Project • CRRP2021–06MY–Jegatheesan
Integrated assessment of existing practices and development of pathways for the effective integration of nature-based water treatment in urban areas in Sri Lanka, the Philippines and Vietnam

OFFSHOOTS OF APN PROJECT

https://www.apn-gcr.org/

Content
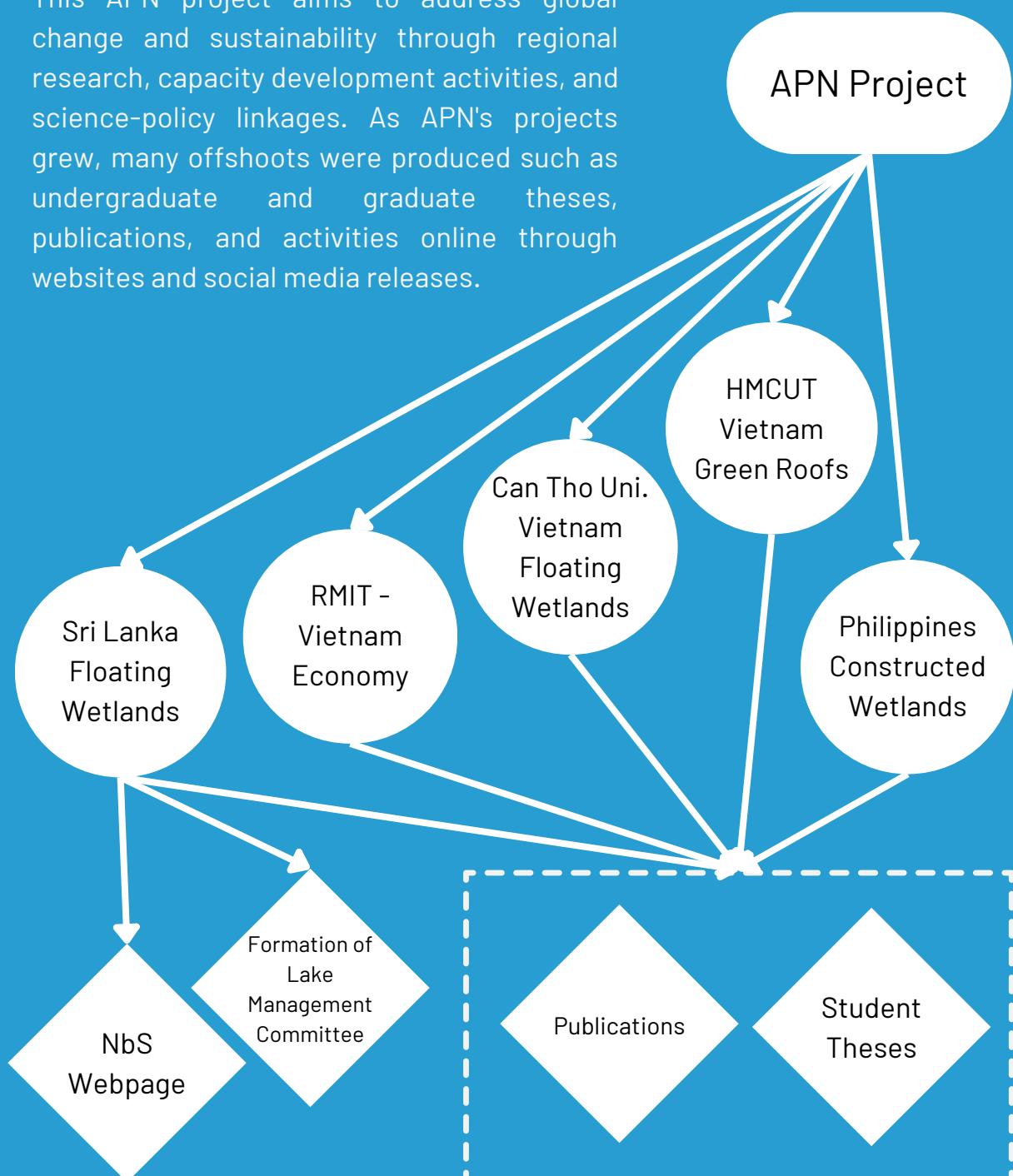
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Impacts of APN Project on NbS

This APN project aims to address global change and sustainability through regional research, capacity development activities, and science-policy linkages. As APN's projects grew, many offshoots were produced such as undergraduate and graduate theses, publications, and activities online through websites and social media releases.

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APN Project
├── Sri Lanka Floating Wetlands
├── RMIT - Vietnam Economy
├── Can Tho Uni. Vietnam Floating Wetlands
├── HMCUT Vietnam Green Roofs
└── Philippines Constructed Wetlands
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- NbS Webpage
- Formation of Lake Management Committee
- Publications
- Student Theses

A. Undergraduate Theses

Name: K.R. Nadini Mahinsa Kekulawala
Year: November 2022
Title: Evaluation of Biomass and Pollutant Uptake of Selected Plant Species in Constructed Floating Wetlands
Degree: Bachelor of Science in Agriculture
Field of Specialization: Environmental Soil Science, Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka
Supervisors: Prof. M.I.M. Mowjood, Prof. D.M.S.H.Dissanayake, and Mrs. J.P.H.U. Jayaneththi

Abstract: Constructed Floating Wetlands (CFW) is an innovative technique to control pollution in urban lakes. A study was conducted to assess biomass production and pollutant uptake by *Canna iridiflora* and *Cyperus alternifolius* in CFWs in Kandy Lake, Kandy, Sri Lanka. Tillers of both plants (20cm in height) were potted in floating PVC frames in the lake. Coconut coir was used as the media for each pot. The reference experiment was conducted by maintaining terrestrial conditions nearby the lake. Reference plants were arranged in polyethylene bags kept to represent the terrestrial condition and watered using lake water. In both experiments, plant samples were collected at weekly intervals of up to 8 weeks by uprooting. The height, fresh & dry weight of shoots and roots were measured. Total nitrogen (TN), and total phosphorous (TP) were also measured in shoot and root samples. The data were statistically analyzed using R software. Results indicated that the biomass of both shoots and roots of *Canna iridiflora* were significantly higher ($p<0.05$) than *Cyperus alternifolius* in both CFWs and reference. The shoot growth was higher on CFWs, and root growth was higher on terrestrial conditions in both plants. The TN and TP contents in shoots of both plant were higher than the roots for both tested conditions. The uptakes of N (23.28 mg/plant) and P (31.09 mg/plant) were higher in *Canna iridiflora* compared to N (14.91mg/plant), P (7.89 mg/plant) uptake by *Cyperus alternifolius*, in CFW over the terrestrial conditions. Consenting, to all results it can be concluded that the growing *Canna iridiflora* in CFW is one of the best solutions to mitigate the pollution of urban lakes.

Name: S. Niluka Sanjeewani

Year: 2022

Title: Development and Evaluation of a Methodology for Plant Selection for Floating Treatment Wetlands

Degree: Bachelor of Science in Agricultural Technology & Management

Field of Specialization: Agicultural & Biosystems Engineering, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya

Supervisors: Prof. M.I.M. Mowjood and Dr. S.S.K. Chandrasekera

Abstract: Floating treatment wetlands (FTW) are a new intervention to purify polluted urban lakes. The selection of appropriate plants for the FTWs is crucial and requires scientific methodology. The objective of this study was to develop an appropriate methodology for plant selection for FTWs. The study consisted of three phases: Criteria selection, screening system, and field study for verification. A literature review followed by preliminary screening using 5 criteria: plants available or not available in Sri Lanka, invasive/non-invasive, aquatic/terrestrial, perennial/annual, and adapted/not adapted to submerged conditions. Weighted scoring was adopted to select 3 plant types i.e., most, moderately, and least suitable for the field implementation. The selected 3 types of plants were used to establish the FTW in Kandy Lake, Kandy. The plants were harvested after 40 days of planting for the assessment of Total Nitrogen (TN), Total Available Phosphorous (TAP), and biomass. The data obtained were statistically analyzed using the pooled t-test in SAS software. Finally, the validation of the developed methodology was carried out. The literature review identified 50 plants used for the FTWs and 9 plants were screened which are suitable for Sri Lankan conditions. *Canna indica, Dracaena sanderiana, and Vetiveria zizanioides (L.)* were identified after weighted scoring as the most, moderately, and least suitable plants., respectively. The average biomass increases of *Canna indica, Dracaena sanderiana, and Vetiveria zizanioides (L.)* were 57.44%, 8.33%, and 29.92% respectively, and their average nutrient removal rates were 11.65%, 15.29%, and -3.08% for N and 275.16%, 8.22%, and 72.38% for P, respectively. It is concluded that Canna indica is the best plant for FTWs under Sri Lankan conditions. Since this study considered nutrient removal efficiency as a parameter for the methodology, further studies are suggested on assessing the other relevant parameters for selecting plants for FTW.

Name: M.F. Fathima Ifhatha

Year: 2021

Title: Application of Constructed Floating Wetland (CFW) as a Remediation Approach : A case study in Thona, Sainthamaruthu, Sri Lanka

Degree: Bachelor of Biosystems Technology

Field of Specialization: Faculty of Technology, South-Eastern University of Sri Lanka

Supervisors: Prof. M.I.M. Mowjood and Dr. M.M. Muneeb

Abstract: Remediation of contaminated water in coastal lagoons become a major concern to restore the coastal aquatic environment for the betterment of living conditions of the people in the vicinity. The coastal lagoon located in Sainthamarthu DS division, Ampara district, Eastern province of Sri Lanka called as "Thona" is not an exception. As the Thona is in the highly urbanized catchment, where land is limited, there is a growing need to find sustainable and environmentally friendly remediation technologies. Constructed Floating Wetland (CFW) is a novel option and cost-effective ecological engineering tool with great potential for water quality improvement. The present study explores the performance of a pilot scale CFW System with the two-fold objectives; (1) To determine the water pollution of Thona and (2) To assess the nutrient removal capabilities of a *Canna indica* in CFW. A pilot-scale CFW experiment was setup in 6 Styrofoam containers with and without the plant *Canna indica*. Water collected from Thona is used with weekly replacement in the containers. The water samples were collected once a week from the Thona before placing the CFW (raw water) and after placing the CFW (after 7 days of HRT) and analyzed for EC, TDS, Turbidity, Nitrate, and Phosphate to assess the performance of CFW for removal efficiency. In addition, Chemical Oxygen Demand (COD), Iron (Fe), Manganese (Mn), Volatile Phenol, and Anionic Surfactants were analyzed in raw water to determine the characterization of the lagoon. Results showed that among all raw water quality parameters EC (1030±144.52 μS/cm), Nitrate (4.098±2.65 mg/L), and Phosphate (1.014±0.25 mg/L) exceeded the standard level for aquatic life. The removal capability of CFW was obtained for EC (12.38 %), TDS (16.42 %), Turbidity (94.20 %), Nitrate (38.64 %), and Phosphate (45.47 %). On the other hand, the removal efficiency increased with the plant density and height of *C. indica* increased. As a whole, the Thona coastal lagoon has been polluted in terms of EC and nutrient pollutants. Therefore, the CFW with *C. indica* will be an appropriate sustainable nature-based treatment technology solution for the remediation of a coastal lagoon, thus approach can be applied on a real scale.

B. Graduate Theses

Name: Ramsia Begam
Degree: MPhil in Agriculture & Biosystem Engineering, Postgraduate Institute of Agriculture, University of Peradeniya (currently reading)
Title: Bioremediation of polluted lagoon using composite ecological floating wetland with biocarrier.
Supervisors: Prof. M.I.M. Mowjood and Dr. S.K. Weragoda
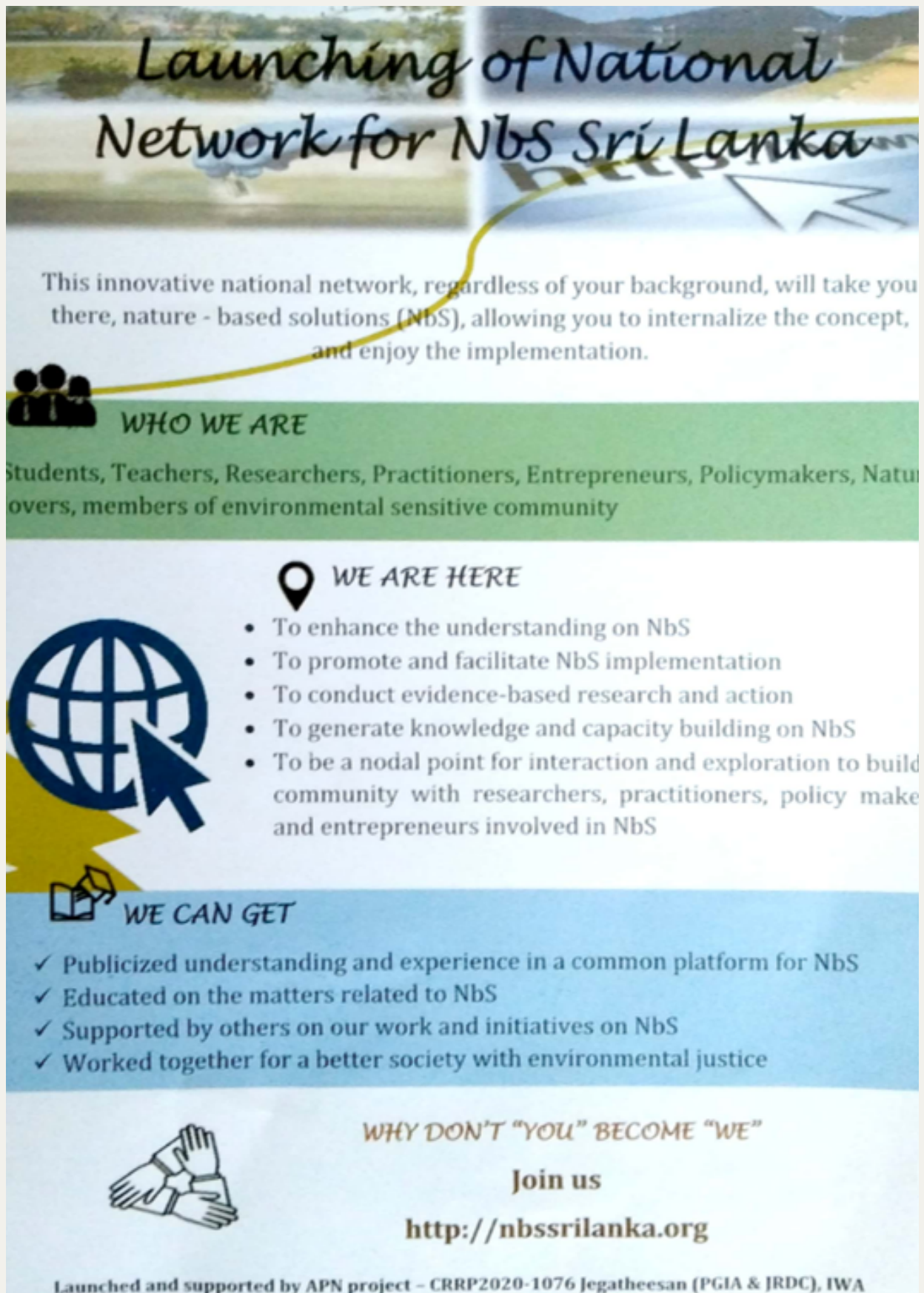
Name: Ms W.D.G.N. Bandara
Degree: BSc in Green Technology, Faculty of Agriculture, University of Ruhuna
Title: Development of Grow-Bed for Constructed Floating Wetland in Urban Lakes: A feasibility study in Kandy Lake, Sri Lanka
Supervisors: Prof. S. Wijetunga, Prof. M.I.M. Mowjood, Prof. K.B.S.N. Jinadasa
Abstract: Constructed Floating Wetlands (CFWs) have been used recently to revitalize the urban lakes in Sri Lanka. In these systems, plants are the driving force and their function is further amplified by the growth media. Therefore, considerable concern should be given to the growth media of CFWs. Coconut Coir Pith (CCP) is a preferred growth media due to its availability and affordability within the country. However, real-world applications needed an approach to address the stability issues when using CCP for CFWs. As an initial step to tackle the problem, a geotextile reinforcement was considered as a Grow-Bed (GB). A feasibility study was conducted in Kandy Lake, Sri Lanka to create the grow-bed for CFWs, aligning with Multi-Objective Design Criteria (MODC), and to evaluate its effect on plant growth and nutrient uptake. The CFW units were made using PVC materials. And the grow-bed was made by using two synthetic geotextiles, Polypropylene (PP) and Polyester (PET) arranged as a pillow-cover, filling CCP ($0.05 \times 0.7 \times 0.7$ m^3). Canna sp. plants were used. Treatments and control were arranged in Completely Randomized Design. Plant heights, number of leaves, flowering, and root growth were measured for a period of 10 weeks. Plant dry mass and Total Nitrogen (TN) (mg/g) and Total phosphorus (TP) (mg/g) were measured at the end of the study. The dry mass of leaves was significantly higher in PP-GB (10.37 ± 1.11 g). The dry mass of stem and leafsheath was significantly higher in PET-GB (9.61 ± 0.75 g). Leaves accumulated higher amount of TN compared to stems and roots. Both PP-GB and PET-GB showed significantly higher TN (g) removal with harvested leaves compared to control, with the highest TN removal in the PP-GB (4.97 ± 0.19 g). TP accumulation was higher in stems and leafsheath of plants. It was significantly higher in PET-GB (2.98 ± 0.01 mg/g). Both PP (2.78 ± 0.03 mg/g) and PET (2.92 ± 0.03 mg/g) based plants showed significantly higher TP accumulation in their leaves compared to controls. Both PET (0.52 ± 0.13 g) and PP (0.78 ± 0.07 g) based plant leaves showed significantly higher TP removal than control. Translocation Factors (TF), for TN and TP indicated higher values for the PP and PET treatments compared to the control, suggesting better nutrient translocation within plants in GT treatments. TF was significantly higher for TN in PET (4.34) based plants. The overall N: P content of the plants was 7:1 in ratio. These results may be due to the ability of PP-GB and PET-GB for stability to develop a strong root system and provide surface for attached growth microbial community.

C. Other Accomplishments

Launching of National Network for NbS Sri Lanka

This innovative national network, regardless of your background, will take you there, nature - based solutions (NbS), allowing you to internalize the concept, and enjoy the implementation.

WHO WE ARE

Students, Teachers, Researchers, Practitioners, Entrepreneurs, Policymakers, Nature lovers, members of environmental sensitive community

WE ARE HERE

- To enhance the understanding on NbS
- To promote and facilitate NbS implementation
- To conduct evidence-based research and action
- To generate knowledge and capacity building on NbS
- To be a nodal point for interaction and exploration to build community with researchers, practitioners, policy make and entrepreneurs involved in NbS

WE CAN GET

- ✓ Publicized understanding and experience in a common platform for NbS
- ✓ Educated on the matters related to NbS
- ✓ Supported by others on our work and initiatives on NbS
- ✓ Worked together for a better society with environmental justice

WHY DON'T "YOU" BECOME "WE"

Join us

http://nbssrilanka.org

Launched and supported by APN project – CRRP2020-1076 Jegatheesan (PGIA & JRDC), IWA

Vietnam

A. Undergraduate Theses

Nguyen Thi Diem My, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), May 2023
Title: Growth of some macrophytes on constructed floating wetlands at Bung Xang canal
Major Adviser: Assoc. Prof. Dr. Ngo Thuy Diem Trang
Abstract: The application of nature-based soulutions (NbS) for wastewater treatment, specifically using constructed floating wetlands (CFWs) planting ornamental plants to treat municipal wastewater is a sustainable solution but has not been popularized in Vietnam. The project entitled "Growth of some macrophytes on constructed floating wetlands at Bung Xang canal" was carried out on CFWs systems with plants to determine the potential of growth and biomass production of some flower species, thereby assessing the reduction of nitrogen (N) and phosphorus (P) concentrations in wastewater. The CFWs were designed and installed by the College of Environment and Natural Resources (CENRes) in April 2022. Pruning of old branches was done every 60 days. The harvested fractions were assessed for growth and fresh/dry biomass of the trimmed biomass, then analyzed for C, N, and P content in biomass to estimate N, P uptake capacity of each species. The results showed that after the first 60 days, the plants started to adapt to the growing conditions, so the biomass generated was not high, in the next 60 days, the plants grew well and created more biomass. After every 60 days, the average total fresh biomass of *Cyperus alternifolius* was the highest. *C. alternifolius* had the highest average biomass of 820.2-4,436 g/raft; followed by *Canna x generalis* with 350-1,920 g/raft; *Echinodorus cordifolius* with 500-1,591 g/raft; *Ruellia tuberosa* with 160-540 g/raft; and *Heliconia psittacorum* with 129-369 g/raft. *C. alternifolius*, *C. generalis*, *E. cordifolius*, *H. psittacorum* and *R. tuberosa* produced in each 60 days in descending order of 248.6-566.5; 79.7-147.4; 106.9-128; 33.7-46.3; and 21.1-35.5 g of dry biomass/raft, respectively. With this amount of dry biomass, 5 plant species helped to accumulate in biomass 328.2-815.8; 255.4-323.9; 96.5-260.8; 66.7-77.1; and 23.4-49.7 g N/raft; 32.3-158.6; 18.3-33.9; 20.3-32.0; 8.1-9.3 and 5.1-8.6 g P/raft; 10.172-22,604; 4,058,1-5,917.8; 3,693.8-5,396.5; 1,083.4-1,579.6 and 1,050.7-1,649.9 g C/raft. Thereby, the plants helped to absorb 37.3-82.9; 14.9-21.7; 13.6-198; 3.8-6.0 and 4.0-5.8 kg CO_2/raft/60 days, respectively. In summary, besides the ability to create green biomass, 5 plants also helped to reduce N and P in urban wastewater through the absorption mechanism to create their biomass. Moreover, it also helps to absorb CO_2 contributing to reducing greenhouse gas emissions. In addition, the combination of planting 5 species at the same time has created a beautiful landscape for the Bung Xang canal with many colorfull beautiful flowers.

Photo by Dave on Unsplash

Truong Cong Phat, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), May 2023
Title: Removal efficiency of total inorganic nitrogen in Bung Xang canal water of Canna generalis in nethouse condition
Major Adviser: Assoc. Prof. Dr. Ngo Thuy Diem Trang
Abstract: The project entiled "Removal efficiency of total inorganic nitrogen in Bung Xang canal water of *Canna generalis* in nethouse condition" was carried out on a constructed floating wetlands (CFWs) to evaluate the growth ability of *Canna generalis* with 3 wastewater concentrations of 50, 75 and 100% and to determine the efficiency of soluble nitrogen removal in the presence of plants. The experiment was arranged in a completely randomized design with 3 replications with three concentrations of 50, 75 and 100% of wastewater and *C. generalis* (unplanted considered as control treatment). The results showed that the water parameters of temperature, pH, EC, TDS were all within the allowable limits. Dissolved oxygen content was improved after 7 days of treatment. The soluble nitrogenous compounds in the water after treatment all were decreased significantly and reached the QCVN 08:2015/BTNMT Column B1, especially $N-NO_3^-$ reached column A1, except for COD which was not. Treatment performance in the treatment with *C. generalis* was better than the treatment without plants. *C. generalis* improved the total inorganic nitrogen (TIN) treatment efficiency to 96.13–97.34%, while in the unplanted treatment only reached 81.32–93.36%. Thereby, it showed that *C. generalis* contributes 3.99–14.8% of the input TIN in the CFWs system. *C. generalis* had the best growth and biomass production in the 100% treatment, followed by 75% and the lowest at 50%. Thereby, it is shown that *C. generalis* was adapted to the conditions of high concentration of urban wastewater and had the ability to handle high soluble nitrogen, while creating beautiful flowers for the treatment area.
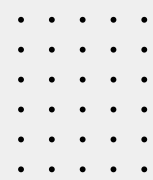
Lam Nguyen Ngoc Nhu, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), May 2023
Title: The effects of concentrations of Bung Xang canal water on growth and inorganic nitrogen removal efficiency of Echinodorus cordifolius
Major Adviser: Assoc. Prof. Dr. Ngo Thuy Diem Trang

Abstract: Using constructed floating wetlands (CFWs) with ornamental plants to treat municipal wastewater while protecting the environment and creating landscapes is a relatively new research direction in the Mekong Delta of Vietnam. The study entitled "The effects of concentrations of Bung Xang canal water on growth and inorganic nitrogen removal efficiency of *Echinodorus cordifolius*" was carried out on the CFWs system with plants for the purpose of determining the efficiency of the plant in removal of dissolved nitrogen and growth ability of *E. cordifolius* at three wastewater concentrations. The experiment was arranged in a completely randomized design with 3 replicates with three concentrations of 50, 75 and 100% of wastewater and selected aquatic plant of *E. cordifolius* and control (unplanted treatment). The parameters of temperature, pH, EC and TDS in treated water were all within the allowable limits. Dissolved oxygen content improved after 7 days of treatment. The inorganic nitrogenous content in treated water all decreased significantly and reached the QCVN 08:2015/BTNMT Column B1, especially $N-NO_3^-$ reached column A1, except for COD which was not. The total inorganic nitrogen (TIN) removal efficiency was better in the treatment with *E. cordifoliusthan* in the treatment without plants. Dissolved nitrogen treatment efficiency of E. cordifolius at 50% WW > 75% WW > 100% WW concentration (98.46% N > 98.12% N > 98.10% N respectively). The COD treatment efficiency was very high (99.31; 99.56; 99.70% corresponding to the three concentrations of 50, 75 and 100% WW), however, the COD content in the effluent water was still not reached the QCVN 08:2015/BTNMT Column B1. *E. cordifolius* had the ability to grow and develop well in all three concentrations of wastewater. Growth parameters such as plant height, root length, number of leaves and number of shoots/branches increased over time. Plant height at concentrations of 50, 75 and 100% was 55.4, 55.6 and 55.7 cm and increase 2.32; 2.33 and 2.34 times, respectively; root length was 45.3; 41.2 and 38.9 cm increased by 3.9; 3.6 and 3.4 times compared to the initial plants. The mean fresh biomass of stems and roots of plants grown at 75 and 100% wastewater concentrations was higher than that of the plants grown at 50% WW. The corresponding fresh biomass at 3 concentrations of 100% WW > 75% WW > 50% WW was 268.0 > 257.5 > 169.3 g/plant, respectively, increased by 4.5; 4.3 and 4.8 times compared to the initial plants. The corresponding fresh root biomass at 3 concentrations of 100% WW > 75% WW > 50% WW was 142.8 > 131.0 > 117.1 g/plant, respectively, increasing by 6.1; 5.6 and 5.0 times compared to the initial ones. Root and stem dry biomass increased by 1.8; 2.5 and 2.6 times; and 2.5; 2.6 and 2.5 times in the concentrations of 50, 75 and 100% WW, respectively.

Lam Chi Khang, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), May 2023
Title: Assessment of water quality changes in Bung Xang canal in the rainy season
Major Adviser: Assoc. Prof. Dr. Ngo Thuy Diem Trang

Abstract: Evaluation of surface water quality in Bung Xang canal on rainy season from 08/2022 to 12/2022 was conducted to understand the level of pollution and propose appropriate treatment and management solutions. Water sampling was carried out at 6 sampling locations along the canal at the high and low tide in order to determine 12 water quality parameters including pH, EC, TDS, dissolved oxygen (DO), chemical oxygen demand (COD), alkalinity, ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, phosphate and total phosphorus (TP). Water quality was compared with national technical regulation on surface water quality (QCVN 08-MT:2015/BTNMT) column B1 for irrigation water quality. The results showed that the studied canal had signs of organic and nutrient pollution with the COD, phosphate, and ammonium-nitrogen concentrations all exceeding the allowable thresholds of QCVN 08-MT:2015/BTNMT 1.5-2.0, 1.8-4.1 and 3.1-17.8 times, respectively. DO content was always low in both tides, ranging from 0.33-3.27 mg/L. The results showed that the surface water quality at Bung Xang canal was contaminated with organic matter and nutrients quite high, therefore, it is necessary to take measures to treat and protect this canal water source.

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Dao Hoang Nam, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), December 2022

Title: Evaluatingthe current status and proposing solutions to manage surface water environment at Bung Xang canal

Major Adviser: Assoc. Prof. Dr. Ngo Thuy Diem Trang

Abstract: Urbanization and economic development have polluted the canal water environment in urban areas of Vietnam. Bung Xang canal is located in the center of Can Tho city, renovated in 2019 making this canal more spacious. However, like other urban areas, Bung Xang canal is facing the problem of water pollution due to the lack of a centralized wastewater treatment plant and the community's low awareness of environmental protection. Households along the canal throw their garbage directly into the canal containing organic waste from food leftovers from restaurants, styrofoam boxes, plastic bags/bottles, making the water source after renovation heavily polluted. This study used a structured questionnaire with both qualitative and quantitative methods to directly interview two groups of business households (30 households) and non-business households (30 households). The purpose is to determine the status of water pollution; causes of pollution; the influence of polluted water on daily life, business activities, people's health and the landscape of the area; difficulties in environmental management and factors affecting people's willingness to pay to improve the water environment and landscape at the Bung Xang canal. People said that the current condition of the canal water environment is at an acceptable level, however, the color and odor of the water is quite poor. Solid waste, untreated domestic wastewater is the cause of canal water pollution. The degree of impact of polluted water on daily life, business activities, people's health and the landscape of the area is assessed at a low level of impact. On average, 58.33% are willing to agree to pay fees for canal water cleaning, of which 42.86% are business households and 57.14% are non-business households. On average, 35-48.33% agree to pay for landscaping and water cleaning in this area with a monthly fee of 10,000 to 15,000 VND.
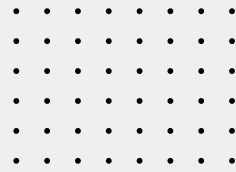
Nguyen Trong Huy. Institute for Environment and Resources – Vietnam National Univeristy Ho Chi Minh City. March 2023

Title: Application of The Green Roof System Domestic Wastewater Treatment Coupling With Green Area Enhancement For Large Cities

Major Adviser: Assoc. Prof. Bui Xuan Thanh

Abstract: The current status of water pollution, to the increase of the greenhouse effect, is a serious problem for the world. The Green roof system (GRs) is a highly effective solution that does not cost too much to operate and install. Study on the ability to treat COD, N, and P of 02 types of plants to domestic wastewater and the adaptability of plants to Green roof system operating conditions. Study on wastewater treatment efficiency of selected plants with 02 different hydraulic loading rate (HLR). Recommend the most appropriate payload. Besides, evaluate the ability to create green patches of 2 experimental plants. The experimental results are as follows:

In Vietnam's climate conditions, the Green roof system with the studied plants (*Vernonia elliptica* and *Campsis radicans*) has a higher wastewater treatment capacity. In terms of adaptability (including survival rate and biomass growth) and wastewater treatment ability, Cuc Tan is the dominant plant over *Campsis radicans*. The horizontal surface flow flat roof Green roof system with *Vernonia elliptica* plants can best treat domestic wastewater at HLR 500 ± 9 m^3/ha. day with an organic load of 345 ± 27 gCOD/m^3. day with a water retention time of 23 ± 1 hour. The efficiency of treatment of indicators such as COD is $89 \pm 5\%$ or 15 ± 7 gCOD/m^2.day; TN is $88 \pm 6\%$ or 1.23 ± 0.20 gN/m^2.day and TP is $75 \pm 10\%$ or 0.031 ± 0.009 gP/m^2.day. The quality of treated water meets Vietnam's discharge standards.

Under Green roof system environment conditions, at HLR 500 ± 9 m^3/ha. day, Vernonia elliptica has a growth rate of 1.65 cm/day and 0.85 cm/day of pepper. The green area from the Green roof system can create green space, help reduce temperature and save energy. In addition, the Green roof system can be an attraction for the animals that make up a biodiversity environment.

In short, the Green roof system has the ability to treat domestic wastewater well and create urban green space. From there, it helps to partially reduce the water pollution and greenhouse effect that is being encountered today.
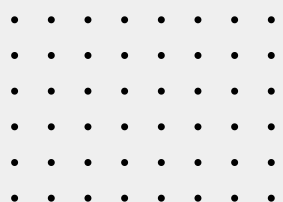
B. Graduate Theses

Vo Thi Phuong Thao, Department of Environmental Sciences, College of Environment and Natural Resources (CENREs), Can Tho University (CTU), October 2023
Title: Potential of water pollution control and landscape creation of constructed floating wetlands at Bung Xang canal, Can Tho city
**Major Adviser:** Assoc. Prof. Dr. Ngo Thuy Diem Trang

Dang Thong. Department of Environmental Manangement, Faculty of Envirotment and Natural Resources, Ho Chi Minh City University of Technology– Vietnam National Univeristy Ho Chi Minh City. December 2022
Title: Application of Green roof system to treat domestic wastewater and enhance green area for large cities
Major Adviser: Assoc. Prof. Bui Xuan Thanh
Abstract: The environmental challenges in cities urge people to explore feasible strategies for resilient, sustainable, healthy and livable built environments, of which designing and building green roof (GR) is an important approach. GR system is a horizontal surface flow constructed wetlands (HSFW) contains charcoal and oyster shell as main sediment layer. The methodological structure used of model operation GR technology on top of Centre Asiatique de Recherche sur l'Eau (CARE) in Ly Thuong Kiet Street, Ho Chi Minh city (HCMC) which was planted with *Vernonia elliptica* and *Campsis radicans*. This study evaluated domestic wastewater at hydraulic loading rate (HLR) of 160 (m^3/ha.day), GR system achieved high removal efficiencies for chemical oxygen demand (COD, 3.90 ± 1.13 and 3.42 ± 1.31 gCOD/m^2.day, respectively), total nitrogen (TN, 0.26 ± 0.13 and 0.25 ± 0.12 gN/m^2.day, respectively) and total phosphorus (TP, 0.007 ± 0.004 and 0.004 ± 0.005 gP/m^2.day, respectively) combined analyses other parameters like ammonia, nitrate, nitrite, pH, turbidity, total Kjeldahl nitrogen (TKN), total suspended solid (TSS) which qualified for column B of QCVN 14:2008/BTNMT. The results show that the best plant is *Vernonia elliptica* was the most suitable plant treating domestic wastewater for the conditions of GR. The system also demonstrates the possibility of developing green area distribution in Ho Chi Minh City according to the city's density. With the best scenario, the number of households using the model GR is 50%, the green area will increase by 31.4 km^2 and 134,769 people will live and work within green area.
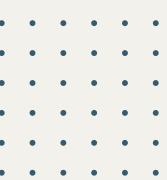
C. Publication

- Vo Thi Phuong Thao, Lam Nguyen Ngoc Nhu, Nguyen Thi Diem My, Tran Thi Huynh Tho, Lam Chi Khang, Truong Cong Phat, Dao Hoang Nam, **Ngo Thuy Diem Trang***, 2023. Evaluation of the growth response of five ornamental species grown hydroponically in urban wastewater. Journal of Agriculture & Rural Development (in Vietnamese), 455: 58-68. ISSN: 1859-4581.

04 Philippines

A. Undergraduate Theses

Dalisay, Michaela Magnaye. Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. June 2022.
Title: Integrated Framework Assessment of the Technical Effectiveness and Impact of Constructed Wetlands in Treating Landfill Wastewater in the Philippines.
Major Adviser: Assoc. Prof. Perlie P. Velasco, PhD

Abstract: Concepts have been developed as a countermeasure to the environmental issues caused by urbanization, with the purpose of creating improved living conditions to reduce the amount of waste that enters and leaves society. One of which is the construction of sanitary landfills. However, improper disposal of wastewater from these landfills significantly affects the contamination of surface water, ground water, and the soil, causing more serious problems to arise. One sustainable option to solve this problem is the use of nature-based solutions or NBS. One common type of NBS for wastewater treatment is constructed wetlands (CWs). However, CWs still remains under-utilized if not unestablished, especially in treating landfill wastewaters in the Philippines, due to the domination of the traditional technology and infrastructures, as well as the lack of knowledge on the alternative solutions for wastewater management. Thus, this study will develop an integrated assessment framework, not only to assess the effectiveness and impact of the CWs, but also to encourage its utilization to promote the improvement or development of new CWs. This can be done through the proposed extensive guide in selecting and analyzing the design of CWs and its operational parameters and other several important indicators to maximize its potential while minimizing its costs and trade-offs for treating landfill wastewater.

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Mueca, Cloie Chie Aleman. Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. January 2023.

Title: Integrated Framework Assessment for the Technical Aspect of Constructed Wetlands Treating Domestic Wastewater in the Philippines.

**Major Adviser:** Assoc. Prof. Perlie P. Velasco, PhD

Abstract: The Paris Agreement is a global treaty ratified in 2015 to act on the destructive effects of climate change, requiring nations to submit a national climate action plan every five years. In the Philippines, problems on water supply and security are ever increasing. Thus, part of the climate action plan of the country is the utilization of constructed wetlands for water management. Constructed wetland is an alternative wastewater treatment system that utilizes plant and substrate to treat wastewater. However, its adaptation in the country is quite limited due primarily to the lack of knowledge about constructed wetlands and the lack of framework or user manual that will guide the local government units in maintaining the said natural alternative for wastewater treatment. In this study, therefore, the major steps for the establishment, operation, and maintenance of constructed wetlands that treats domestic wastewater in the Philippines was developed. Although the framework includes steps on the socio-economic aspect, it mainly focused on the technical aspects of the wetland. These include the design considerations and effluent wastewater quality parameters to assess its effectiveness. Criteria tables were created to evaluate the standards for a certain design component such as substrate and vegetation were met. A table for the summary of assessment that would indicate whether the effluent wastewater passed or failed in the significant indicators was also formed. The framework was validated in consultation with government agencies, such as the Department of Environment and Natural Resources (DENR) and Department of Interior and Local Government (DILG).
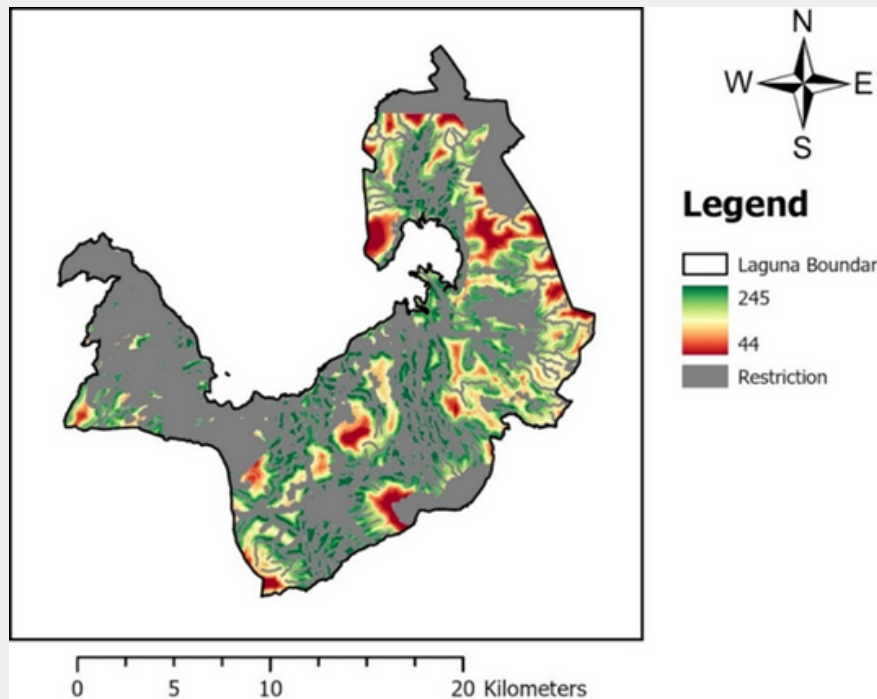
Casas, Rey Jintalan. Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. June 2023.
Title: Suitability Mapping of Constructed Wetland for Domestic Wastewater Treatment in Negros Oriental Philippines.

Major Adviser: Asst. Prof. Perlie P. Velasco, PhD

Abstract: Developing countries, including the Philippines, are falling behind in wastewater treatment due to the continuing challenges brought by rapid population rowth and limited financial resources. A solution to this issue is to implement a cost-effective wastewater treatment system such as constructed wetlands (CW), wherein the initial step involves identifying and evaluating suitable locations for this type of technology. In this study, a multicriteria evaluation (MCE) technique was applied to geographical information system (GIS) to produce a suitability map of CW in Negros Oriental, Philippines. The decision criteria based on literature and consultation with experts were land use, soil type, slope, distance to water bodies, and distance to populations. The criteria weights were derived using the Analytical Hierarchy Process (AHP), where the final weights assigned to each criterion are 45% for distance to water bodies, 23% for distance to population centers, 15% for slope, 9% for land use, and 7% for soil type. The criteria maps were reclassified and normalized with the guidance of the experts. In the province of Negros Oriental, an estimated 133,456 ha of land area is considered very suitable. Three candidate areas were proposed wherein one is near the coast, one is the nearest to Bayawan CW, and one is in the central part of the province. Furthermore, the candidate areas were assessed based on the decision criteria and their susceptibility to seismic, volcanic, and hydro-meteorological hazards.
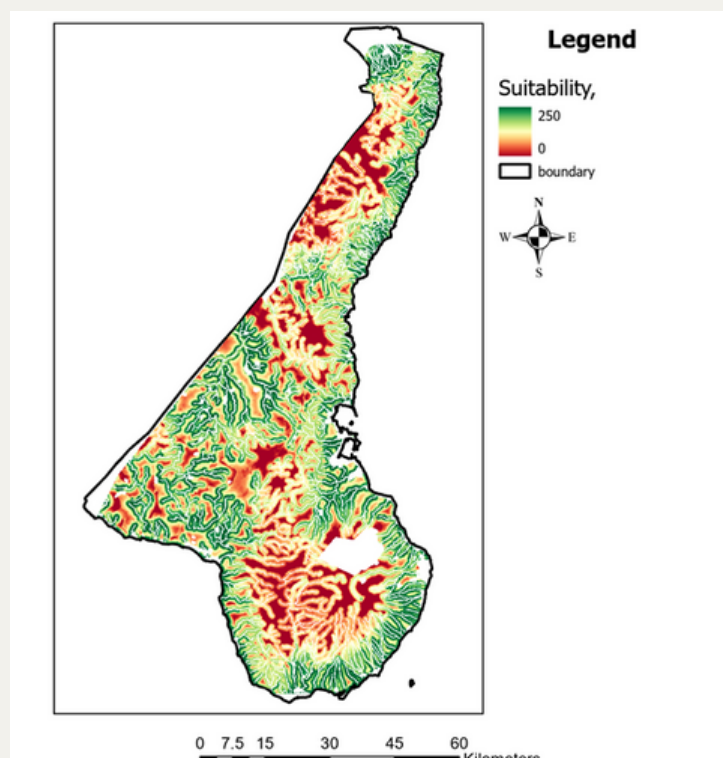
Galicia, Angelika Natividad. Department of Civil Engineering, College of Engineering and Agro-industrial Technology, University of the Philippines Los Baños. June 2023.
Title: Suitability Mapping of Constructed Wetlands for Domestic Wastewater Treatment in Laguna, Philippines Using Analytical Hierarchy Process and Geographic Information System.
**Major Adviser:** Assoc. Prof. Perlie P. Velasco, PhD
Abstract: Water pollution has become a serious issue in the Philippines, primarily due to the substantial volume of wastewater generated in the country resulting from rapid population growth, urbanization and industrialization. The presence of untreated wastewater poses significant risks to both human health and the environment. While conventional wastewater treatment methods are effective, they come with high costs for construction, operation, and maintenance. As a cost-effective and nature-based alternative, constructed wetlands offer a viable solution for wastewater treatment. Accordingly, to implement constructed wetlands, the first step would involve identifying suitable locations. Conducting a suitability mapping would be a viable approach for this purpose. Hence, this study aims to develop a suitability map of constructed wetlands in Laguna using Geographic Information System (GIS) combined with Multi-Criteria Evaluation (MCE) technique. Five criteria were considered in the evaluation process: land use, slope, soil type, distance to water bodies, and distance to population centers. The Analytical Hierarchy Process (AHP) was utilized to assign weights to these criteria, reflecting their relative importance. Buffer zones encompassing surface waters, protected areas, and built-up areas were also considered. By inputting the computed weights and normalized maps of each criterion into ArcGIS Pro, a suitability map was generated. Three sites were shortlisted as potential sites for constructed wetlands, and these are in Barangay Buboy, Pagsanjan, Barangay Halayhayin, Magdalena, and Barangay San Lucas 1, San Pablo City. These locations demonstrate ideal conditions for constructed wetlands in the province of Laguna.

Camua, Clar Francis Doloiras. Department of Civil Engineering, College of Engineering and Agro-industrial Technology, University of the Philippines Los Baños. June 2023.

Title: Suitability Mapping of Constructed Wetlands for Domestic Wastewater Treatment in Bulacan, Philippines.

Major Adviser: Assoc. Prof. Perlie P. Velasco, PhD

Abstract: The domestic wastewater treatment status in the Philippines is quite alarming since only 10% of the wastewater is being treated. One of the ways to treat the accumulated domestic wastewater is with the implementation of constructed wetlands (CW). CW is a system designed to use natural processes for wastewater treatment incorporating wetland plants, soil, and bacteria. It is also known for being more cost-effective to construct than other forms of treatment facilities. With this, the implementation of CW in the coastal province of Bulacan would aid its domestic wastewater treatment problems. Prior to installing CW across the province, it is important to locate first suitable site locations to avoid wastage of resources, including time, effort, and financial investments. Thus, creating a suitability map in the province can be of great help in carrying out the project. The study aims to generate a suitability map of CW for wastewater treatment in Bulacan using ArcGIS, a Geographical Information System (GIS) software and Analytical Hierarchy Process (AHP), a Multi-Criteria Decision Making (MCDM) method. After generating the suitability map of CW, the upper 20% is generated to represent the high suitability of CW. Top three suitable areas were chosen from the upper scale range of 250 to 255 values and were further verified using Google Earth Pro. The three suitable areas were situated across numerous municipalities for each area, which are at Cambio up to Maligaya, San Miguel, Bulacan, Camias up to San Agustin, San Miguel, Bulacan, and Pantubig up to Balagtas, San Rafael, Bulacan This study will serve as a reference and guideline for future studies and for the local government of the province for the possible implementation of CW.

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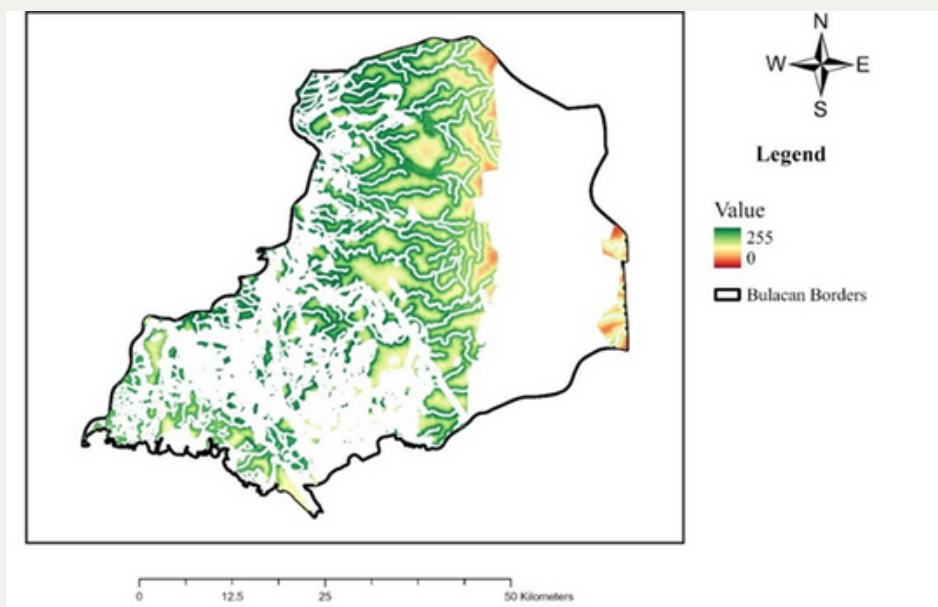
Guila, Patricia Marie Caparas. Department of Community and Environmental Resource Planning, University of the Philippines Los Baños. June 2023.

Title: Gray or Green: Will Households Pay for Constructed Wetlands as Nature-Based Water Treatment in Peri-urban Areas in the Philippines?

Major Adviser: Assoc. Prof. Casper B. Agaton, PhD

Abstract: Constructed wetlands (CWs) are globally recognized as effective nature-based wastewater solutions. These systems use natural processes to clean wastewater, which has significant environmental and socio-economic benefits. As a result of increasing urbanization and a growing population, the Philippines is suffering from extreme water pollution. Effective wastewater management is essential in human settlements planning as it protects public health and the environment by reducing water source contamination and disease transmission. It also enhances overall sustainability and livability, leading to a higher standard of living. Economic analysis is required to determine the long-term viability of sustainable projects such as CWs. This study employed the contingent valuation approach to investigate the willingness to pay (WTP) of 270 households in Fishermen's Gawad Kalinga Village in Bayawan, Negros Oriental. Results showed that 96.3% of the respondents were willing to pay for constructed wetland services, with a mean WTP of 107.28 PHP. This holds a significant promise for the government and other stakeholders to embrace and invest in NBS for wastewater treatment such as CW projects. Future research should focus on cost-benefit analysis and real-options analysis to strengthen the study by comparing costs and benefits and investigating the flexibility and adaptability of the project.

Rodriguez, Anne Dominique Hitape. Department of Community and Environmental Resource Planning, University of the Philippines Los Baños. December 2023.

Title: Ecosystem Services Valuation of Constructed Wetlands in Panguil River Ecopark Using Travel Cost Method

Major Adviser: Assoc. Prof. Casper B. Agaton, PhD

Abstract: The increasing number of visitors in eco-tourism parks often face the challenge of wastewater management to maintain the ecological integrity of the park. In the case of Pangil River Ecopark, the increasing wastes, in terms of garbage and sewage, have led to the diminishing capacity of the ecosystem services being provided by the river to the nearby communities. To address this problem, a constructed wetland (CW) is proposed to be installed in several areas in the park. The purpose of the study is to analyze the economic value of the CW project in Pangil River Ecopark using Travel Cost Method (TCM). TCM is a useful tool to estimate the use value of an environmental good or service, particularly for sites that are used for recreation, such as national parks. The value of the change in the quality or quantity of a recreational site (resulting from changes in water quality due to CW) can be inferred from estimating the demand function for visiting the site that is being studied. The value of CW to the visitor is at least equal to the travel costs the consumer is willing to incur to obtain the desired good or service. Hence, people's willingness to pay to visit the eco-park is estimated based on the number of trips that they make at different travel costs. In this study, a survey questionnaire will be conducted to the visitors of Pangil River Ecopark and the surrounding communities to gather data on their zone of origin, distance from the destination, travel time, cost of travel, and number of visits per year with and without the CW. Key Informant Interviews will also be conducted to support the study and to provide valuable insights for policymakers and other stakeholders on the economic viability of CW as a nature-based solution to wastewater treatment.

B. Publication

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