CReW+

Lessons Learned

in the Design of Nature-Based Solutions for Wastewater Treatment in the Wider Caribbean Region

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Acronyms and abbreviations

IDB	Inter-American Development Bank
BMZ	*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* Federal Ministry for Cooperation and Development (Germany)
BWS	Belize Water Services
CRA	Drinking Water and Sanitation Regulatory Commission (Colombia) *Comisión de Regulación de Agua Potable y Saneamiento (Colombia)*
CReW	Caribbean Regional Fund for Wastewater Management
DEWATS	Descentralized Wastewater Treatment Systems
DOE	Department of the Environment (Belize)
FSTP	Faecal Sludge Treatment Plant
GEF	Global Environmental Facility
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit (Germany)*
INAPA	National Institute of Drinking Water and Sewerage (Dominican Republic) *Instituto Nacional de Agua Potable y Alcantarillado (República Dominicana)*
MIMARENA	Ministry of of Environment and Natural Resourcesof the Dominican Republic *Ministerio de Medio Ambiente y Recursos Naturales de República Dominicana*
MinAmbiente	Ministry of Environment and Sustainable Development (Colombia) *Ministerio de Ambiente y Desarrollo Sostenible (Colombia)*
MinVivienda	Ministry of Housing, City and Territory (Colombia) *Ministerio de Vivienda, Ciudad y Territorio (Colombia)*
NBS	Nature-Based Solutions
OAS	Organization of American States
PVC	Polyvinyl chloride
SDG	Sustainable Development Goals
UASB	Upflow Anaerobic Sludge Reactor
UASD	Autonomous University of Santo Domingo (Dominican Republic) *Universidad Autónoma de Santo Domingo (República Dominicana)*
UNEP	United Nations Environment Programme
WHO	World Health Organization

WWTP	Wastewater Treatment Plant(s)
UV	Ultraviolet

Context

High population growth and the impacts of climate change increase inequality in access to safe water and sanitation services in the Wider Caribbean Region. In addition, more than 60 % of wastewater discharged into the Caribbean Sea is untreated, posing a risk to both human and ecosystem health (De la Peña et al., 2022). The region generally lacks access to adequate sanitation. Where sanitation is available, it is of low quality and unequally distributed, as funding in the sector is insufficient (Pan America Health Organization, 2020). Therefore, Nature-based Solutions (NBS) were designed within the framework of the GEF CReW+ project to contribute to the mitigation of the effect of untreated wastewater discharge to ecosystems in the region. In this context, NBS designs are practices that integrate natural features or processes into engineered technologies to promote a sustainable management and restoration of ecosystems (Cross et al., 2021; United Nations Environment Programme, 2022).

The GEF CReW+ Project "An integrated Approach to Water and Wastewater Management using Innovative Solutions and Promoting Financing Mechanisms in the Wider Caribbean Region" is a partnership project funded by the Global Environment Facility (GEF) and co-implemented by the Inter-American Development Bank (IDB) and the United Nations Environment Programme (UNEP) in 18 countries of the Wider Caribbean Region. This innovative project builds on the successful previous phase called "The Caribbean Regional Fund for Wastewater Management (CReW)" (2011-2017).

The Global Environment Facility (GEF) has provided $22 million in grants and financial resources and mobilized nearly $120 billion to co-finance more than 5,200 projects and programmes. The GEF is the largest trust fund focused on enabling developing countries to invest in nature and it supports the implementation of international conventions on biodiversity, climate change, chemicals, and desertification. It unites 184 governments, as well as civil society, international organizations, the private sector, and other partners.

In Belize, Colombia, the Dominican Republic, and Suriname, the GEF CReW+ is being executed by the German Agency for International Cooperation GmbH (GIZ) on behalf of the IDB. This project was taken over by the GIZ through its global programme Sanitation for Millions, which was launched in 2016 by GIZ and the German Federal Ministry for Economic Cooperation and Development (BMZ) as lead donor. Sanitation for Millions is a multi-donor initiative to address water and sanitation issues and contribute effectively to achieving Sustainable Development Goals (SDGs) 6, 4 and 3. It is implemented in 14 countries on three continents.

The GEF CReW+ components include the creation of innovative, small-scale (local, rural, peri-urban and community) technological solutions for Integrated Water and Wastewater Management. This document shares lessons learned in the design of NBS to mitigate the health and ecosystem risk caused by the discharge of wastewater and sludge without adequate treatment in the Wider Caribbean Region, especially Belize, Colombia, Dominican Republic, and Suriname. In this way, it is intended to contribute to the implementation of NBS in wastewater treatment and thus improve access to safe and adequate sanitation in the region.

Case Study: Designing Nature-based Solutions for Wastewater Treatment

Centralised sanitation on Caye Caulker, a tourist island in Belize

Issue

Caye Caulker is an island located north of Belize City. It is the second largest cay. It is currently an area whose economy is based mainly on tourism and whose population grows rapidly – it has doubled in the last 10 years.

The island is divided into two regions, the Northern Region, and the Southern Region. Between those, there is an asymmetry of development. Tourism activity is concentrated in the division of the two regions.

The island has a high water table, much of it is at a depth of 0.15–1.80 m below ground level, and the terrain is essentially flat. In addition, there is no centralised wastewater system and household septic tanks are prevalent. Also, due to the high level of development in the Southern Region, space for the installation of a centralised wastewater system is limited.

Figure 1: Above-ground septic tank in Caye Caulker, South Region. Photo: ©GIZ/AKUT

Addressing the issue

GIZ in agreement with the Department of Environment (DOE) of Belize formulated activities for the execution of a feasibility study for a centralised sanitation solution on Caye Caulker. The feasibility study included a sanitation diagnosis of the intervention area, estimation of sanitation demand, characterisation of wastewater, evaluation of wastewater collection and treatment alternatives, and determination of risk mitigation measures for the implementation of the recommended centralised sanitation solution.

The feasibility study was awarded to an international private sector consulting firm and was developed with the participation of stakeholders such as DOE, the local water authority, Belize Water Services (BWS), and GIZ. Through follow-up sessions with stakeholders, findings were discussed, and feedback was provided to meet the needs of key stakeholders for the development of the project. The consulting team was supported by national consultants who managed close cooperation with the Belizean counterparts.

Geotechnical, topographical (water table, flat terrain, unstable soil), and financial aspects (investment and operation and maintenance costs) and the complexity of the system (availability of spare parts and suppliers and level of personnel training required) were considered in the choice of the type of sewer. This directly influences the operational sustainability. It was determined that condominial, vacuum and solids-free sewers are viable alternatives with respect to the topographic and geotechnical conditions prevailing in Caye Caulker. These have lower energy consumption, capital and operation and maintenance costs compared to conventional sewers, which require the use of a large number of pumping stations and exposure to very high infiltration rates. In particular, it was recommended to choose the vacuum sewer, whose estimated capital cost is 58 % of that of a condominium sewer, and which does not present the risks associated with user interaction found in the use of a solids-free sewer.

On the other hand, the evaluation of wastewater treatment technologies preferred those with a low construction footprint, wide operational flexibility to hydraulic and organic shocks, lower risk of vectors and odours, low cost (Investment, operation, and maintenance) and high system simplicity. As a result, a **French constructed wetland** was selected as the **most appropriate wastewater treatment option** for Caye Caulker, compared to activated sludge (sequential batch mode) and trickling filters. It requires an area of 2.2 hectares to be installed on the available land.

The French constructed wetland is less dependent on electromechanical devices, has high performance (80-90 % COD and TSS removal), can be integrated into the landscape, and has very low operating and maintenance costs. They are also very flexible in operation, which is necessary to ensure adequate treatment in tourist areas with high seasonal variations. Therefore, the French system is very suitable for wastewater treatment on Caye Caulker.

Optimisation of a lagoon system and a water reuse system in San Antero de Córdoba, Colombia

Issue

San Antero de Córdoba, Colombia, is a coastal area that can be used for agriculture purposes due to its climatic conditions. Because of its beaches and mangrove forests, it has become a tourist hotspot of the department of Córdoba. The San Antero wastewater treatment plant in the department of Córdoba is in poor condition. It has been in operation for more than 20 years and has been inadequately maintained. The treatment plant consists of a lagoon system consisting of two facultative lagoons and a maturation lagoon, where there is significant infiltration of wastewater into the soil, increasing the risk of groundwater and soil contamination. Besides, there is heavy weed growth that accelerates damage to the embankments. In addition, the lagoons are clogged with silt due to a lack of maintenance. Inadequate management of wastewater treatment has resulted in odour nuisance and consequent annoyance to local residents.

The wastewater from the treatment plant is discharged into the Caño Cardales, a man-made intermittent river that flows into the Caribbean Sea. This disposal of wastewater violates current regulations, and as a result, numerous sanctions have already been imposed. Thus, the current state of the sewage treatment system causes additional costs, inconvenience to local residents, environmental pollution, and also has a significant impact on the surrounding waters, such as the mangrove system.

Addressing the issue

To contribute to the improvement of wastewater treatment in San Antero de Córdoba, the design for the optimization of the respective WWTP and a pilot project for the reuse of its effluent was carried out. The design activities were formulated by GIZ in partnership with the Ministry of Environment and Sustainable Development (MinAmbiente), in collaboration with other stakeholders such as the Ministry of Housing, City and Territory (MinVivienda), and awarded to private sector providers.

In 2021, a feasibility study was developed to diagnose the management and current status of the San Antero de Córdoba WWTP, to approach stakeholders in the community and to propose technical improvements at the conceptual level for the optimisation of the WWTP and the reuse of its effluent. At that time, wastewater reuse regulations in Colombia were in transition. Therefore, robust reuse applications that could meet the expected regulations were identified.

Subsequently, after assessing the feasibility of implementation, detailed design activities were formulated, which included the sizing of the infrastructure, the corresponding costs, the preparation of the documents required for construction, and the development of a manual, aimed at facilitating the preparation of potential operators for the operation and maintenance of the proposed design. Key findings and progress were discussed in regular follow-up meetings with experts from the participating organisations, including the San Antero mayor's office, the current operator of the treatment plant (Aqualia Latin America), MinAmbiente, MinVivienda, the Drinking Water and Sanitation Regulatory Commission (CRA), and GIZ. In addition, the needs and expectations of local farmers and community representatives were taken into account through their participation in workshops in San Antero de Córdoba.

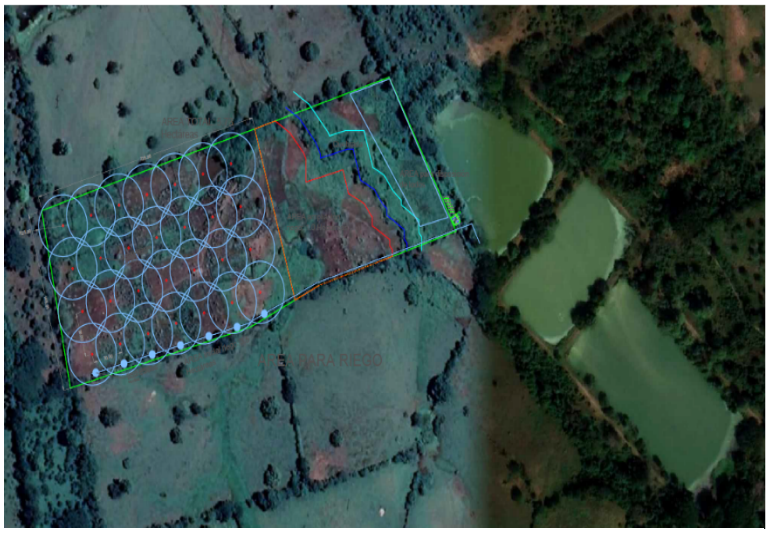

Figure 2: San Antero de Córdoba WWTP and the area destined for reuse. Source: Google Earth, adapted by GIZ/Acuameunier S.A.

The improvements to the San Antero de Córdoba WWTP were selected through an analysis of alternatives by

considering construction and operational criteria that favour the sustainability of the measures that can be implemented. As a result, to **increase the performance and capacity of the lagoon system**, the modification of the inlet and outlet structures and the incorporation of baffles were included. In addition, it was proposed to remove sludge from the lagoons, to cut the vegetation that threatens the stability of the slopes, to improve the preliminary treatment and to use devices for measuring flow and sand retention.

It was proposed to use 5 l/s of the treated wastewater from the lagoon system for irrigation of forage pastures. The community provides a good outlet market, and it would be a good income opportunity for local small-scale farmers. The design of the pilot reuse system includes a detour canal that conveys a portion of the treated effluent to a storage tank where the effluent is pumped into a filter battery to be directed to an engineered irrigation network. This would cover an area of 3.5 ha.

Rehabilitation of a lagoon system and reuse system for agricultural irrigation in Sabana Yegua, Azua, Dominican Republic.

Issue

The Sabana Yegua WWTP is located in the province of Azua and was abandoned more than 30 years ago. A few years ago, there was low water availability in the area, especially for agricultural irrigation, so local small-scale farmers interrupted the sewerage system to use raw sewage for harvesting their crops. This represents a considerable sanitary risk and caused the Sabana Yegua WWTP to go out of operation. However, through dialogue with the stakeholders involved, it was established that the long period of abandonment is mainly attributed to the lack of resources for the rehabilitation of the system and to weaknesses in the governance and institutional framework of the water and sanitation sector in the Dominican Republic. In addition, the system did not incorporate facilities to treat and use the sludge from wastewater treatment.

Figure 3: Status of the facultative lagoon in August 2021. Photo: ©GIZ/PROAMSA

Near the Sabana Yegua WWTP the infrastructure of the YSURA irrigation system is located. This infrastructure covers 30,000 ha and manages water for agriculture in the area. Irrigation is carried out by flooding furrows. In doing so, the supply of water for irrigation varies greatly and there are no measures to control and monitor the amount of water used for irrigation. In addition, the distribution network consists of earth channels, which cause a significant loss of water.

Figure 4: In-ground irrigation canal (left) and furrow flooding technique (right). Photos: ©GIZ / TECCA Caribe

Addressing the issue

Improvements for the rehabilitation of the Sabana Yegua WWTP and its wastewater reuse system were designed. The design was carried out in cooperation with the Ministry of Environment and Natural Resources of the Dominican Republic (MIMARENA) and in collaboration with governmental organisations such as the National Water and Sanitation Institute (INAPA), the UASD, Santiago Campus, and the YSURA Irrigation Board. On the other hand, the design was awarded to providers from the private sector.

First, the current state of the infrastructure was diagnosed, risks were identified, and a proposal at the conceptual level was made for the improvements required for rehabilitation through a feasibility study. Subsequently, the detailed design was developed, which included the preparation of preliminary studies, the sizing, specifications and costs of the proposed improvements, training on the proposed design and the preparation of a manual to facilitate the operation and maintenance of the design.

The design of the Sabana Yegua WWTP included a pre-treatment system consisting of manual screens and a grit trap to remove large solids that, if not retained, would reduce the efficiency of the lagoon system. In addition, due to soil conditions, the lagoons will be sealed with a high-density polystyrene geomembrane to reduce the likelihood of groundwater contamination and to ensure proper function of the lagoons. It is also proposed to establish a maturation lagoon with an area of 13,447 m² and a useful depth of 1 m to remove mainly pathogenic microorganisms, which will also allow an acceptable quality for the reuse of wastewater in crop irrigation according to World Health Organization (WHO) parameters. The accumulation of sludge in the plant reduces the efficiency of the lagoon system, so it is proposed to remove it by dredging and to dewater and stabilize it in three drying beds with a total capacity of 1000 m³. Finally, biosolids can be obtained through composting, which can be used as a soil conditioner.

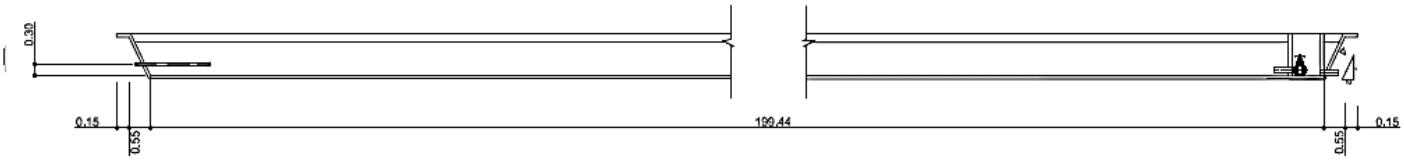

Figure 5: Lateral section of a maturation lagoon. Source: GIZ/TECCA Caribe (2022)

In addition, the treated wastewater from the Sabana Yegua treatment plant could be used for irrigation of agricultural land in the surrounding areas. Therefore, it is first proposed to establish a demonstration plant for sub-leaf irrigation on one hectare of on agricultural land where bananas are grown (banana cultivation takes place on about 70 % of the agricultural land in the region) to develop best practices among the producers and the organizations involved, such as the Ysura Irrigation Board. Subsequently, it is recommended to extend the technology up to an area of 30 ha of agricultural land for banana cultivation.

The storage of treated wastewater for irrigation covers 10,583 m³. The proposal includes gravity conveyance of treated wastewater to irrigation points, primarily through buried PVC pipes. In addition, a drainage system will be installed to accelerate the runoff of accumulated rainwater, reducing the likelihood of crop loss. It is also expected to significantly reduce water consumption and to decrease the likelihood of spreading plant diseases compared to the technology which is currently used.

Rehabilitation of PTAR at the UASD, Santiago Campus, Dominican Republic, as an academic research laboratory

Issue

The WWTP at the UASD, Santiago Campus, was built in 2004 and has not been used since its construction. Currently, its infrastructure is highly deteriorated, due to inadequate maintenance and operation. It also fails to prevent the emission of methane into the atmosphere and, in general, does not incorporate facilities for the treatment and reuse of wastewater treatment by-products (biogas and sludge). Next to the WWTP, there are unused green areas covered with brush, where some fruits, bananas, and other plants grow.

Figure 6: UASB status, August 2021. Photo: ©GIZ/ PROAMSA

Addressing the issue

The respective improvements were designed for the rehabilitation of the WWTP of the UASD, Santiago Campus, and its respective treated wastewater reuse systems. The design was carried out in alliance with the Ministry of Energy and Mining of the Dominican Republic (MIMARENA) and in collaboration with the UASD, Santiago Campus, and awarde to providers from the private sector.

First, the current state of the infrastructure was diagnosed, risks were identified, and a proposal at the conceptual level was made for the improvements required for rehabilitation through a feasibility study. Subsequently, the detailed design was developed, which included the preparation of preliminary studies, the sizing, specifications and costs of the proposed improvements, training on the proposed design and the preparation of an operating manual to facilitate the operation and maintenance of the design.

The construction at the UASD, Santiago Campus, contained the recovery of the pre-treatment infrastructure, the Upflow Anaerobic Sludge Blanket (UASB) and the upflow anaerobic filter. The design incorporated the infrastructure for collection and treatment of biogas generated from the UASB, for energy use and reduction of methane emissions into the atmosphere. Besides, drying beds for sludge dewatering and stabilization, ring filters and UV disinfection were added, in order to provide the required effluent quality for reuse. During the design phase, the advantage of using the wastewater treatment plant (WWTP) as a laboratory for students and teachers was taken into account. Therefore, the installation of a subsurface flow wetland demonstration unit was considered, which will treat a fraction of the anaerobic filter effluent. This could be used mainly for research and other academic purposes at the university.

In the design of the WWTP at the university campus, it is planned to irrigate with the treated wastewater an area of about 2 ha near the WWTP, suitable for planting ornamental plants and forestry, among others. In this way, an irrigation system for treated wastewater is proposed with a usable storage of 521 m^3 and a pressure micro-sprinkler system. As in the previous case, the design takes into account a drainage system that reduces the excessive accumulation of water in the soil to minimize the damage to the plants.

A pilot plant for faecal sludge treatment in Paramaribo, Suriname

Issue

Suriname is one of the countries with the highest per capita water availability worldwide. However, there is a risk of water resource contamination due to poor wastewater and faecal sludge management in and around Paramaribo, where 80 % of the population live.

About 90% of households discharge their wastewater into septic tanks, which are often not properly maintained. In addition, the sludge from the septic tanks is removed only irregularly and is often discharged untreated into Suriname's river channels, endangering the health of the population and the ecosystem.

Addressing the Issue

In order to protect ecosystems and public health from inadequate faecal sludge management in Paramaribo, Suriname, GIZ managed a conceptual design for the installation of a pilot Faecal Sludge Treatment Plant (FSTP) in the area. The conceptual design was framed in cooperation with the Ministry of Environment and Spatial Planning and implemented in cooperation with the NGO BORDA within the scope of a subsidy agreement. Specifically, it was agreed to include the development of a diagnosis (including a review of governance aspects, existing sanitation infrastructure and stakeholder analysis), a market study of the faecal sludge management service, a land evaluation, a business model proposal, a pre-design of the pilot plant, an environmental and social impact assessment, capacity building activities, among others.

The project consisted three phases developed from May to September 2022, which included two visits to Paramaribo. In the preparatory phase, a first approach was made to stakeholders, and information was collected. Subsequently, in the pre-feasibility phase, a conceptual draft was prepared and the role and needs of related stakeholders were identified in further detail. Finally, in the preliminary design phase, the conceptual design was consolidated, and the findings were shared with stakeholders, including related capacity building measures.

In particular, the FSTP pilot project would have a capacity to effectively treat 100 m^3 of faecal sludge per day, regardless of specific characteristics of the facility. The proposed treatment technologies were chosen based on criteria such as sustainability, environmental impact, reliability, costs (capital and operation and maintenance), scaling-up potential and value of by-products.

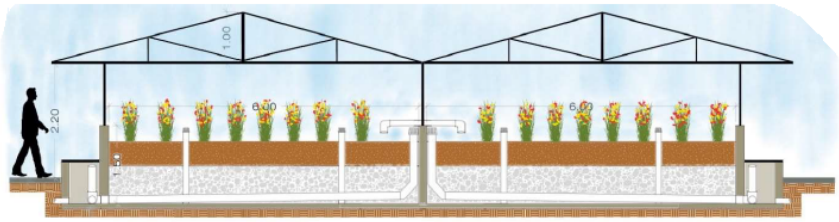

Figure 7: Drying beds with plants. Source: BORDA Las Américas (2022)

As a result, the proposed treatment consists primarily of NBS and requires an area of approximately 10,000 m^2. Preliminary treatment (consisting of screens, grit removal chambers and grease traps) is proposed to remove coarse solids, inerts (including sands) and fats, oils and grease from the sludge entering the plant. Liquid-solids separation is carried out in sludge thickeners. The concentrated solids fraction is conveyed by gravity to **drying beds with plants**, through which the sludge is dewatered and stabilized to reduce its hazardousness. The sludge can then be co-composted with other organic waste from the city and used as a soil improver. Meanwhile, the less concentrated fraction from sludge thickeners and leachate from plant-based drying beds receives secondary treatment in DEWATS™ [1] (Decentralized Wastewater Treatment Systems). The effluent from secondary treatment is directed to **a maturation lagoon** for safe reuse. As a result, the by-products of the treatment could be utilized, and the amount of waste released into the environment is reduced.

[1] For more information on DEWATS™, please have a look at the following source: Reuter, S., Demant, D., Heredia, G., Lüthi, C., Reymond, P., Schertenleib, R., Ulrich, L., Zurbrügg, C. (2022). *Compendium of Sanitation Systems and Technologies for the Wider Caribbean Region*. Bremen Overseas Research and Development Association (BORDA). Bremen, Germany.

Legend
1: Administration area
2: Picnic area
3: Workshop/factory
4: Truck cleaning area
5: Sand storage area
6: Grit removal chambers
7: Store house
8: Settlers
9: Industrial water for truck cleaning
10: Drying beds with roofed plants
11: Compost storage area
12: Composting area
13: DEWATS™
14: Gravel filter with plants
15: Polishing lagoon
16: Treated wastewater tank
17: Entrance

Figure 8: Overview of the pilot plant for faecal sludge management in Suriname. Source: BORDA Las Américas (2022)

Relevance for Development

High population growth and the impacts of climate change and ecosystem degradation put pressure on sanitation services in the Wider Caribbean Region. In this context, NBS in wastewater treatment favour the sustainability of sanitation services in the region by reducing the gap in safe access to water and sanitation, protecting water resources and improving their quality. Therefore, the design of NBS for wastewater treatment contributes mainly to the achievement of Sustainable Development Goal (SDG) 6. In the cases indicated above, they proved to be viable technologies for wastewater treatment in coastal and/or rural areas, and their advantages often include low operating costs, low energy consumption and a simple construction design.

Facilitating the implementation of wastewater disposal services in the region mitigates the risks posed by the discharge of untreated wastewater into water bodies. This also minimizes health risks and improves ecosystem health.

In addition, the integration of NBS in planning allows the safe reuse of treated wastewater, reducing pressure on natural water sources and the use of fertilizers. In addition, the Wider Caribbean Region is highly vulnerable to the effects of climate change, making wastewater reuse an important adaptation measure by increasing water availability (**SDG 13**). In particular, the reconditioning of the Sabana Yegua WWTP in the Dominican Republic contributes to food security (**SDG 2**) by incorporating an irrigation system for agricultural production in an arid area. Additionally, the implementation of the proposed design in Colombia is expected to create new sources of income for small-scale farmers in a rural area with low availability of consumption water, which would also contribute to the reduction of poverty (**SDGs 1 and 8**).

The introduction of NBS in the aforementioned designs would mitigate the deterioration of ecosystems and loss of biodiversity caused by the construction of wastewater treatment infrastructure (SDG 15). Lagoon and wetland systems are ecosystems in which flora and fauna species can coexist. Additionally, there is little landscape disruption compared to other conventional treatment technologies.

The conducted trainings were a measure to sensitise people who play an important role in the implementation and subsequent operation of the planned infrastructure. In addition, knowledge on robust, cost-effective, and sustainable technological solutions

for wastewater treatment was provided. In particular, capacities were strengthened to ensure that the WWTP can be operated and maintained efficiently once the design has been implemented.

Integrating wastewater reuse into the proposed approaches for activities in Colombia and the Dominican Republic will support their innovative initiatives to safely reuse wastewater. The approach provides a practical model on how to implement the principles and best practices at the country level. In the case of the Sabana Yegua wastewater treatment plant, the integration of the water-energy-food nexus approach led to new discussions between government organizations that normally work separately, such as INAPA and the Junta de Regantes YSURA, to develop a project with an integrated water management approach. In this way, the inclusion of NBS in the design paves the way for the provision of more sustainable sanitation services in the Wider Caribbean Region that can be replicated and expanded.

Lessons learned

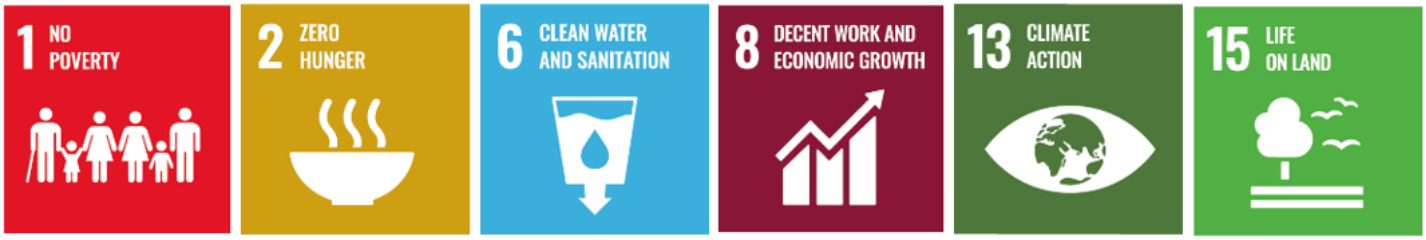

Figure 9: SDGs benefited from the design of NBS in the Wider Caribbean Region through the GEF CReW+ project. Source: United Nations (2023)

What should be avoided?

- In each of the cases mentioned in this document, there was **no clarity on the ownership of some of the land** that could be intervened during the design or the pre-dimensioning stage. This leads to delays and additional costs, as it raises possible alternative solutions if the land cannot be acquired within the project timeframe. In addition, it is an important aspect in the design process of NBS, as it usually requires a high availability of land. Therefore, it is advisable to conduct a verification of land ownership before starting the design of the infrastructure.
- **Excluding an action plan for implementing project risk mitigation measures in feasibility studies** causes delays and reduces the likelihood of a successful implementation. For example, the absence of an action plan during the earlier stages in response to the risk of budgetary constraints for construction can result in implementation delays, as more time is needed to find the necessary additional funding. Therefore, it is recommended to include detailed risk mitigation measures and the respective action plan right from the early stages of the project.
- **When developing a sanitation service, an analysis of possible alternatives should be conducted in advance.** In the development of a technological sanitation solution for a community, it is recommended to include an environmental assessment and then evaluate feasible alternatives according to the findings of the diagnosis made. In this way, resources are invested in solutions that may have greater sustainability according to the context of the intervention area.

What should be promoted?

- **Involving farmers' representatives through workshops or trainings** facilitates their participation and the development of the reuse proposal. In this process, the farmers' working conditions, needs and fields of activity are identified. In this way, the sustainability of the reuse service offered by the implemented NBS is promoted. It also strengthens their capacity to reuse treated water safely and efficiently.

"Para nosotros fue muy valiosa la capacitación, entendemos que se enmarca en la importancia que tiene el asunto de no solamente venir y decir "Vamos a hacer esta obra" sino te capacitan para que tú sepas como manejarlas. Nosotros pudimos ver, en esta capacitación, países que tienen este tipo de sistemas funcionando, vimos cómo funcionan. La idea de la GIZ es que cuando nosotros tengamos esta obra funcionando [la PTAR de Sabana Yegua] podamos tener la capacidad de ponerla a operar. Nos sentimos bien agradecidos con la capacitación y esperamos que se repita"

Félix Mora, Municipio de Sabana Yegua, República Dominicana. Fotografía ©Katia Gutiérrez

"For us, the training was very valuable. We understand that it is important not to just come and say, "We're going to do this work," but to be trained so that you know how to manage it. At this training, we were able to see countries that run these kinds of systems, and we saw how they work. The idea of GIZ is that when we have this project [the Sabana Yegua wastewater treatment plant] up and running, we will have the capacity to put it into operation. We are very grateful for the training and we hope it will be repeated."

Félix Mora, Sabana Yegua, Dominican Republic. Photo: ©Katia Gutiérrez

- **Communication with key stakeholders in the intervention communities** favours the development of a realistic design that meets the needs of the community. The community is usually most affected during the operation of the proposed works and plays an important role for the sustainability of this project.
- For private wastewater planning companies, it provides an opportunity to replicate the experience of planning integrated wastewater systems in their consultancies, where their by-products are used, with a vision of circular economy. In this way, it favours the **strengthening of the capacity of private companies** in this field, which promotes the expansion of the vision above.
- **Conducting follow-up meetings** with experts from the organizations involved favours the development of solutions that are feasible and robust. By doing so, alternatives from different perspectives and experiences are analysed.
- **Developing training or capacity building activities** for selected individuals during the design process encourages key

Figure 10: Training on Faecal Sludge Management for selected individuals from the government sector in Suriname. Photo: ©BORDA Las Américas

stakeholder participation in the project and facilitates responsibility of the proposed solutions.

- The **preference for cost-effective, simple, and energy-efficient wastewater treatment solutions** often meets the needs of users and implementers in the Wider Caribbean Region. The operating and maintenance costs for wastewater collection and treatment must be kept low so that the process is profitable for the regions.

Sustainability & Replication

The NBS mentioned above can be replicated and scaled in other locations in the Wider Caribbean Region and in peri-urban and rural areas in the tropics. The main challenge regarding the replicability of lagoon and wetland systems is the availability of land. They typically require a larger area of land compared to other conventional wastewater treatment technologies. Therefore, they are more likely to be used in rural areas where land availability is greater than in urban areas. They are also preferred in the tropics, where the warmer climate improves their performance. The treatment technologies proposed in the designs are simple and cost-effective effective (both in terms of operating and capital costs) and the energy consumption is low and, which increases their sustainability for their application in the region. Therefore, it is important to maintain these features when scaling-up.

The project in San Antero de Córdoba, Colombia, and the one in Sabana Yegua, in the province of Azua, Dominican Republic, are pilot projects for the safe reuse of wastewater to increase agricultural productivity. These are simple and cost-effective systems, which could be replicated in other rural areas in the region. This will contribute both to greater food security and sustainable reuse of wastewater in the region, reducing pressure on surface or groundwater sources and improving the sustainability of the project.

"Ese proyecto (rehabilitación de la PTAR de Sabana Yegua) va a ser muy importante, porque a través de él se va a replicar. Servirá como ejemplo para que puedan implementarlo en las demás provincias, por a veces tenemos épocas de estiaje, con poca agua en los primeros días del año, entonces eso ayudaría" (María de León Pepen, Ministerio de Medio Ambiente y Recursos Naturales).

"This project (rehabilitation of the Sabana Yegua WWTP) will be very important, because it will be replicated. It will serve as an example so that it can be implemented in other provinces, because sometimes we have low water levels during the first days of the year, so that would help" (María de León Pepen, Ministry of the Environment and Natural Resources).

However, proper management of treated wastewater reuse systems for agricultural irrigation requires inter-organizational arrangements. Their operation and maintenance overlap with the responsibilities of organizations that were not previously directly linked. For example, in the Sabana Yegua wastewater reuse project, roles and responsibilities must be formally agreed upon between the national water agency (INAPA) and an irrigation association (Junta de Regantes YSURA) that manages water for agricultural activities in the area.

Meanwhile, the project could be replicated at other departments of the UASD Santiago Campus to train future experts for the region in integrated wastewater treatment systems using NBS and with a circular approach that makes appropriate use of treatment by-products. On the other hand, considering the tourism development in Caye Caulker, Belize, the proposed approach can be adapted to other coastal and tourism areas with a high-water table and a flat topography. The replicability and sustainability of the implementation of the proposed concept in Suriname is highly dependent on the presence of an enabling environment with respect to aspects such as governance for the proper faecal sludge management, which is only beginning to exist in the Wider Caribbean Region. Therefore, it is important to focus on creating enabling conditions for governance, financing, and capacity development for

faecal sludge management in the region in order to implement sustainable technologies to protect public health and water resources in the long term.

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