrove and biodiversity conservation, are not equipped with the knowledge and ethical practices to reduce mortality rate for the turtles caused by incidental entanglement in fishing nets. Land type issues may also arise due to degradation, infrastructure development, and more. While this project presents a critical intervention, there are certain challenges which may impact afforestation and reforestation projects in the province. Based on the assessed data the following challenges exist:

Category	**Challenge**	**Drivers and Underlying Cause**				**Severity (High, Medium, Low)**
		Socio-Economic	Environmental	Technical and Financial	Political	
Land-Use	Deforestation and degradation	Population growth	Climate change, sea level rise, coastal erosion, pollution, saline water intrusion	Lack of awareness pertaining to sustainable management of natural resources	Frequent changes in governance and a lack of oversight	Low
	Coastal development		-			Low
Livelihood	Aquaculture expansion	Critical source of livelihood for coastal communities	-	Lack of awareness about sustainable fishing	Balochistan Sea Fisheries (Amendment) Act, 1986 bans trawling, yet a lack of oversight	Medium

				practices and exploitation of resources	has led to illegal trawling	
	Fuelwood, fodder, cattle grazing, timber theft	Lack of alternative livelihoods and avenues for revenue generation	-	Lack of awareness and poverty	Lack of oversight	Medium
Capacity and Awareness[49][50]	Lack of awareness	Low education and socio-economic levels,	-	Lack of fiscal resources, inflation and poverty	While ambition exists and the government of the province has participated in critical interventions, further action is needed.	Medium
	Lack of research		-			
	Lack of capacity and expertise		-			
Climate Change[51]	Frequent storms, rising sea levels and changing salinity patterns	Lack of awareness pertaining to adaptation and mitigation	Lack of adaptive capacity due to degradation	-	-	Medium

49 A.S. Rovai, R.R. Twilley, E. Castañeda-Moya, P. Riul, M. Cifuentes-Jara, M. Manrow-Villalobos, P.A. Horta, J.C. Simonassi, A.L. Fonseca, P.R. Pagliosa
Global controls on carbon storage in mangrove soils
Nat. Clim. Change, 8 (6) (2018 Jun), pp. 534-538, 10.1038/s41558-018-0162-5
50 Lovelock, C. E., Barbier, E., & Duarte, C. M. (2022). Tackling the mangrove restoration challenge. PLOS Biology, 20(10), e3001836. https://doi.org/10.1371/journal.pbio.3001836
51 Lovelock, C. E., Barbier, E., & Duarte, C. M. (2022). *Tackling the mangrove restoration challenge*. *PLOS Biology, 20*(10), e3001836. https://doi.org/10.1371/journal.pbio.3001836

SECTION 8. STAKEHOLDER IDENTIFICATION AND ENGAGEMENT PLAN

This section encapsulates a Stakeholder Identification and Engagement plan to ensure a data-driven, informed and collaborative approach to the project.

The proposed project aims to inculcate critical change across Balochistan's mangrove sites and leverage the potential of the global carbon market not only ensure environmental regeneration and resilience, but also socio-economic upliftment and revenue generation. To do so, the role of stakeholders is crucial. The objective of this Stakeholder Identification and Engagement Plan is to engage relevant actors and entities to undertake a data-driven, informed and collaborative approach, ensuring sustainable success.

Stakeholder Identification and Relevance

Stakeholders will be categorized into four primary groups: public sector, private sector, development sector, and independent subject experts. Each group will play a critical role in aligning the project with local needs, regulatory requirements, and global carbon offsetting standards. Effective engagement with these stakeholders will foster collaboration, enhance transparency, and help achieve the project's environmental and socio-economic objectives. The table below identifies the stakeholders that will play a key role in informing and guiding the proposed project:

Category	Description		Relevancy
Public Sector	**Provincial**	BPPPA	• Client of the project and a critical partner guiding project process
		Balochistan Environmental Protection Agency (BEPA)	• Regulates environmental impacts of forestry projects. • Ensures compliance with environmental laws and conducts environmental and social impact assessments (ESIAs).
		Forest and Wildlife Department	• Responsible for forest management, wildlife conservation, and afforestation initiatives in the province. • Overlooks the implementation of policies related to forestry and biodiversity preservation.
		Local Government Authorities	• Coordinates community engagement and capacity-building for forestry projects at the grassroots level.

			• Supports initiatives aimed at involving local communities in project planning and execution.
		Provincial NDC Focal Points	• Ensure alignment of forestry initiatives with Pakistan's climate commitments under the NDC. • Facilitate in provincial and federal Coordination
		Sindh Forest Department	• Would ensure aligning successful projects like the Delta Blue Carbon (DBC) thereby incorporating lessons learned as a reference project for the study.
		Social Welfare Department, Balochistan	• Facilitates community engagement, social inclusion, and welfare programs related to project impacts.
		Women Development Department, Balochistan	• Ensures gender-sensitive approaches in project planning, implementation, and capacity-building initiatives.
		Labor and Manpower Department	• Addresses employment opportunities, fair labor practices, and skills development for local communities involved in the project.
		School Education and CHTE Department	• Promotes awareness campaigns and capacity-building related to forestry and environmental conservation within communities.
	Sindh Province	Delta Blue Carbon Team	• The Delta Blue Carbon team has led the development and successful implementation of the DBC project in Sindh, Pakistan, and can provide valuable insights to guide this project and support proponents in ensuring best practices.

	National	Ministry of Climate Change & Environmental Coordination (MoCC&EC)	• Aligns the project with national climate policies, NDC commitments and funding programs
		Pakistan Environmental Protection Agency	• Ensures environmental compliance, conducts EIAs and monitors project impacts under national environmental laws.
		National Disaster Management Authority (NDMA)	• Integrates forestry into disaster risk reduction strategies and supports afforestation in climate-vulnerable areas.
Private Sector	Investors and business involved in promoting ESG, forestry, agriculture, or carbon trading, Renewable energy companies		Engagement with private sector stakeholders will primarily support the exploration of investment opportunities and contribute to the project's design phase.
Development Sector	International NGOs (e.g., WWF, IUCN), UNDP, World Bank, Local NGOs focusing on environmental conservation		Engagement with development sector stakeholders will contribute by providing technical assistance, securing funding, and ensuring alignment with global environmental standards and sustainable development goals.
Independent Subject Experts	Climate scientists, Environmental economists, Forestry experts, Carbon market consultants		Engagement with independent subject experts will help address data gaps, validate data, and provide expert advice on the project's design and feasibility.
Global practitioners and Investors	Engagement with international experts to support a contextualized project delivery mechanism. This may include project developers, implementers and if required and on the availability of resources, sponsors will be engaged		For a sound project planning and implementation, catering for all risks and mitigation plans. The project team, fostering their existing relationships with carbon market players across the globe, will continuously engage to identify the potential platforms where the project can be socialized. The team will also try to arrange bilateral of BPPPA with potential investors and credit buyers to facilitate the

		partnerships for implementation of a successful project. The resources required for this activity is not part of the budget and can be discussed later understanding the need and potential of the opportunity.

Stakeholder Engagement Plan

With the aim is to collaborate with stakeholders to lead an inclusive, data-driven and effective process to guide this project, the project team has developed a comprehensive stakeholder engagement plan. The plan will also define the modes of engagement with each stakeholder, ensuring that their input is effectively integrated into the project's development and execution. The stakeholders will be consulted throughout the project for various purposes ranging from data collection, to knowledge exchange, and validation.

Objectives

i. Ensure an inclusive and transparent approach across levels, incorporating the voices of government, local authorities, citizens and all relevant stakeholders
ii. Gather information and insights from all stakeholders to guide the project
iii. Inculcate a grounded and localized approach to data collection and engagement to guide the development of project deliverables
iv. Foster ownership, enhance ambition and mobilization across all stakeholders for the proposed project

The stakeholder engagement process with the above noted stakeholders will be conducted for various purposes such as consultations, validation workshops, stakeholder consultation meetings and closed group seminars as denoted below:

Engagement Type	Purpose
Stakeholder Meeting	Stakeholder meeting entails a discussion for purpose of information collection.
Focus Group Discussion (FGD)	FGDs include an in-depth discussion, particularly for communities, to engage and collect critical data
Engagement and Consultation	Engagement and consultation entail close coordination and alignment to ensure deliverables.
Validation Meeting	Validation to gather feedback and approval of collected information, processes and data

Stakeholder Engagement Monitoring Plan

<table>
<tr><th rowspan="2">Deliverable</th><th rowspan="2">Stakeholders</th><th rowspan="2">Type of Engagement</th><th colspan="2">Key Performance Indicators (KPIs)</th><th rowspan="2">Means of Verification</th></tr>
<tr><th>Description</th><th>Target</th></tr>
<tr><td rowspan="2">Deliverable 2: Technical Study Report</td><td>Balochistan Forest Department, Independent Experts, MoCC&EC, Delta Blue Carbon Project Team</td><td>Stakeholder meeting, Validation meeting</td><td rowspan="2">• Optimal and effective stakeholder engagement with community incorporation
• Development of a technical study incorporating baseline project feasibilities and a business plan
• Areas assessed for project implementation</td><td>03 stakeholder meetings</td><td rowspan="2">• Meeting minutes and attendance records
• Community Workshop Reports
• Approved and documented technical study
• GIS maps and assessment</td></tr>
<tr><td>Community</td><td>Focus Group Discussion</td><td>2 community FGDs</td></tr>
<tr><td>Deliverable 3: Carbon Pricing Feasibility</td><td>Independent Subject Experts, Delta Blue Carbon Project Team</td><td>Stakeholder meeting, validation meeting</td><td>• Adherence to international best practices in carbon markets
• Cost-benefit analysis and financial modeling completed
• Conducive market dynamics identified</td><td>1 stakeholder meeting</td><td>• Global projects documented as reference models
• Carbon Pricing Feasibility Report Documented
• Cost-benefit analysis documented
Benefit Sharing model documented</td></tr>
</table>

			• Crafting Pragmatic benefit-sharing model crafted		
Deliverable 4: Initial Environment Examination Report	BPPA, Balochistan Forest Department, Communities, civil society and research institutions	Stakeholder meetings, FGDs	• All possible project impacts identified • Mitigation strategies developed and validated	2 community FGDs	• Approved and documented project Initial Environment Examination Report • Community engagement records and feedback reports
Deliverable 5: Financial Modelling and Viability/ Government Support Assessment	Financial Experts, BPPA, MoCC&EC	Stakeholder meeting, validation meeting	• Financial viability and gaps identified • Financial model developed and validated	2 financial experts consulted	• Documented financial modelling and viability assessment report
Deliverable 6: Project Risks, Options and Economic Analysis	Independent Subject Experts, BPPA, Forest Department	Stakeholder meeting, validation meeting	• Comprehensive risk matrix developed, along with risk specific mitigation presented • Most Implementable Project Mode Selected • Detailed Economic analysis with cost-benefit metrics presented	2 Independent Subject Experts consulted	• Risk matrix approved and Documented • Record of stakeholder endorsement • Economic analysis is well documented • All the above housed in the documented Project Risks, Options and Economic Analysis report

Deliverable 7: Legal and Regulatory Assessment	Independent experts, BPPA	Stakeholder meeting, validation meeting			• Legal and Regulatory Assessment report documented
Deliverable 8: Bid Management	BPPA	Engagement and Consultation	• Number of Bids evaluated and awarded	Coordination and consultation with BPPPA	• Bid Management Report Documented
Deliverable 9: Transaction Negotiation and Financial Closure	BPPA	Engagement and Consultation	• Project Completion Agreements • Financial closure achieved		• Signed Project Agreements • Transaction Negotiation and Financial Closure report documented

SECTION 9. GLOBAL CARBON MARKET LANDSCAPE

This section provides an overview of the global carbon market landscape for the forest sector, identifying key standards and methodologies that guide and inform carbon market project development. This section also provides examples of blue carbon projects active around the world.

Carbon Markets and Forests

Carbon Markets have emerged as a crucial tool in the global fight against climate change. They provide a mechanism for reducing greenhouse gas emissions by allowing for the trading of carbon credits, which represent the right to emit a certain amount of carbon dioxide or other greenhouse gases. These markets have gained significant traction in recent years, with the global carbon market reaching a value of over $272[52] billion in 2020. Developing countries are looking to leverage the benefits of carbon market to improve climate resilience and sustainable development across key sectors, especially forest.

Carbon credits, especially those generated through nature-based interventions, protect, sustainably manage, and restore natural ecosystems. The overarching aim is to not only ensure the preservation of naturally existing carbon sinks and reservoirs, but to also ensure that this conservation is conducted in lieu of reaping a plethora of benefits from the environment we live in. Nature based Solutions have the ability to provide 37% of our mitigation efforts needed by 2030.[53] In 2022, about 30% of all carbon offset credits for forestry projects came from voluntary registries, including IFM, REDD+, and afforestation, among other types[54]. Additionally, carbon credits issued through nature-based interventions accounted for 37%-or 53 million credits- of all issuances in 2023.[55]

Forest based carbon credits involve 3 major categories: Afforestation, Reforestation and Revegetation (ARR), Improved Forest Management (IFM), Reducing Emissions from Deforestation and Forest Degradation (REDD+). These projects vary from protecting our forests to restoring them, all of which are key to achieving sustainable development and climate resilience. While Deliverable III: will provide an in-depth assessment of carbon markets, this section will provide a brief overview and introduction to critical components that guide and inform the development of forest sector carbon market projects.

Carbon Standards

Carbon standards are critical components in the development of carbon market projects, they are frameworks that ensure the quality, integrity, and measurability of carbon offset projects, ensuring high-quality emission reductions and removals. They are composed of rules and guidelines that projects follow to be considered legitimate and effective in their goal of

52 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/coal/012721-global-carbon-market-grows-20-to-272-billion-in-2020-refinitiv

53 https://www.sylvera.com/blog/nature-based-solutions-and-biodiversity

54 https://carboncredits.com/forest-carbon-offsets-everything-you-need-to-know/

55 https://www.agriinvestor.com/nature-based-solutions-dominate-h1-carbon-credits-issuance/#:~:text=Carbon%20credits%20issued%20through%20nature,across%20global%20voluntary%20carbon%20markets.

reducing or removing emissions. Standards verify and certify projects, ensuring generation of credits. As carbon market projects gain popularity, standards play an important role in ensuring transparency and effectiveness of projects across sectors. Significant organizations that develop and manage carbon certifications and standards include acclaimed entities such as Verra, Gold Standard Foundation, Plan Vivo Foundation, and the Global Carbon Council (GCC). Associated standards by each entity includes:

Verra Carbon Standards (VCS)

- Managed by Verra
- Purpose: Verification of carbon offset projects to ensure they aign with relevant requirements
- Project Types: Renewable energy, agriculture, forestry, land-use, waste, chemical industry, and more

Climate, Community, and Biodiversity Standards (CCB)

- Managed by Verra and issued as a complementary standard
- Ensures that a project provides social and biodiversity benefits and incorporates considerations

Sustainable Development Verified Impact Standards

- Managed by Verra and issues as a complementary standard
- Measures sustainable development impacts

Gold Standard

- Managed by Gold Standard Foundation
- Purpose: Focus on stronf sustainability and development benefits in carbon offset projects
- Project Types: Renewable energy, clean water, biomass or liquid biofuel, energy efficiency, forestry, waste and more

Plan Vivo

- Managed by Plan Vivo Foundation
- Purpose: Community0-ed forestry and land-use projects for climate mitigation and sustainable livelihoods
- Project Types; Agroforestry, land-use, agricultural land management, forestry, wetland restoration and conservation, REDD+

Global Carbon Council (GCC) Standard

- Managed by the Global Carbon Council (GCC) that is based in Qatar
- Project Types: renewable energy, energy efficiency, waste to energy and more

Methodologies

In carbon market project development, methodologies also play a crucial role in the development of projects. Developed by certification entities, methodologies are detailed procedures that projects mist follow to quantify greenhouse gas (GHG) benefits, ensuring emission reductions are real and additional, and are used to determine project boundaries, baselines and additionality.[56] Methodologies guide the development of projects by providing a scientific framework. Significant methodologies for blue carbon and mangrove-based projects, developed by the identified registration bodies, are noted as follows:

1. Verra

Methodology		Year	Project(s)
VM0033	Methodology for Tidal Wetland and Seagrass Restoration	2023	Delta Blue Carbon project in Sindh, Pakistan
VM0015	Methodology for Avoided Unplanned Deforestation	2023	HIwi REDD+ Project, Rio Madeira Grouped REDD+ Project
VM0007	Estimation of baseline carbon stock chnages and GHG emissions from unplanned deforestation and unplanned wetland degradation	Revised in 2024 to include tidal wetland restoration and conservation activities	Kubu Peatland Project, REDD Pantanal

2. Gold Standard

Methodology	Year	Project(s)
Methodology for Sustainable Mangrove Management	2024	Mangrove Afforestation in Indonesia,

3. Plan Vivo

Methodology		Year	Project(s)
-	Coastal Blue Carbon Methodology	2024	Concept note approved for this methodology

56 Verra Methodologies

4. Global Carbon Council (GCC)[57]

Methodology		Year	Project(s)
GCCMA001	Methodology for Forestry Project Activites on lands exceot Wetlands	2024	No projects registered as yet
GCCMA002	Methodology for Project Activities on Degraded Mangrove Habitats	2024	No projects registered as yet

Global Mangrove Carbon Projects

1. Delta Blue Carbon (DBC) Project

Location: Sindh, Pakistan
Registry: Verra
Methodology: VM0033

Throughout its 60-year lifespan, the project is expected to restore 350,000 hectares of mangroves, resulting in the removal of an estimated 142 million tonnes of CO2e emissions. The project also extends numerous benefits to the local communities, offering hundreds of jobs, enhancing livelihoods and well-being, facilitating access to clean drinking water, improving healthcare, and upgrading educational facilities to foster environmental awareness across the 60 forest-dependent villages in the project vicinity. These community-centric benefits are poised to uplift over 70% of the population who previously lived below the poverty line, subsisting on less than US $1.25 per day.

2. Hiwi REDD+ Project[58]

Location: Bujari, Acre, Brazil
Registry: Verra
Methodology: 0015

Registered in 2024, The Hiwi REDD+ Project is a 20,505-hectare area of tropical rainforest located close to the municipalities of Bujari, Rio Branco and Porto Acre, in the state of Acre, Northern Brazil. The state of Acre is facing a rise in deforestation due to cattle ranching activities, with an 8.3% increase of cattle heads from 2020 to 2021. The municipality of Rio Branco has the highest cattle herd in the State, with 14% of the total . Bujari also presented an increase of 15.5% from 2018 to 2020 , while Porto Acre the growth was of 23.5% in the same period. Deforestation in the municipalities from 2018 to 2020 had a boost of 198%, 89% and 154%, respectively. The project will promote forest conservation and, consequently,

57 Global Carbon Council Methodologies
58 HIWI REDD+ Project

reduce greenhouse gas emission that would occur due to deforestation. A consortium of 4 rural properties comprises the Hiwi REDD+ Project Area.

3. Blue Carbon project Gulf of Morrosquillo[59]

Location: Colombia
Registry: Verra
Methodology: VM0007

Registered in 2021, The Blue Carbon Project Gulf of Morrosquillo is a grouped project whose expansion region includes all the mangrove forests present in the Gulf of Morrosquillo, in the Colombian Caribbean. In this region are some of the most important mangrove and marine-coastal protected areas of the Caribbean coast: the mangroves of Cispatá Bay, La Balsa-Tinajones and adjacent sectors of the Sinu River estuarine delta; the mangrove ecosystems and lagoons of La Caimanera; and the Mangrove System of the Boca de Guacamayas Sector. The main objective of the project is the reduction of greenhouse gas emissions through activities that allow the identification, prioritization and execution of actions for the adequate management of mangroves, the promotion of sustainable development, the strengthening of local governance and the promotion of alternative productive activities, while contributing to the protection of high values of community conservation and biodiversity. The project has a duration of 30 years; during this period, the reduction of 1,221,717 tCO2e is expected through the implementation of activities related to four strategic lines: strengthening of governance, alternative productive projects, recovery and rehabilitation of mangrove areas, and monitoring. In addition, it is expected that this project will provide community benefits related to the strengthening of local governance and management of regionally protected marine-coastal areas, the maintenance of sustainable community management practices of mangrove forests and increased perception of the value of forest resources, as well as the economic empowerment of community groups and increased employment opportunities. Positive impacts on biodiversity include conserving the mangrove's ecosystems and biodiversity and maintaining the hydrobiological connectivity of the coastal-marine landscape. The manatee and needle caiman are two vulnerable species that are found in this area.

4. Reforestation and Restoration of Degraded Mangrove Lands, Sustainable Livelihood and Community Development in Myanmar[60]

Location: Ayeyarwady, Myanmar
Registry: Verra
Methodology: AM0014

Registered in 2017, The proposed project falls under the ARR (Afforestation, reforestation, and Revegetation) category of the Verified Carbon Standard (VCS). The project will be implemented on 2265.47 ha of degraded lands of the Northern part of Ayeyarwady Division of Myanmar. The lands that will be restored under the project belong to Magyi, Thabawkan

59 Blue Carbon Project Fulf of Morrosquillo
60 Reforestation and Restoration of Degraded Mangrove Lands in Myanmar

and Thaegone village tracts and this restoration will create a healthy mangrove ecosystem. The objective of the project is to establish and maintain a sustainably managed mangrove ecosystem for carbon sequestration, natural disaster risk reduction, poverty reduction with sustainable livelihoods in the coastal communities. A vital component of the project is the conservation of bio-diversity and establishment of the first mangrove gene bank in Myanmar. As per latest information, 2020 vintage credits are available for purchase at $39.

5. Vao Aina, Madagascar

Location: Madagascar

Registry: Plan Vivo

Methodology: PM001 Agriculture & Forestry Carbon Benefit Assessment Methodology

In the Fianarantsoa and Antsiranana provinces of Eastern Madagascar, smallholder farmers and fishing communities are working together to establish climate-resilient agroecosystems. Both regions have been subject to degradation, with the formerly forested areas in Fianarantsoa turning to grassy savannah (due to bush fires) and the mangroves forests of Antsiranana disappearing. The Voa Aina project works with local smallholder farmers and communities to restore these ecosystems, in turn supporting sustainable food production. A holistic, seedling-based ecosystem restoration approach has been adopted. Seedlings are planted to foster ecosystem restoration and mangrove rehabilitation and to create sustainable fisheries, resulting in a boost for biodiversity and local food security. The implemented project interventions aim to improve sustainable agricultural productivity, increase carbon sequestration and improve climate resilience.

CONCLUSION

The Balochistan Carbon Offset Project, focusing on environmental resilience through mangrove conservation and regeneration, envisions a Balochistan province that harnesses the potential of its vast and diverse natural resources, especially those stored within mangroves. This document is a crucial step in this direction as it encompasses a comprehensive and detailed Technical Feasibility Report. The report provides a detailed assessment of 06 proposed sites: Sonmiani Khor, Kalmat Khor, Sahidi Khor, Sawar Khor, Shabi and Ankara Creek and Jiwani Khor, analyzing LULC and carbon sequestration and finds that there is 34,351 ha of land available for potential regeneration and afforestation of mangroves across the areas, providing a viable foundation for this effort. The carbon sequestration analysis using NDVI and AGB-based satellite imagery reveals a total annual carbon sequestration of approximately 106.19 tonnes/ha/year across a combined forest area of 6,646.50 hectares. The site with the highest carbon sequestration per hectare per year is Sawar Khor, with 23.40 t/ha/year, despite having a small forest area (1.5 ha), indicating its high biomass productivity and carbon density. Conversely, larger sites like Miani Hor and Kalmat, while contributing significantly to total carbon sequestration due to their size, have lower per-hectare rates (10.90 and 11.46 t/ha/year, respectively).

As per this technical feasibility assessment, 34,351 ha is identified across the sites as potential project area to be afforested and regenerated. This critical information has provided the project with the path forward to designing and planning the proposed intervention through the identified project design. Furthermore, it draws upon a robust desk analysis of land use change drivers, potential interventions and mitigation strategies, past projects for mangrove restoration and conservation, potential challenges, specific mitigation strategies and interventions that present the potential for environmental resilience and socio-economic upliftment to assess and analyze the project sites.

The report also devises a stakeholder identification and relevance section to identify critical players and partners to ensure a data-driven and collaborative approach. An overview and introduction to carbon markets, its standards and methodologies is also provided to understand the global carbon market landscape within which this project will be strategically positioned. On the basis of this assessment and an analysis of the socio-economic situation of the region, baseline carbon assessment is conducted, and carbon sequestration potential of the project is calculated. The results have been discussed in detail to guide an informed decision making and investment opportunity.

Annexures

ANNEX I

SOP: Field Inventory of Forests (Above-Ground Biomass and CO_2 Calculations)

1. Objective

To conduct a systematic field inventory of Mangrove forests in Balochistan using cluster plot sampling to estimate above-ground biomass (AGB), below-ground biomass (BGB) and soil organic carbon SOC to calculate CO_2 sequestration potential.

2. Scope

This SOP covers the procedures for field data collection in mangroves, including plot establishment, measurements of tree variables and plot biomass and carbon estimation, focusing on above-ground biomass, below-ground biomass (using root shoot ratios),. The sampling method will be cluster plot sampling using a circular plot of 0.1 ha area.

3. Team Composition

- **Team Lead**: Oversees the entire inventory process, ensures data quality, and manages the team.
- **Deputy Team Lead**: Assists the team lead, focuses on mangrove tree height measurements, and ensures smooth operations.
- **GNSS Operator**: Records GPS coordinates of plot centers and waypoints.
- **Botanical Assistant**: Identifies tree species and measures tree diameters.
- **Field Sampler & data operator**: Collects data within the plot using Kobo Toolbox.
- 1 team will be deployed consisting of 5-7 persons

4. Equipment and Tools

- GPS device
- Diameter tape or caliper
- Hypsometer (for mangrove tree height measurement)
- Compass
- Measuring tape (More than 20-meter)
- Data recording sheets (Optional)
- Device with data entry software (Tab/mobile)
- First aid kit (bandages, antiseptic, aspirin, etc.)
- Personal protective equipment (PPE): gloves, boots, hats, and sunscreen
- Rope.
- Yellow spray paint.

5. Procedures

5.1. Plot Establishment

1. **Plot Selection**:
   - Sampling will be carried based on the primary analysis using visual interpretation of the systematic plots at 2.5 x 2.5 minutes intervals with in the study area using Openforis Collect Earth
   - Cluster plot sampling consisting of five plots will be identified for data collection in field. Each cluster will have one primary plot (center) and four secondary plot diagonally located from the primary sample plot and each at 200 m distance from each secondary sampler plot
   - Available accessible forest plots will further be located in the field using GPS for collection of trees variables

2. **GPS Coordinates**:
   - The GNSS operator will record the GPS coordinates of the plot center using a GPS device.
3. **Marking the Plot**:
   - Mark the center of the plot with a wooden stake.
   - Use a **17.84-meter** rope or a measuring tape to demarcate the plot boundary.
   - Sampled trees within the plot boundary will be marked with yellow spray paint.
4. **Soil Sampling:**
   - Soil samples will be selected from the Primary Sampling Unit (PSU) as well as Secondary Sample Units (SSUs).
   - A composite soil sample will be collected upto 100 cm depth (as per availability) in a polythene bag. The bag will be sealed and labeled.
   - Fresh weight of the soil sample will be recorded at the time of sample collection.
   - Collected samples will be transported to lab for further analysis.

5.2. Tree Measurements

1. **Tree Identification**:
   - The Botanical Assistant will identify and record the species of each tree within the plot using the species code list and name
2. **Diameter at Breast Height (DBH) (1.3 meters above ground)**:
   - Measure the DBH of all trees with a diameter greater than **5 cm**
   - Prefer a tree caliper for quick and accurate measurements.
3. **Tree Height**:
   - The Deputy Team Lead will measure the height of every tree within the plot using a hypsometer.
   - Record the height from the base of the tree to the top.
   - Height will be recorded for basal area separately.
   -

5.3. Field sampler

- The field sampler will record all the data within the plot using an offline tool (Kobo Collect) and paper-based tool.
-
- The recorded data will be maintained in the database for further quality checks and further reporting.
- Make sure all the data has been recorded successfully with minimal errors.

5.4. Biomass Estimation

1. **Above-Ground Biomass (AGB)**:
   - Use allometric equations to estimate AGB based on DBH and tree height.
2. **Below-Ground Biomass (BGB):**
   - As the destructive sampling is not allowed in the natural forests of Pakistan therefore a root shoot ratio from the existing forest inventories will be used for BGB estimations.

3. **CO2 Sequestration**:
   - Convert AGB to carbon stock using a conversion factor.
   - Calculate CO2 equivalent.
4. **SOC**:
   - Soil testing lab will provide the bulk density and SOC from the collected samples.

5.5. Data Recording

1. **Field Forms**:
   - Record all measurements in the field forms adopted from the National Forest Inventory Manual.
   - Ensure all data is legible and complete.
2. **Photographs**:
   - Take photographs of the plot in the four cardinal directions (North, East, South, West).
   - Label each photograph with the plot ID and direction.

5.6. Quality Control

1. **Internal Data Verification**:
   - The Team Lead will cross-check all measurements for accuracy.
   - Re-measure a subset of mangrove trees to ensure consistency.
2. **Data Entry**:
   - Enter data into a digital database (Kobo toolbox/excel sheets) for further analysis.
   - Perform range checks to identify outliers or errors.

3. **External Data Verification**:
    - The forestry team from Balochistan Forest Department will be invited to go random quality control checks on the field activities as per the National Standards.
    - Upon identification of any outliers/errors, re-measure will be conducted of that site.
    - If required after quality checks, the plots will be remeasured for calculating any missing parameters.

6. Health and Safety Aspects

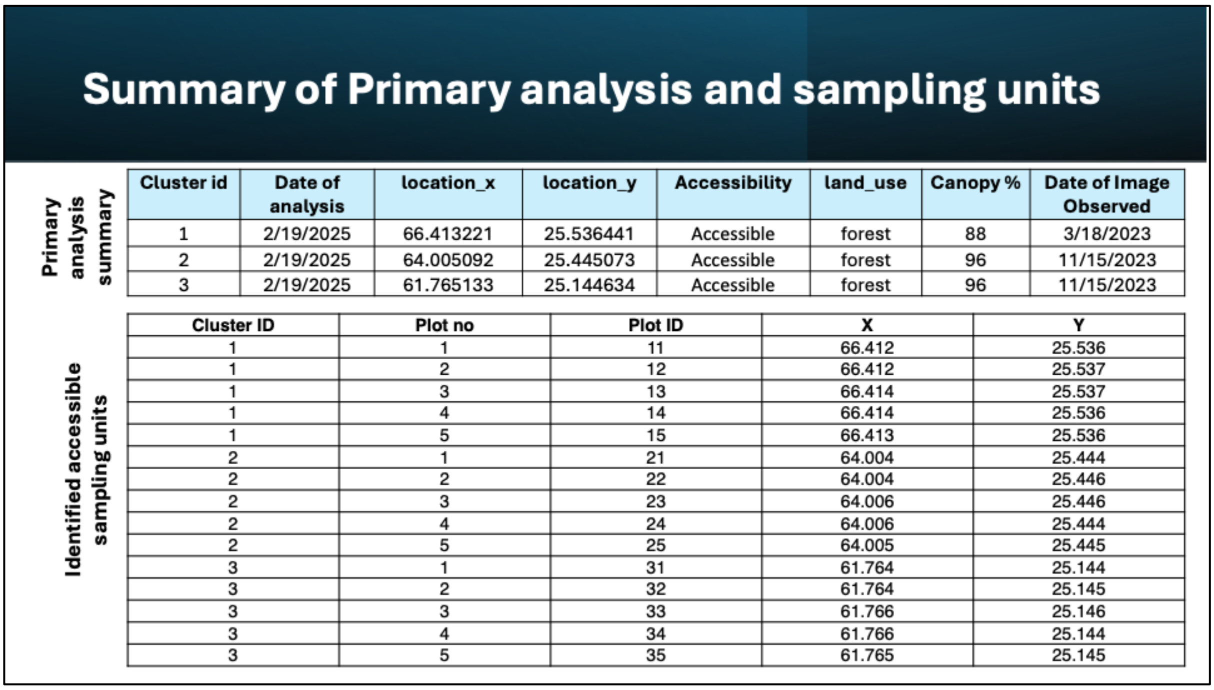
1. **Personal Protective Equipment (PPE)**:
    - Ensure all team members wear appropriate PPE, including gloves, boots, hats, and sunscreen.
    - Use insect repellent to protect against insect bites.
2. **First Aid Kit**:
    - Carry a well-stocked first aid kit at all times.
    - Ensure all team members are trained in basic first aid procedures.
3. **Hydration and Nutrition**:
    - Carry sufficient water and snacks to stay hydrated and energized during field work.
    - Use caps/hats to protect from high incident sunlight.
4. **Emergency Procedures**:
    - Establish an emergency communication plan in case of accidents or medical emergencies.
    - Ensure all team members have access to a mobile phone for communication.
5. **Wildlife Awareness**:
    - Be aware of potential wildlife hazards, such as snakes or insects, and take necessary precautions.
    - Avoid disturbing wildlife and maintain a safe distance.

ANNEX II

Selected sample plots with observed canopy cover changes

Sr. No.	location_x	location_y	Canopy2020 %	Canopy 2024 %
1	66.4438	25.59173	40	56
2	66.52713	25.5084	96	96
3	66.40213	25.5084	12	16
4	61.77713	25.1334	28	32
5	66.5525	25.52028	20	44
6	66.51806	25.44861	16	20
7	66.52389	25.44778	16	20
8	66.51972	25.46722	60	80
9	66.52556	25.45694	24	40
10	66.50472	25.46083	36	60
11	66.53261	25.46525	40	60
12	62.11163	25.21215	44	64
13	63.46021	25.28146	60	70

ANNEX III



Summary of Primary analysis and sampling units

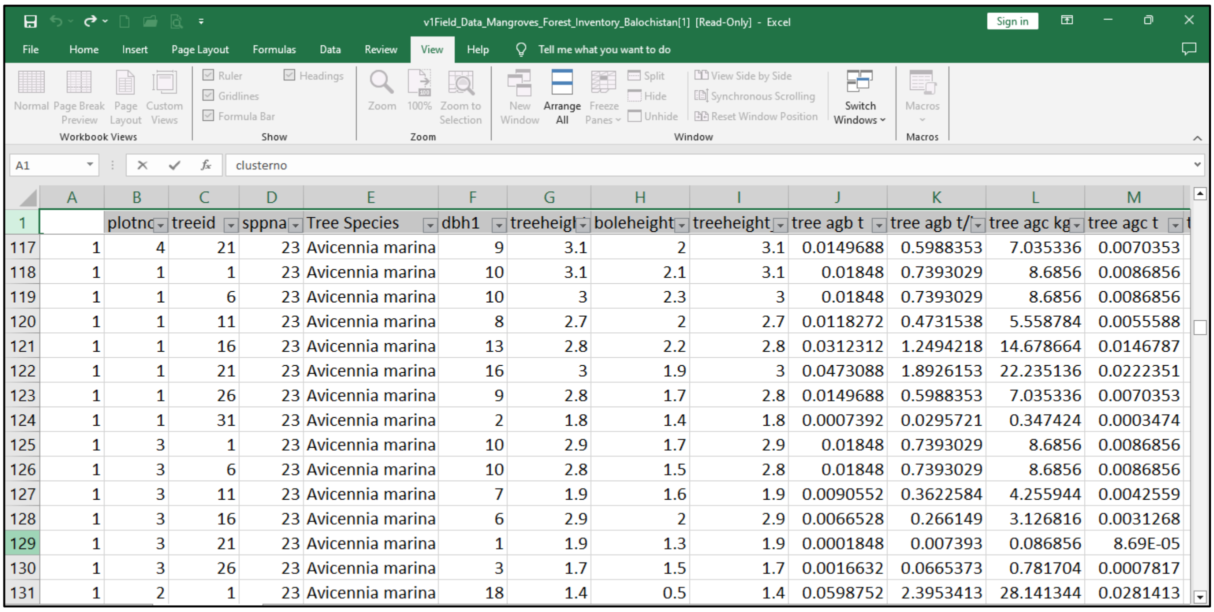
Primary analysis summary

Cluster id	Date of analysis	location_x	location_y	Accessibility	land_use	Canopy %	Date of Image Observed
1	2/19/2025	66.413221	25.536441	Accessible	forest	88	3/18/2023
2	2/19/2025	64.005092	25.445073	Accessible	forest	96	11/15/2023
3	2/19/2025	61.765133	25.144634	Accessible	forest	96	11/15/2023

Identified accessible sampling units

Cluster ID	Plot no	Plot ID	X	Y
1	1	11	66.412	25.536
1	2	12	66.412	25.537
1	3	13	66.414	25.537
1	4	14	66.414	25.536
1	5	15	66.413	25.536
2	1	21	64.004	25.444
2	2	22	64.004	25.446
2	3	23	64.006	25.446
2	4	24	64.006	25.444
2	5	25	64.005	25.445
3	1	31	61.764	25.144
3	2	32	61.764	25.145
3	3	33	61.766	25.146
3	4	34	61.766	25.144
3	5	35	61.765	25.145

Figure 3: Summary of the primary analysis and forest plots visited for field inventory



	A	plotnc	treeid	sppna	Tree Species	dbh1	treeheigl	boleheight	treeheight	tree agb t	tree agb t/	tree agc kg	tree agc t
117	1	4	21	23	Avicennia marina	9	3.1	2	3.1	0.0149688	0.5988353	7.035336	0.0070353
118	1	1	1	23	Avicennia marina	10	3.1	2.1	3.1	0.01848	0.7393029	8.6856	0.0086856
119	1	1	6	23	Avicennia marina	10	3	2.3	3	0.01848	0.7393029	8.6856	0.0086856
120	1	1	11	23	Avicennia marina	8	2.7	2	2.7	0.0118272	0.4731538	5.558784	0.0055588
121	1	1	16	23	Avicennia marina	13	2.8	2.2	2.8	0.0312312	1.2494218	14.678664	0.0146787
122	1	1	21	23	Avicennia marina	16	3	1.9	3	0.0473088	1.8926153	22.235136	0.0222351
123	1	1	26	23	Avicennia marina	9	2.8	1.7	2.8	0.0149688	0.5988353	7.035336	0.0070353
124	1	1	31	23	Avicennia marina	2	1.8	1.4	1.8	0.0007392	0.0295721	0.347424	0.0003474
125	1	3	1	23	Avicennia marina	10	2.9	1.7	2.9	0.01848	0.7393029	8.6856	0.0086856
126	1	3	6	23	Avicennia marina	10	2.8	1.5	2.8	0.01848	0.7393029	8.6856	0.0086856
127	1	3	11	23	Avicennia marina	7	1.9	1.6	1.9	0.0090552	0.3622584	4.255944	0.0042559
128	1	3	16	23	Avicennia marina	6	2.9	2	2.9	0.0066528	0.266149	3.126816	0.0031268
129	1	3	21	23	Avicennia marina	1	1.9	1.3	1.9	0.0001848	0.007393	0.086856	8.69E-05
130	1	3	26	23	Avicennia marina	3	1.7	1.5	1.7	0.0016632	0.0665373	0.781704	0.0007817
131	1	2	1	23	Avicennia marina	18	1.4	0.5	1.4	0.0598752	2.3953413	28.141344	0.0281413

Figure 4: Depiction of data collected and analysed