AquaForest:

A nature-based solution for dredged sediments

AquaForest is a demonstration project led by Jan De Nul showcasing a green-grey approach, where dredged sediments are being reused to create 50 hectares of mangrove habitat in the Guayas Delta, Ecuador. The project aimed to advance knowledge on the conceptual design and eco-engineering approaches of mangrove habitats, while strengthening local engagement and generating diversified income opportunities for local communities. A new mangrove island was built in the end of 2024 and is currently being monitored to quantify the provision of ecosystem services over time with the aim of future upscaling of this type of nature-based solutions.

El Morro Port: The perfect spot for drone flight demonstrations during the survey workshop with the local authorities, NGOs and local community leaders.

Designing and eco-engineering a mangrove forest on dredged sediments

Dredged sediments tend to be overlooked as disposable and unwanted material from port, channel and estuary maintenance, which may pose significant environmental and logistical challenges. Traditionally, they are disposed of at sea or stored in containment sites, where potential environmental impacts on marine and coastal ecosystems are considered as an inherent side effect. However, driven by the realisation that primary resources are finite and scarce, the value of dredged sediments is being nowadays reassessed with a number of promising examples.

In many cases, dredged sediments are reused on land, particularly along coastlines or for island creation. Such applications rely on a combination of physical, chemical and engineering techniques, such as rock protection and compaction. These methods aim to ensure material cohesion, limit erosion and guarantee long-term hydraulic stability.

To develop a sustainable and innovative alternative for the reuse of dredged sediments, we drew inspiration from nature's most effective coastal stabilisation systems: mangrove forests. These natural ecosystems offer a combination of key functions that traditional fixed and non-adaptive stabilisation structures often lack. These functions, or else, "mangrove ecosystem services" include coastal protection and erosion control, biodiversity support and habitat creation, water quality improvement, carbon sequestration, climate change mitigation and adaptation, and even socio-economic benefits.

Jan De Nul's 25-year concession for maintaining the access channel to the port of Guayaquil in Ecuador provided a suitable location within the Guayas Delta for implementing this concept. Subsequently, the idea of developing a new island with mangroves by elevating an existing sand flat, received financial support from the government of Flanders and the International Union for Conservation of Nature, also widely known as IUCN.

Local stakeholder engagement

Local stakeholders play a vital role in the success and sustainability of mangrove restoration and conservation projects. Their involvement ensures that projects are ecologically effective, socially acceptable and economically viable and sustainable during their lifetime. Therefore, the location for the pilot project implementation was selected also based on the opportunities for local stakeholder engagement. From the outset, local stakeholders were identified and assessed as part of the environmental and socio-economic assessment, paving the way for the development of a strategy plan for local engagement.

The potential locations for project implementation fell within a protected area under the authority of the Ministry of Environment of Ecuador. Within this protected area, the mangrove habitat is subject to a custody programme, whereby it is leased by the state to fishing associations for sustainable exploitation in exchange for mangrove habitat conservation actions. The Ministry of Environment appointed crab fishing associations from the village of Puerto El Morro to be involved in the pilot project.

We identified relevant authorities, crab fishing associations and NGOs as context setters, key players, and subjects, respectively, and involved them at different levels in the project, using various communication channels. To facilitate good relations with the local community, we appointed a community relations officer who organised information committees where the project was explained and community concerns were addressed. The relationship with the authorities was nourished by reporting on time, identifying key contact persons and keeping them informed and engaged about the project.

In total, we consider that the project implementation created 59 full-time jobs for 4 months. In addition, approximately 500 individuals, representing different age and gender groups in the local community, received training on topics related to mangrove restoration and around 1,000 individuals attended a project communication activity.

Feasibility phase

The feasibility phase lasted one year and resulted in a successful permitting process, including a positive environmental feasibility assessment and the receipt of the environmental permit and various approval letters. These letters were provided by key stakeholders in the project area, such as the Municipality of Guayaquil, the Ecuadorian Navy, Ministry of Environment and the National Chamber of Aquaculture. Notably, these approval letters were not statutory requirements, but rather a self-imposed measure to ensure project sustainability. The complete process required a time-consuming yet detailed approach. The primary causes of this long process were identified as changes in contact personnel within administrations, often triggered by departures or reforms following new elections and communication challenges between cooperating administrations. And, as is often the case with innovative and unique projects, we encountered the recurring challenge of navigating the regulatory framework, which can struggle to accommodate novel initiatives.

Nevertheless, this provided us with valuable know-how for the implementation of similar projects in the area.

During the project feasibility phase, we conducted field investigations to derive initial boundary conditions for the island design. A baseline study assessed the environmental and socio-economic aspects of the project. For example, the presence of the bottlenose dolphins in the project area necessitated extensive monitoring of its population during our operations.

We also visited similar mangrove areas in the Guayas Delta to identify key parameters for mangrove growth. In addition, various protection measures against erosion of the planned land mass (island), such as geotextiles and temporary semi-permeable bamboo structures, were tested to determine the most sustainable design. Furthermore, two experiments were planned and conducted with partner universities to validate mangrove nursing in dredged sediments in both laboratory and in situ conditions.

Based on the information gathered during the feasibility phase and co-creation between the project partners and local stakeholders, an in-house eco-engineering of the mangrove island has been performed leading to an innovative eco-design of the new habitat. Our target was to achieve the optimal conditions for mangrove habitat development, incorporating protection against wave action, ideal conditions for land elevation, a suitable sediment medium and a tailored afforestation plan. The hydraulic stability of the design was verified using hydrodynamic modelling and presented to the relevant authorities.

Construction and afforestation phases

In March 2024, we commenced mobilising the equipment for our construction operations and the first shiploads of dredged sediment were deposited in June 2024. The construction phase lasted 4 months, during which a 50 hectare intertidal zone (an existing tidal flat) in the Guayas River delta was raised by an average of 1 metre. Coarse sediment was selected to shape a sand dyke, measuring 1.5 kilometres in length, which protects the new land mass (island) from ship-induced waves along the side of the nearby access channel. The other side of the island is protected by a temporal semi-permeable structure, made from natural materials.

Following natural compaction and drainage of the reclaimed island area, a first mangrove planting campaign was organised. The afforestation plan includes three native mangrove species: Rhizophora mangle, Avicennia germinans, and Laguncularia racemosa. As part of both scientific research and practical implementation interest, we created different zones where we tested various planting densities and techniques, such as propagule release, propagule planting and sapling planting. In total 12,000 saplings and 21,500 propagules of mangrove were planted.

A local nursery provided the mangrove saplings, while crab fishing associations collected and sorted the mangrove propagules, and participated in the 5-day planting event.

Social impact actions

Socialisation of the project

In March 2024, a socialisation workshop was held in Puerto El Morro to share project information, address questions and foster community relationships. This was followed by a meeting to discuss the contracting of local labour for the construction activities.

In total 12,000 saplings and 21,500 propagules of mangrove were planted.

Fishermen from the partner associations building the locally designed, semi-permeable structure using natural materials.

6 months after the initial planting, the plant survival rate at AquaForest is 90%.

Women volunteers planting mangrove saplings at AquaForest.

Capacity building workshops

During the project preparation and construction, several stakeholders' events were organised:

- In July 2024, a topographic and bathymetric survey workshop was organised, where local authorities, NGOs and local community leaders could learn more about the surveying techniques used for the AquaForest follow-up.
- The same month, two other workshops were held in Puerto El Morro and Guayaquil to discuss climate change, its impacts and the challenges for mangrove ecosystems with local communities and authorities. During these workshops, testimonies were shared regarding the restoration and conservation of mangroves, highlighting the importance of local community involvement in environmental stewardship.
- In December 2024, a workshop with international participants presented sustainable aquaculture solutions to members of the National Chamber of Aquaculture of Ecuador, including mangrove integration strategies in aquaculture ponds.
- Local workers were trained for the construction of the semi-permeable structure, propagule collection and sorting, and mangrove planting on AquaForest.

Local communication and awareness-raising workshops

- In July 2024, activities to raise awareness of the benefits of mangrove ecosystems were organised at the Puerto El Morro college, further strengthening ties with the local community and enhancing social engagement efforts.
- In September 2024, a workshop for children on mangrove birds was organised with the local NGO "Aves y Conservación" to provide educational opportunities about local biodiversity and mangrove conservation efforts.
- In October 2024, a technical visit to the AquaForest mangrove island was arranged at the end of the afforestation works for stakeholders, including authorities and the presidents of the fishing association.

Mangrove clean-up

Floating debris and garbage is often trapped in the mangrove root systems, inadvertently turning them into a sight that incites pollution. Clean-up is crucial for maintaining the health and functionality of mangrove habitats. On AquaForest, 4 days of mangrove clean-up were organised in 2024. We foresee future clean-ups being undertaken at least twice a year.

Signature of commitment acts

In early 2025, more than 80 persons, including AquaForest partners, local associations, local NGOs and authorities, gathered for a socialisation of the project progress and the official signing of the commitment acts of the project. The objective of the acts is to promote collaborative work between the members of the AquaForest consortium, the protected area administration and the local community through the fishing associations of Puerto El Morro, for the protection of mangroves in general, and of the AquaForest island specifically. The acts aimed to align the AquaForest calendar with the institutional planning of the protected area and with the interests of the crab fishing associations.

Monitoring of the new mangrove habitat

Quantification of the provision of ecosystem services over time is validated with field monitoring of the new habitat. Monthly topographic drone surveys track land mass stability, while mangrove habitat development is assessed through in situ measurements, multispectral drone flights and LiDAR (Light Detection and Ranging) scans. Currently, the Coastal Engineering Research Group of Ghent University (Belgium) evaluates the wave-dampening effect of the semi-permeable wall within a Master-Thesis work.
In addition, the 'WETCOAST - Blue Cluster VLAIO' research project, coordinated by the University of Antwerp (Belgium), evaluates carbon sequestration in soil and plants. Monthly benthic inventories and bird observations led by ESPOL, the local university in Ecuador, assess biodiversity colonisation. The involvement of local communities in biodiversity monitoring at AquaForest is crucial to foster long-term habitat stewardship and provides a unique opportunity for capacity building and knowledge sharing.

Early results from our monthly drone monitoring campaigns indicate high survival rates and normal growth for the mangrove saplings and sediment compaction on the new mangrove island. Six months after the initial planting, the plant survival rate at AquaForest is 90%. Monthly biodiversity assessments by ESPOL will further refine the evaluation of ecosystem services, currently estimated to generate approximately 570,000 EUR annually upon the full maturation of the mangrove habitat. AquaForest's rich biodiversity will also be showcased in a biodiversity guide, developed in collaboration with local NGOs and fishing associations, to enhance ecological awareness and support the growth of potential eco-tourism initiatives around AquaForest.

Potential for upscaling

The initial results of the AquaForest demonstration project are highly encouraging and prove that innovative restoration initiatives have positive impact on local biodiversity and community resilience. We place great emphasis on local involvement, as we firmly believe that long-term sustainability is achieved when innovative projects are firmly embedded within the local context. Finally, AquaForest exemplifies a nature-based solution that can provide important ecosystem services such as: flood protection, biodiversity enhancement and climate adaptation and mitigation. With this project we hope to inspire authorities, researchers, project developers, consultants, contractors and stakeholders around the world to enable , support and implement similar projects.

Acknowledgements

The AquaForest project received financial support from the government of Flanders through the Flanders International Climate Action Programme, and from the International Union for Conservation of Nature (IUCN) through the Blue Natural Capital Financing Facility.

Jan De Nul coordinates AquaForest and the project consortium of eight partners (MANTIS CONSULTING, HAEDES BV, South Pole, Escuela Superior Politécnica del Litoral (ESPOL), Universiteit Antwerpen (UA); Vrije Universiteit Brussel (VUB), Fundación CALISUR).

Nothing better than a craft activity to help children discover the diversity of endemic mangrove birds in Ecuador.

Dr. Vicky Stratigaki
Lead Engineer
Project Development & Conceptual Design Department,
Jan De Nul Group, Belgium

Jelle Evenepoel
Manager
Marine Environmental Department,
Jan De Nul Group, Belgium

Dr. Noa Ligot
Engineer
Marine Environmental Department,
Jan De Nul Group, Belgium