Climate Change Mitigation through Landscape Design of Blue Carbon Reservoir Ecosystems in
Pugad Baboy Mangrove Forest, Kawit, Cavite

Greenhouse gases are the most significant driver of climate change (IPCC, 2013). In 2021, the concentration of CO_2 reached 34.9gtCO_2 (WMO, 2021). At current emission levels, the carbon budget will exhaust in 10 years (IPCC, 2021). The current situation warrants for more emission cuts in even less time. Blue Carbon Ecosystems (BCE), which include mangroves and seagrass meadows, are beginning to be recognized for their ability to sequester and store large amounts of atmospheric carbon. This study aims to explore the application of landscape design for the restoration, conservation, and optimization of BCEs. Guided by the theories of Carbon Storage & Sequestration and Integrated Coastal Management, Pugad Baboy Mangrove Forest in Kawit, Cavite was developed as a BCE through designing for vegetation, soil, water, and people.

How can landscape design aid in the **conservation** of existing BCEs?

How can landscape design help with the **restoration** of degrading BCEs?

How can landscape design **optimize** the reservoir potential of BCEs?

MAIN PROBLEM

How can landscape design restore, conserve, and optimize blue carbon reservoir ecosystems for climate change mitigation?

GOALS OF THE STUDY

Apply a synthesis of climate-responsive landscape design strategies for a blue carbon reservoir ecosystem development

BLUE CARBON RESERVOIR ECOSYSTEM

- Carbon Storage & Sequestration
  - Plant diversity
  - Plant biomass
  - Bahl (2020); Lynn (2020)
- Integrated Coastal Management
  - Restoration Ecology (SER (2004))
  - Community-oriented design (IPOPCORM (2007))

LANDSCAPE DESIGN FOR BLUE CARBON RESERVOIR ECOSYSTEMS

Designing for

Vegetation | Soil | Water | People

DESIGN CONCEPT
BAKAUAN *(RHIZOPHORA SPP.)*

Tagalog for Mangroves, which are the primary ecosystems in this BCE and is a symbol of flexibility and stability.

DESIGN THEME
PERI-URBAN MIX

Located in peri-urban Cavite, the design theme exudes the quirky fusion of rural and urban, of soft country and edgy aesthetics. Materials used are locally-available and blend in with the rest of the suburb while also exhibiting some traces of the concrete city.

FORM COMPOSITION
POLYGONAL / ORGANIC MATRIX

As a result of flexibility and stability of the design concept + the soft and edgy design theme, forms are a combination of both organic and polygonal shapes. Organic forms are inspired by mangrove roots and the water tides, while polygons include modular triangles, rectangular grids, and hexagons.

SITE SELECTION CRITERIA

	Proximity to urban area
	Mangroves are historically present
	Area is along the coast (coastal wetland)
	Defined water source
	Brackish water
	Seagrass are historically present
	Fringe area for development
	Presence of local community
	Opportunity for restoration
	Emerging threats

Sources: Melana, et al (2000)

PUGAD BABOY MANGROVE FOREST, BRGY. WAKAS II & POBLACIÓN, KAWIT, CAVITE

Mangrove Forest: 13 ha
Former Fishpond: 10 ha
Fringe Area: 3 ha

SWOT ANALYSIS

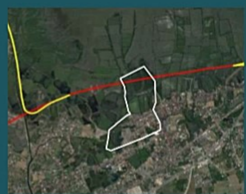
STRENGTH	• Proximity to urban area (1 hr drive) • Mangroves and seagrass are historically present in the area • Area is along the coast, a sign of high biodiversity • There is an adjacent fringe area for terrestrial development • Freshwater from Panamitan river flows into • Brackish water where mangrove and seagrass can thrive • Presence of local community
WEAKNESSES	• Site is divided by Kaligtasan St. (reclaimed land road) • Informal settlers along Panamitan River • Lack of prominent entrance and connect to the rest of Barangay Wakas II or Kawit
OPPORTUNITIES	• Formerly a fishpond, there is an opportunity for restoration • Recent re-discoveries of the Pugad Baboy Mangrove Forest as a tourist destination in 2021 (Lakwatserong Caviteno, JOM's Liwaliw, Lakwatserong Labandero)
THREATS	• Proposed reclamation projects nearby causing direct impact to the area • Proposed Cavitex Segment 5.1 will explicitly traverse the mangrove area

Functional Diagram

Circulation Diagram

RECLAMATION THREATS

Proposed Reclamation Projects
Source: Google Earth Street View (2021)



Cavitex Segment 5.1
Source: MPTC Cavitex

SITE DEVELOPMENT PLAN

LEGEND

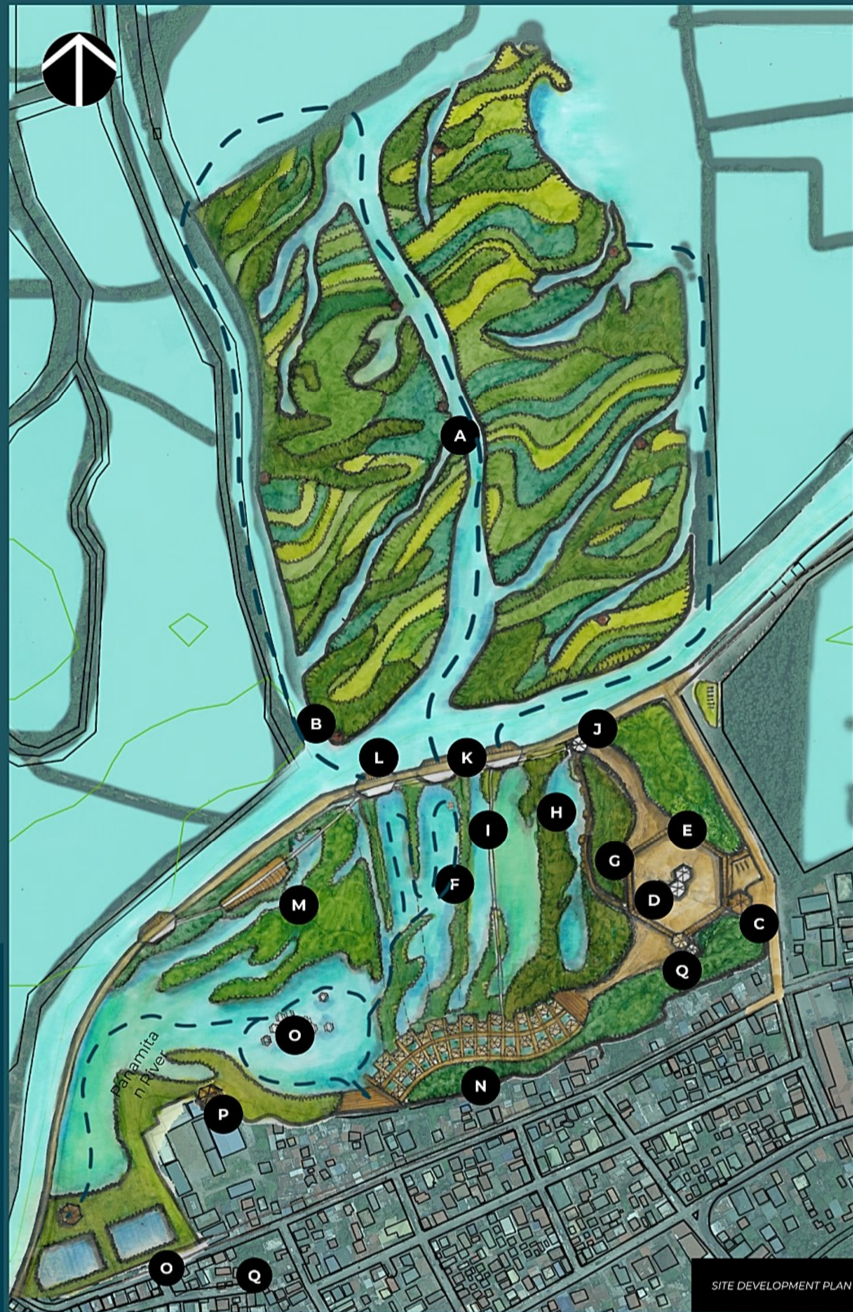
Pugad Baboy Mangroves Conservation Area
- A. Mangrove Forest
- B. Mangrove Outpost

Research Complex
- C. Main Entrance & Visitor Center
- D. Research facilities
- E. Mangrove & seagrass nurseries
- F. Mangrove & seagrass plantation

Wetland Recreation
- G. Boardwalk
- H. Wetland terraces
- I. Stilts bridge

Kaligtasan St. Viewing
- J. Viewing Tower
- K. View deck
- L. Boating dock
- M. Wildlife Sighting

Community Area
- N. Mangrove housing
- O. Aquasilviculture pens
- P. Outdoor classroom
- Q. Materials Recovery Facility



BLUE CARBON RESERVOIR ECOSYSTEM

Carbon Storage & Sequestration | Integrated Coastal Management

Plant diversity | Plant biomass | Restoration Ecology | Community-oriented design

Bohl (2020); Lynn (2020) | SER (2004) | IPOPCORM (2007)

LANDSCAPE DESIGN FOR BLUE CARBON RESERVOIR ECOSYSTEMS

Designing for

Vegetation | Soil | Water | People

DATA — DEDUCTIVE STRATEGY → ANALYZE

DESIGN ← INDUCTIVE STRATEGY — ANALYZE

GOALS OF THE STUDY

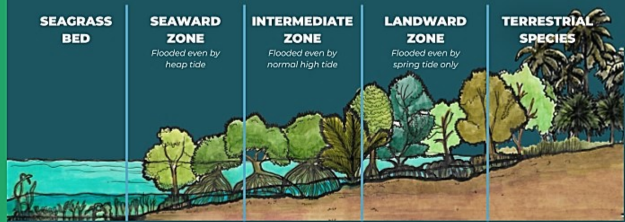
Apply a synthesis of climate-responsive landscape design strategies for a blue carbon reservoir ecosystem development

Vegetation

- Identify existing species
- Individual species studies

- Plant Grouping
- Plant systems

Zonation of identified species



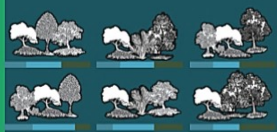
Identified Mangrove species according to zonation

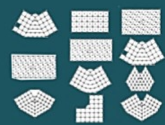
PREFERRED ZONE		TRUE MANGROVES SPECIES	ACCOMPANYING SPECIES
Seaward		*Sonneratia alba* (Pagatpat)	*Avicennia spp., Rhizophora spp.*
Seaward		*Rhizophora stylosa* (Bakauan Bato)	*Avicennia spp., S. alba, Rhizophora spp.*
Seaward	Intermediate	*Rhizophora mucronata* (Bakauan Babae)	*A. marina, S. alba, Rhizophora spp.*
Intermediate		*Rhizophora apiculata* (Bakauan Lalaki)	*A. marina, S. alba, Rhizophora spp.*
Intermediate		*Nypa fruticans* (Kulasi)	*Various species; at river fringes*
Intermediate		*Ceriops tagal* (Tangal)	*Avicennia spp., R. apiculata, S. alba*
Landward		*Excoecaria agallocha* (Buta-buta)	*Avicennia spp., N. fruticans, Rhizophora spp.*
Landward		*Lumnitzera racemosa* (Kulasi)	*Avicennia spp., C. decandra, S. hydrophyllacea, Rhizophora spp.*
Landward		*Avicennia alba* (Miyapi/Api-api)	*Avicennia spp.*

Sources: Primavera, et al. (2004); Mandal & Bar (2019)

TOLERANCE TO SALINITY	PREFERRED ZONE	SEAGRASS SPECIES
Most Tolerant	Seaward	*Enhalus acoroides* (Tape Seagrass)
↓	↓	*Halophila ovalis* (Dugong grass)
		Halodule uninervis (Needle seagrass)
		Thalassia hemprichii (Pacific turtle grass)
Least Tolerant	Landward	*Cymodocea rotundata* Ribbon seagrass)
		Syringodium isoetifolium (Noodle seagrass)

Sources: Seagrass Watch Philippines (2014)





Soil

- Identify root types
- Identify preferred substrate

- Soil and Planting plan
- Growth stabilizing structures
- Permeable, low-carbon surfaces

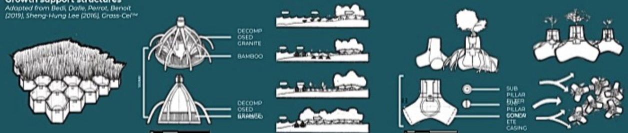
Deduce adaptive root abilities

Identified Mangrove species according to zonation

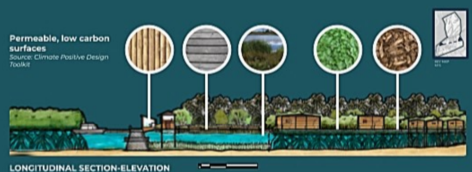
#	Mangrove Species	Preferred Soil Type	Root type	Adaptive root abilities
1	**Pagatpat *(Sonneratia alba)***	Sandy to muddy	Pneumatophore	Adaptive to anaerobic substrate
2	**Bakauan Bato *(Rhizophora stylosa)***	Coraline / sandy / rocky	Stilts	Withstand soil erosion
3	**Bakauan Lalaki *(Rhizophora apiculata)***	Sandy to muddy	Stilts	Withstand soil erosion
4	**Bakauan Babae *(Rhizophora mucronata)***	Silty clay	Stilts	Withstand soil erosion
5	**Nipa *(Nypa fruticans)***	Silt to clay / brackish	Rhizomes	Withstand soil erosion
6	**Tangal *(Ceriops tagal)***	Silt to clay	Buttress	Withstand soil erosion
7	**Buta-buta *(Excoecaria agallocha)***	Sandy to muddy, hard mud	Stilt	Soil binding ability
8	**Kulasi *(Lumnitzera racemosa)***	sandy, muddy	Buttress	Soil binding ability
9	**Miyapi / Api-api *(Avicennia alba)***	Coraline / sandy	Pneumatophore	Adaptive to anaerobic substrate

Sources: Primavera, et al. (2004); Mandal & Bar (2019)

Growth support structures
Adapted from Bedi, Dalle, Perrot, Benoit (2019), Sheng-Hung Lee (2016), Grass-Cel™



Permeable, low carbon surfaces
Source: Climate Positive Design Toolkit

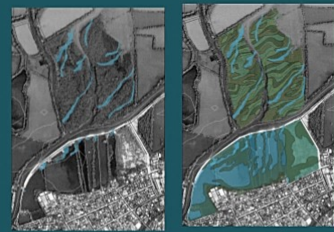


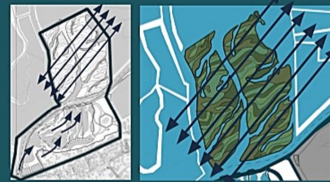
Water

- Gather historical site data
- Compare vegetation growth patterns

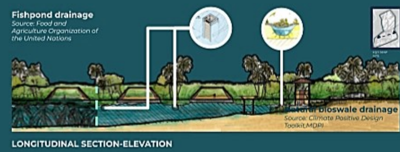
- Design around waterways
- Drainage plan

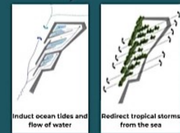
Map waterways and tide direction





Fishpond drainage
Source: Food and Agriculture Organization of the United Nations





Source: Turenscape (2019) for Sanya Mangrove Park, China

People

- Community demographics
- Quantify informal settlers along Kaligtasan St.
- Review literature on community perceptions of blue carbon development

- Mangrove housing
- Outdoor classroom, IEC signages
- Boating docks, Aquasilviculture pens
- Materials Recovery Facilities (MRF)

Locate relocation sites based on land-use

Assign spaces for community facilities

Barangay Poblacion

Classification	Rural
Population (2020)	820
As of 2015 Census:	
Households	248 (ave. 3.75 members)
Median Age	29.37 years
Youth Dependency Ratio	44.93
Estimated elevation above sea level	5.9 meters (19.4 feet)

Barangay Wakas II

Classification	Rural
Population (2020)	2,175 (2.02% of Kawit)
As of 2015 Census:	
Households	609 (ave. 4.17 members)
Median Age	25.87 years
Youth Dependency Ratio	40.37
Estimated elevation above sea level	4.0 meters (13.1 feet)

Visual Inspection: 30-40 households

Mangrove housing
Adapted from Hung Nguyen Architects (2017), Architects for Society (2016)

Research & MR facilities
Adapted from Architects for Society (2016)

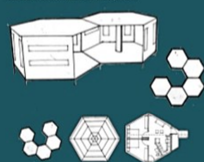


Photo courtesy of Smithsonian (top), Google Street View (left, right)

Modular Aquasilviculture pens