Maintenance and Management of Ecological Campuses
– A Case Study in West Cigu Campus, National University of Tainan

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ABSTRACT

National University of Tainan, Taiwan, strives to utilize ecological approaches in all aspects of campus landscape management and maintenance in its West Cigu Campus as it is situated near an ecological conservation area. Recommendations on water management include the building of stormwater detention ponds based on flood inundation probabilities evaluated by FLO-2D software, the installation of revetment of which the ground elevation is set in response to the tidal variations and water level changes after torrential rain monitored by water level measurement sensors in tidal creeks around the campus, and the constructed wetlands that deal with sewage disposal. On land management, GIS is adopted to determine the distribution of campus vegetation that contributes to the creation of ecological corridor, and ways of improving soil quality and a list of halophytes are put forward to maximize the survival of vegetation on the basis of soil salinity testing results. From the case studied, the research aims to present a model for the maintenance and management of ecological campuses.

KEYWORDS

ecological campus, maintenance and management, ecological conservation, constructed wetlands

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1. INTRODUCTION

1.1 Motivation

The littoral area of Southern Taiwan is renowned for its abundant wildlife resources and diverse ecological systems while Cigu Campus, National University of Tainan (NUTN) is surrounded by ecological resources and ecological conservation area for black-faced spoonbills. For maintaining the original status and preventing direct impact during campus development, feasible schemes should be undertaken in the future. Tainan County Government approved a gratuitous appropriation of 120 hectares of land in Shin-sheng Section, Cigu Township in 1998 for building new NUTN campus, with 38 hectares for East Cigu Campus and 82 hectares for West Cigu Campus. As West Cigu Campus is close to the habitat of black-faced spoonbills, the original ecological system must be retained under the development scheme. By utilizing the geographical conditions and conforming to the regulations and its philosophy of sustainable campus management, NUTU strives to be the first ecological university in Taiwan.

1.2 Research Purpose

Ecological conservation is the main idea of environmental preservation in Cigu Campus. Taking account of original geographical conditions, utilizing geographical advantages and resources, issues like flood control safety, domestic wastewater treatment and water resource reuse in the campus site can be accomplished by comprehensive planning and management and implementation of eco-conservation, in order to maintain ecological environment for indigenous inhabitant and vegetation.

2. THEORY AND METHODOLOGY

Discussion and planning had been carried out with NUTN administration, experts, scholars and program designers. Theoretical analysis of campus site was undertaken in both aquatic and terrestrial areas; site management was concluded through case study of related ecological campuses and areas in order to achieve ecological management and conservation plan.

2.1 Aquatic Area

2.1.1 Flooding

The flood simulation analysis was run by FLO-2D model. The analytic procedures and methods were based on "Reference Manual on the Regulation of Drainage and Planning of the Environment Rehabilitation" issued by Water Resources Agency (WRA).The data needed for flood simulation included terrain data from field measurement and rainfall data from neighboring rainfall station. The highest probability distribution versus the rainfall of respective return period was obtained via examination on the analysis of rainfall and rainfall frequency and the applicability of probability distribution. Adding hyetograph design and rainfall in flooding simulation, the result was generated. Three sides of the campus were right by the tidal ditch while the height of the bank protection was determined by water level changes caused by the tidal period, thus 6 observation posts for monitoring water level were installed at the outside edge of the campus in order to avoid being flooded by rain water.

2.1.2 Wastewater Treatment

The constructed wetland was built using ecological engineering approach for water pollution control. It can reach the same effect as the traditional wastewater treatment does, and benefit from features like power-saving operation, lower setup costs and easy maintenance. It also has additional values such as providing habitats for wild animals, and landscaping under the conditions of better water quality control and sufficient land area. For handling wastewater treatment issues in West Campus, constructed wetland with free water surface (FWS) system is more suitable to local ecological system as such systems have been implemented for over 30 years around the world. For instance, the Natural Treatment Systems has been used since 1980s in the U.S. to filter pre-treated sewage (by septic tanks or other means) for water purification. In the research, the planning for wastewater management strategies was based on the three-stage designing model for constructed wetlands proposed by the U.S. Environmental Protection Agency(EPA, 2000) as shown in Figure 1.

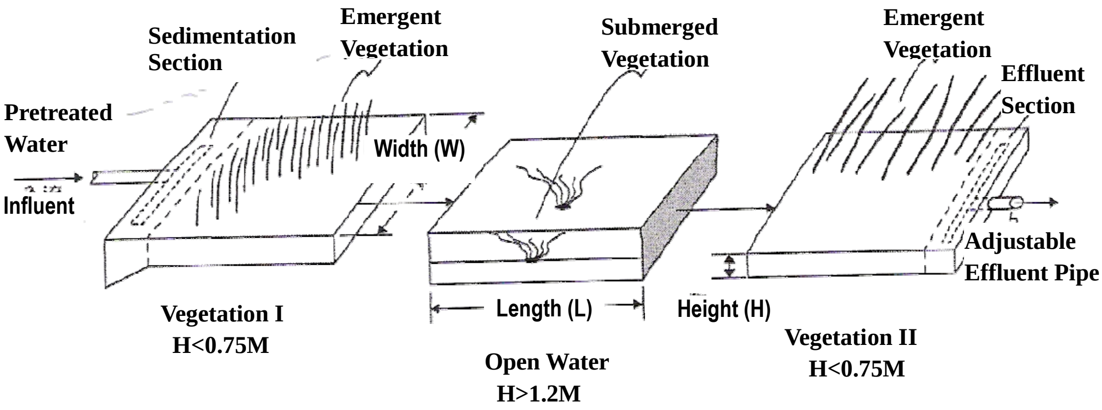

***Figure1:** Three-stage Designing Model for Constructed Wetland s (suggested by US EPA)*

2.2 Land Area

2.2.1 Ecological Corridor

The Cigu Campus was once appropriated by local residents to raise fish and crops, therefore many natural habitats were destroyed and need to be reconstructed. Geographic Information System (GIS) was used to analyze ecological distribution, and the result was adopted for constructing ecological corridor and habitat. For remediation, maintenance and management of eco-environment and habitat reconstruction, eco-engineering approach was utilized. Shian-De Lin (2001) proposed his design of ecological corridor which is mainly composed of hedges, water ways, levees, roads and slope protection. Yet green belt and corridor does not have to be a continuous, sometimes it can be configured as checker-board-like spots for wildlife to move from one spot to another. Lin's design was based on the four principles of “Island Biogeography Theory" (Figure2), the foundation of eco-green network. The primary effects of the theory are: (1)Area Effects: The larger the green space, the more animal and vegetation will be conserved. (2)Edge Effects: If the edge of a green space is longer, it will receive more foreign impact. Given identical area, a circular one is better than a long and narrow one, while a square one is superior to a rectangular one. (3)Distance Effects: The closer the distance between green spaces, the easier for wildlife to migrate. (4)Connection Effects: When a great number of green spaces are inter-connected with zonal green corridors, wildlife's migration will be accelerated. The green corridor and space along the brooks can provide their important functions. Besides, irregularly configured green spaces will affect wildlife's migration, forage and courtship, even gene flow. According to German scholar Wildermuth H. (1980), animals can not leave well-covered green space too far (Table 1). This can be used as the basis for the configuring green belts within the campus.

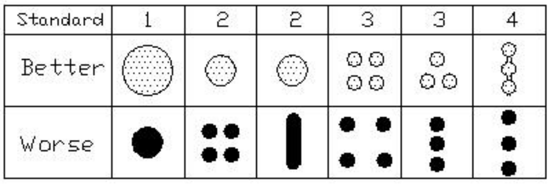

Figure 2: *Theory of Island Biogeography in Green Space Ecology*

Table 1. Maximum Movement of Animals Leaving Covered Green Space

Animals	*Beetle*	*Ant*	*Shrike*	*Chinese Bulbul*	*Frog*	*Shrew*	*Chinese Mink*	*Fox*	*Raccoon Dog*
Movement	50 m	50 m	50 m	150 m	150 m	200 m	250 m	300 m	1 km

Source: Shian-De Lin , 2001

2.2.2 Soil Salinity Testing

As the campus is situated near littoral area, for probing into the soil salinity and ensuring survival rate of planting, test method for chloride in water -- mercuric nitrate titration method, NIEA W406.52C, was adopted as a way to find out the soil salinity as well as monitor the environment, in order to provide strategies for growing salt-tolerant plants.

3. RESEARCH PROCESS AND RESULT

3.1 Flooding Area

The waters surrounding the campus were analyzed with FLO-2D, a 2-dimentional dynamic flood and mudflow routing model, to probe into the inundation potential in West Campus. The result (Figure 3) was adopted for setting up flood detention reservoirs, fish ponds, wetlands and marsh banks. With the assessment by FLO-2D and the observation on 100-year recurrence interval of the flooding area in West Campus before and after its land grading, it showed that flooding frequently occurred in the north-west corner of West Campus with a maximum depth of 1.5 meters.
Therefore the flood detention reservoir with 7.1 hectares of area and 1.5 meters in depth was set in this area for flood mitigation. It lowered the depth of flooding in west campus from 75 cm to 25 cm; if operated in conjunction with a fine drainage and fish pond water level control system, the flooding problem will be solved. Flood detention reservoir is curved and irregular in shape to extend the length of its void-structured bank. Dead woods and rock piles were placed in the reservoir to provide habitat for wildlife. In terms of water source and vegetation management, clean and stable water sources should be provided in order to maintain a diversified eco-system.

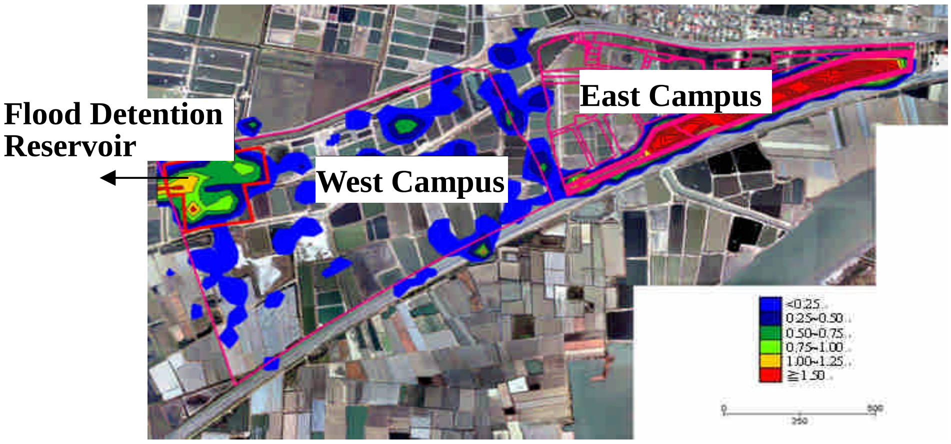

Figure 3: *Flooding Area in Cigu Campus, NUTN, Based on 100-year Recurrence Interval*

3.2 Tide level Observation at Tidal Ditch

The tidal ditch was built to stop water from flooding over the bank protection during high tide or high rainfall. Six water level sensors were installed on the south and north of Cigu Campus; 54 monitoring tests were undertaken from July 2007 to June 2008. (Table2) When typhoon Wutip came in August, 2007, sensor No.5 in the south of West Campus reached a highest record of 77 cm. The campus site engages with the outer branches of Zengwun River here, yet draining water away is not a problem. Overall assessment showed that tidal range at the ditch will be larger if torrential rain sweeps, but smaller, only about 20 to 30 cm when affected by daily tidal waves. The research suggested that the height of bank protection along tidal ditch at the south side should be over the highest water level record while the coefficient of safety should be also higher in order to keep the campus safe.

Table 2. A Comparison of Elevations of Tide at the Tidal Ditch

Sensor \ Elevation \ Times	1~6	7~12	13~18	19~24	25~30	31~36	37~42	43~48	49~54	EL highest	EL ranking
1	0.893	0.733	0.693	1.003	0.873	0.823	0.823	0.773	0.673	1.003	6
2	0.908	0.868	0.838	1.108	1.108	1.108	0.388	0.838	0.388	1.108	5
3	1.57	1.23	1.32	1.65	1.44	1.33	1.28	1.18	0.58	1.65	3
4	1.626	1.246	1.316	1.676	1.536	1.376	1.686	1.266	1.096	1.686	2
5	1.7	1.08	1.3	1.69	1.44	1.27	1.46	1.2	1.1	1.7	1
6	0.907	0.377	0.677	0.877	0.857	0.787	1.127	0.587	0.727	1.127	4

EL: Sea Level Elevation System

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3.3 The Design of Constructed wetland

The constructed wetland was built to treat the wastewater generated by nearly 7,000 students in East Campus. As the sewage discharge is located at the southwest of East Campus, the constructed wetland in West Campus is positioned close to the East Campus. According to the wastewater quality in East Campus (Table3), influent wastewater is 1000 m3/day while Biological Oxygen Demand (BOD) is 160.0mg/L; the flow rate of effluent and reclaimed water is 999.8 m^3/day and the BOD is 8.0mg/L after wastewater treatment as demanded by regulation. Campbell (1999) formula was adopted for calculating the area of constructed wetland and hydraulic retention time (HRT).

Table 3. Mass Balance Calculation Sheet of Cigu Campus Sewage Treatment Plant

	Point Description	*Source*	*Flow rate*	*BOD*		*TSS*		*TN*		*Remarks*
			m^3/day	*mg/L*	*Kg/day*	*mg/L*	*Kg/day*	*mg/L*	*Kg/day*	
1	*Influent Waste Water*	1	1000.0	160.0	160	160.0	160	40.0	40	
2	*Equalization Tank Effluent*	1+7	1005.9	159.1	160	160.7	162	39.8	40	
3	*Bio-treatment Unit Effluent*	2-4	1003.8	8.0	8.0	8.0	8.1	10.0	10.0	
4	*Waste Sludge*	4	2.1	8.0	0.017	15000	31.6	10.0	0.021	
5	*Effluent and Reclaimed Water*	3-6	999.8	8.0	8.0	8.0	8.0	10.0	10.0	
6	*Dehydrator Filter Rinse Water*	–	4.0	8.0	0.03	8.0	0.03	10.0	0.04	
7	*Dehydrator Unit Filtrate and Rinse Water*	4+6-8	5.91	8.2	0.05	272.8	1.61	10.3	0.06	
8	*Dehydrated Sludge Cake*	–	0.19	–	–	–	30.0	–	–	

Source: NUTN, 2008

$$As= \frac{Q(\ln Co- \ln Ce)}{Kt\times D\times N} \quad \text{---- Equation (1)} \qquad As= \frac{1000(\ln 160-\ln 8)}{0.983\times 0.4\times 0.65}$$

$$HRT= V/ Q= As\times D\times N/ Q \quad \text{---- Equation (2)} \qquad HRT= 11721\times 0.4\times 0.65/ 1000$$

In Equation (1): As= Wetlands Area =11,721 m^2
Q= Flow Rate of Influent Waste Water =1,000 m^3/day
Co= Influent BOD Concentration 160mg/L
Ce= Effluent BOD Concentration 8mg/L
Kt= Removal Rate Constant =0.983
D= Depth (m) =0.4
N= Void Ratio (wetlands with lush vegetation, set to 0.65)
In Equation (2): HRT= Hydraulic Retention Time=3 days
V = Volume (m^3)=11,721*0.4*0.65
Q= Flow Rate of Influent Waste Water =1,000 m^3/day

Setting influent waste water flow rate to 1,000 m^3/day in East Campus as a standard, 1.2 hectares of constructed wetlands should be needed in West Campus, and should be further expended for eco-landscaping. The wetland should be built by stage: 2 hectares in first stage and 4 hectares in second stage. There are free water surface (FWS) and subsurface flow (SSF) system for constructed wetland, but NUTN adopted FWS system as SSF system needed to backfilled the wetland with large amount of sand and stones and would be overly artificial, uneconomical, and difficult to keep clean. FWS system consists of influent inlet, vegetation area I, open water, vegetation area II and effluent outlet. (Figure4) Referring to the decontamination and degradation ability of constructed wetland toward nitrogen, phosphorous, SS, BOD and COD, the Aquatic vegetation planted was shown in Table 4 as suggested by Cing-Guang Wun (2007). According to US EPA, 4 to15 days of HRT is suggested. If the HRT is longer, the pollutant concentration in effluent will be lower and water quality will be better. Yet water treatment capacity will be reduced (Meng-Heng Shih & Shian-De Lin 2006) .

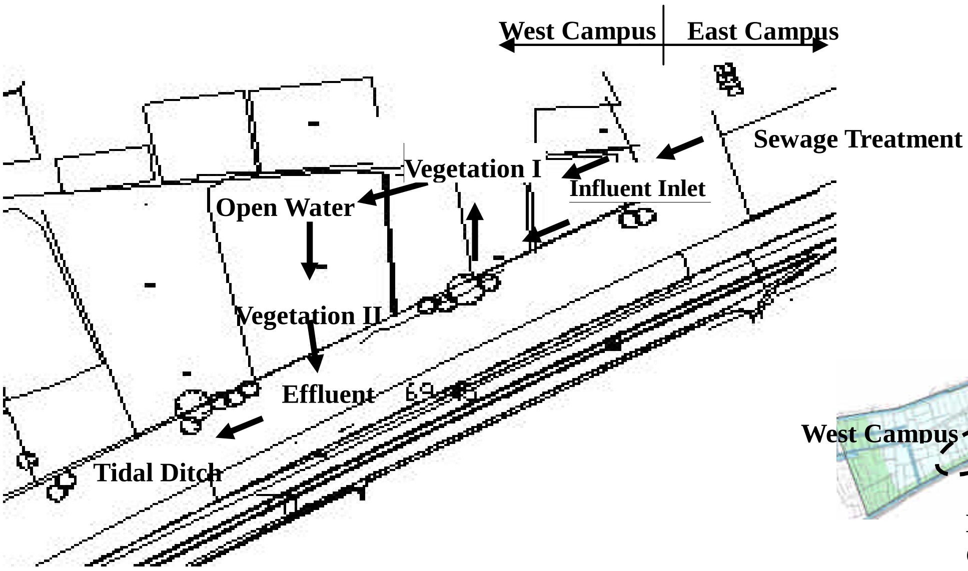

Figure 4: *Plan of Constructed Wetland*

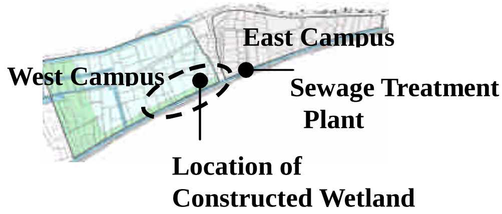

Figure 5: *Location of Constructed Wetland*

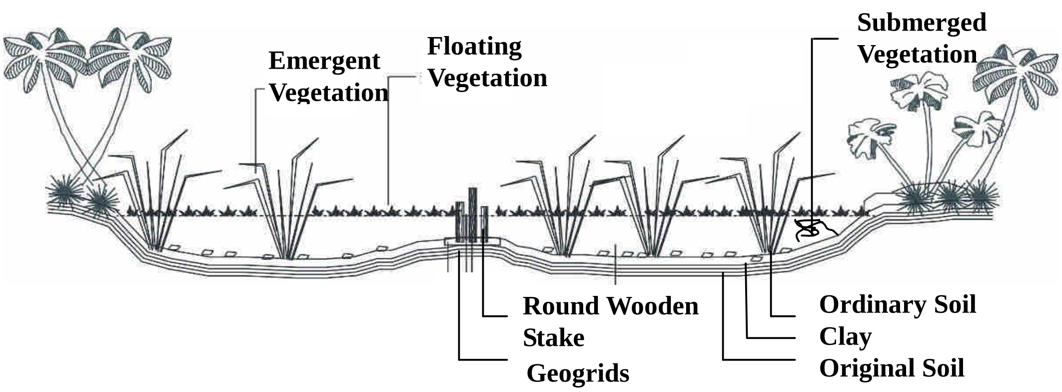

Figure 6: *A Cross-sectional View of Constructed Wetland*

Table 4. Recommendation for Wetland Vegitation

Zone	*Category*	*Recommendation*	*Spacing for Each Plant*	*Depth of Water*	*Days Retaining*
Vegetation I	Emergent Vegetation	Cattail, Cyperus Alternifolius, Reed	20cm	40cm	2
	Floating Vegetation	Water Hyacinth, Water Lettuce	30cm		
Open Water	Emergent Vegetation	Ludwigia X Taiwanensis Peng, Water Chestnut, Phragmites vallatoria	30cm	130cm	2
	Floating Vegetation	Clover Fern, Trapa japonica, Yellow Water Lily			
	Submerged Vegetation	Potamogeton Crispus (Curly Pondweed), Ottelia alismoides, Limnophila trichophylla Komarov,			
Vegetation II	Emergent Vegetation	Hydrophila pogonocalyx Hayata, Ludwigia octovalis (Jacq.) Raven	20cm	40m	2
	Floating Vegetation	Azolla, Common Duckweed, water spinach	30cm		

Source: Cing-Guang Wun ,2007, Meng-Heng Shih , Shian-De Lin ,2006 & EPA,2000

3.4 Result of Geographic Information System (GIS)

As for land area, the research adopted GIS to find out the distribution of various land characteristics within Cigu Campus, and worked in conjunction with the eco-island theory and the sustainable eco-network philosophy concerning green space, in order to form a remediation plan for ecological green space in land area. According to the result, in West Campus, the places with more green belts are flood detention reservoirs on the northwest, the currently disused nursery garden on the southwest, constructed wetland southeast, and the existing fish ponds and marsh on the northeast. As for geological distribution rate referring to GIS statistics, 41.6 hectares of fish ponds accounted for 51% , 26.1 hectares of wasteland for 32%, 7.3 hectares of dry farmland for 9%, 3.3 hectares of roads for 4%, 1.6 hectares green belts for 2%, and 1.5 hectares of tidal ditch for 2%. (Figure7) The construction of ecological green net in land area is conformed to the distribution of above-mentioned green belts and the plan for roadside vegetation and ecological island.

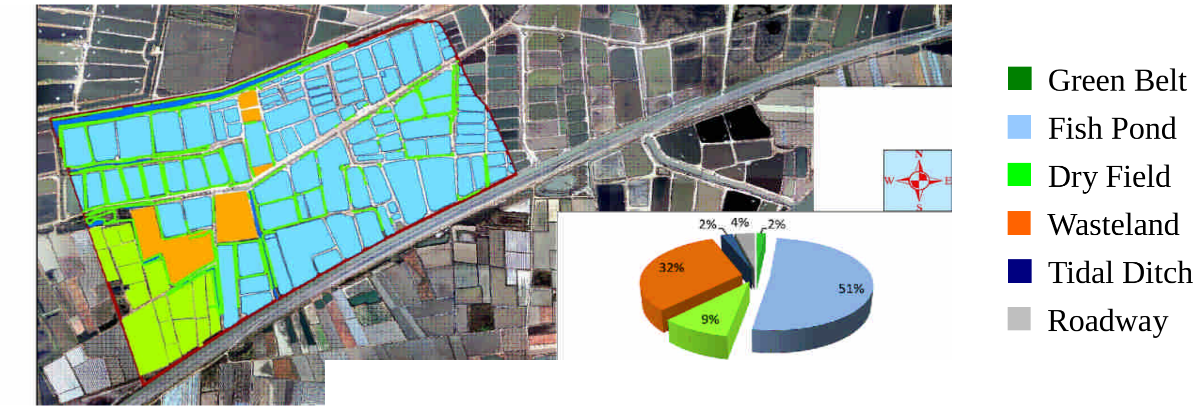

Figure 7: *GIS Analysis of West Campus, NUTN*

3-5 Salt Injury Test Result on and Countermeasures

Jing-Ping Yang (2002) indicated that salt tolerances among common trees are varied; some will die if it is over 3 g/kg. In this research, soil salinity was tested for totally 12 times at 6 test spots in Cigu Campus most of the test values were higher than 3 g/kg. (Table5) which indicated that vegetation in Cigu Campus should be with higher salt tolerance to survive referring to Shin-Huei Lin's and Chun-Yen Chang's (2005) recommendation. (Table6) The strategy for soil salinity control was that for newly planted trees, For soil salinization, applicable countermeasures are: (1)Soil Washing: soak soil into water for a period of time repeatedly to remove salt from soil.(2)Soil Modification: replace the soil that accumulated salt with salt-free soil.(3)Planting Cleaning Crops: rotate cropping to reduce soil salinity.

Table5. Soil Salinity Test Record

Sampling Location		*Test Items Salinity in Soil (g/kg)* 07/10/2007	12/12/2007	*Remarks*
East Campus	*A*	19.4	18.5	
	B	15.3	11.6	
	C	11.8	14.6	
West Campus	*D*	10.3	10.3	
	E	3.47	6.87	
	F	1.25	9.16	

Source: Tsing-Hua Technology Co. Ltd., 2009

Table 6. Recommendation for Salt Tolerant Vegetation

Tree Species	*Vegitation Recommended*
Trees	Portia Tree, China Tree, Indian Almond, 、Pongam Tree, Odollam Erberus-tree, Hernandia Nymphiifolia (Presl) Kubi, Ring-cupped Oak, Formosan Aglaia, Indiapoon Beautyleaf, Formosan Nato Tree, Pittosporum Pentandrum, Phoenix Hanceana Naudin, Beefwood, Pithecellobium Dulce, Washingtonia Filieara, Calocedrus Formosana, Excoecaria Agallocha, Liodendron Formosanum, Distylium racemosum Sieb. & Zucc., Idesia polycarpa Maxim, Pourthiaea lucida Decaisne
Bushes	Lumnitzera racemosa Willd, Screw pine Scaevol, Beach Morning-glory, Slivery Messerschmida, Five-stamens china laurel, Boxleaf Eugenia, Colubrina Asiatica
Ground Cover	Ruellia brittoniana Leonard, Sesuvium portulacastrum (L.) L., torpedograss, Paspalum vaginatum Sw., Wedelia biflora (L.) DC., Wild Morning-glory, Operculine Tuperthum. (L.) S. Mansq.

Source: Shin-Huei Lin & Chun-Yen Chang, 2005

3.6 Zoning Plan, Road System and Windbreak Forest

The research avoided changing the original terrain features, thus the campus was divided into 3 major areas: "Ecological Conservation Park", "Research Park" and "Education Park" (Figure8) with regard to terrain features. Among them the Ecological Conservation Park was further divided into nursery garden green area, ecological lake area and mangrove area; Research Park was zoned as constructed wetland and solar power research area; Education Park was separated into wind power research area and windbreak forest area. (Figure9)

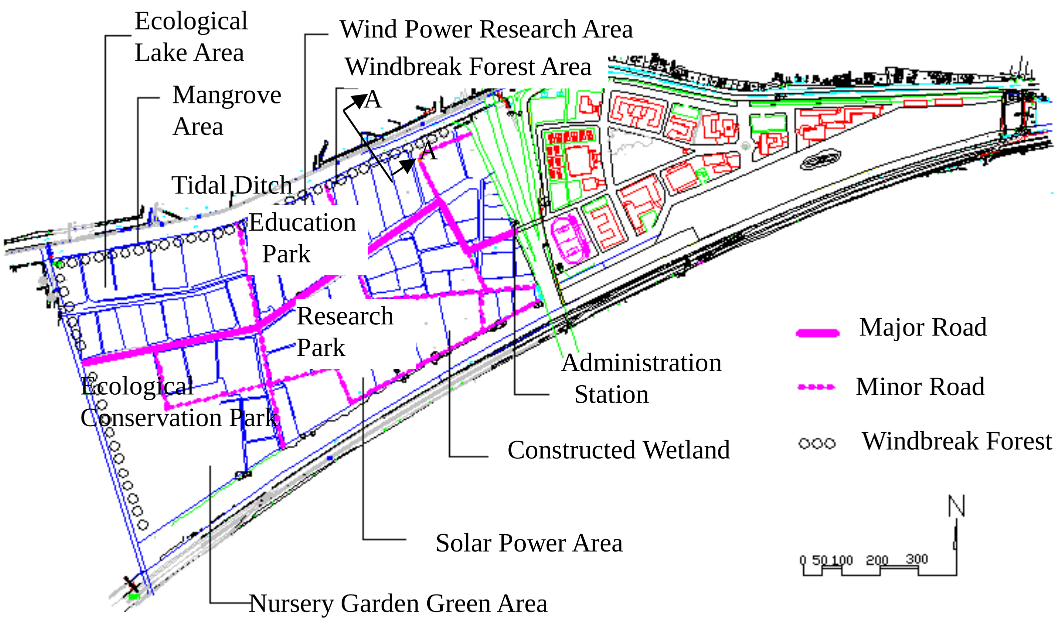

Figure 8: *Land-use Zoning Plan of Cigu Campus, NUTN*

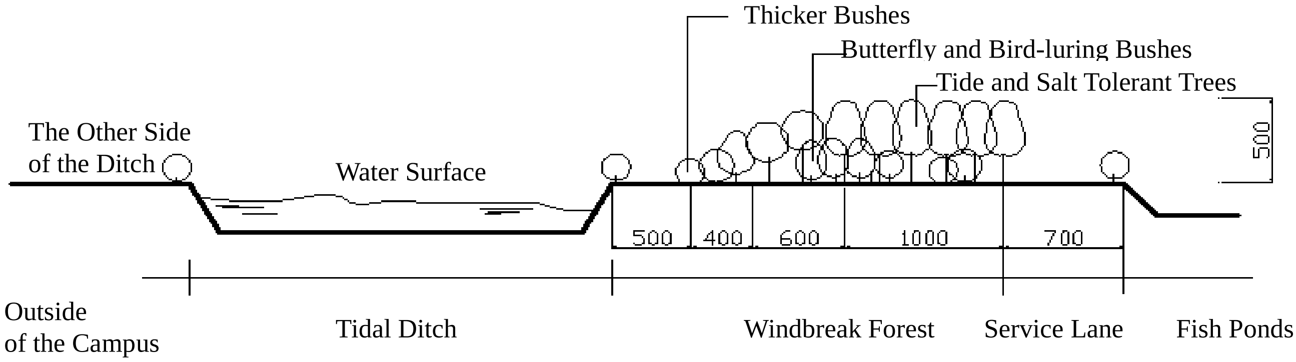

Figure 9: *Cross-Section Diagram of Windbreak Forest A-A*

4. CONCLUSION

The research utilizes the concept of the creation and recovery of sustainable ecological system with ecological engineering to set up a mechanism for ecological campus maintenance and management. As for the aquatic eco-engineering, the most critical issue is the flood within the campus. In addition to the construction from flood-controlling riverbank at the outter rim of the campus site to the flood detention reservoirs at the possible flooding area, water level observation devices should be installed for permanent water level monitoring. Although wastewater treatment system using aquatic plants as filter can provide both landscaping and water treatment, due to ill management, it frequently causes water eutrophication that contains overly high content of nutrient salts such as nitrogen and phosphorus, and results in mass-production of algae covering water surface and consequently death to plants and aquatics from lacking of oxygen. Therefore mechanical filtering system can be added at the wastewater inlets as supplemental equipment for wastewater treatment. For terrestrial eco-engineering, the idea is to construct habitats ideal for local wildlife; that is to say to configure diversified vegetation communities based on "eco-island theory" in order to set up ecological corridors for wild animal. However, in addition to setting up windbreak forests and soil improvement for countering local sea wind and soil salinity, plants in unfavorable growing condition should be replaced periodically, so as to maintain a well-preserved eco-system and beautiful landscape. Overall, the critical work of ecological campus management and maintenance should be done by setting up a perfect ecological monitoring system, for both aquatic and terrestrial areas, as a early warning measure for following changes and ill management of the campus environment, in order to support the campus's sustainable development.

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