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Application and Maintenance Strategies for Eco-Friendly Facilities in Landscape Trees Nurseries

Young Sun Seok[1], O Man Kwon[2], and Yun Eui Choi[3,*]
[1]*Carbon Neutrality Support Center, Yongin Research Institute, Yongin 16976, Republic of Korea*
[2]*Department of Architecture Design, Kyungdong University, Yangjui, 11458, Republic of Korea*
[3]*Department of Landscape Architecture, Kangwon National University, Chuncheon 24341, Republic of Korea*

Abstract

Recently, as the number of landscaping plant nurseries have increased, environmental problems such as topographical damage due to indiscriminate changes in land use, increased non-point pollution, and increased impervious areas are also occurring. In this study, we propose eco-friendly facilities and a detailed maintenance manual that can enhance the eco-friendliness and scenic beauty of landscaping plant nurseries that are increasingly located near cities. By exploring previous reports on eco-friendly facilities and related laws, we cataloged the types of eco-friendly facilities, and by referring to examples of eco-friendly facilities introduced in overseas cases and the environmental functions of agriculture, we cataloged the types of eco-friendly facilities suitable for introduction in plant nurseries. The selected facilities are rain gardens, tree boxes, vegetated filter beds, bio-retention, infiltration trench, infiltration tanks, permeable pavements, and sand filtration systems. The maintenance tasks of eco-friendly facilities were categorized and management plans were proposed, which is expected to be utilized as a basic data to prepare eco-friendly space planning and operation management plans when creating a landscape plant nurseries in the future.

Key Words: multifunctionality in agriculture, detention facility, vegetated facility, infiltration facility, equipment-based facility

Introduction

The flower, horticulture, and landscaping tree nurseries and markets are developing as urban green and landscape development projects expand to address various environmental problems such as climate change response, fine dust reduction, and water circulation management, and improve urban brand value as a garden city. In particular, the creation of horticultural complex, landscaping plant nurseries, flower and seedling distribution, and sales complex is becoming active in suburban areas where distribution to cities is advantageous. However, as the number of agricultural facilities increases rapidly, environmental problems such as topographic damage, increased non-point pollution, and increased impermeable area due to indiscriminate land-use changes are occurring (Pluimers et al. 2000; Wang et al. 2009; Wainwright et al. 2014). In particular, facility horticultural complexes that focus only on plant productivity cause lower groundwater cultivation functions, energy loss problems (Son et al. 2018), and water pollution (Son et al.

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Corresponding author: Yun Eui Choi
Department of Landscape Architecture, Kangwon National University, Chuncheon 24341, Republic of Korea
Tel: +82-33-250-8343, E-mail: uni313@kangwon.ac.kr

2019). In addition, the natural and positive landscape unique to rural areas is changing into a negative image due to the increase in facility-type landscaping water production facilities such as greenhouses and greenhouses (Kong et al. 2017).

As landscape tree production facilities negatively affect the environment and visitor perception, there are cases in the United States and the Netherlands where eco-friendly facilities are introduced and operated in plant production complexes as an alternative to overcome this. Gotham Greens in the United States is an urban agricultural farm established in Brooklyn, New York, that uses renewable energy to produce various plants in greenhouses installed in individual farm buildings, giving consumers a positive image of eco-friendly cultivation and actively contributing to agricultural education and environmental projects by operating free farm tour programs (Gotham Greens 2024). Little Leaf Farms in the United States operates eco-friendly facilities through the establishment of a rainwater collection and recirculation system and a virtuous cycle and reuse system of nutrients to save water and energy consumed in an agricultural environment (Little Leaf Farms 2021).

North Creek Nurseries in the United States is a large-scale sapling and horticultural cultivation site and a wholesale and retail sales facility. In addition to the production and sale of various horticultural and landscaping plant, the eco-friendliness of the cultivated land is increased through the operation of test gardens such as rain gardens, ecological waterways, and rooftop garden, and education such as water circulation and rainwater recycling is provided to retail customers (Delilah Onofrey 2011). GROWx in the Netherlands is the first high-tech vertical farm in Amsterdam established with the aim of developing sustainable urban agriculture. It is attracting attention as an advanced example for supplying fresh crops to consumers in the city and encouraging eco-friendly urban farming methods (Akka Architects 2019). As such, overseas eco-friendly facilities such as rain gardens, ecological waterways, and rooftop garden facilities are introduced and operated as a way to cope with water pollution and increased water use caused by the production of landscaping plant. Eco-friendly facilities introduced to overseas landscaping tree agricultural facilities are low-impact development (LID) that is commonly applied for urban non-point pollution source management or water circulation system maintenance. Therefore, in Korea, the introduction of LID facilities can be considered as a way to increase the eco-friendliness and landscape of landscaping tree agricultural facilities. LID facilities are highly likely to be used in Korea and other countries. However, overseas, it has a great influence on agricultural sites such as urban planning and environmental policies, but in Korea, discussions on introducing LID facilities in agricultural sites are insufficient. In addition, there are a number of manuals on application plans and design standards for the introduction of LID facilities. However, most of the contents focused only on the detailed structure of the LID facility or the points to note when installing the LID facility. In other words, in terms of maintenance, only very simple information is provided, so there is a limitation that it is difficult to continuously perform pure functions after introducing the LID facility.

Therefore, in this study, we would like to propose a LID facility and a detailed maintenance manual that can enhance eco-friendliness and landscape in the recently increasing landscaping plant nurseries in the suburbs of the city. Through this, it is expected that it can be used as basic data to prepare eco-friendly space plans and operational management plans when creating the landscaping plant nurseries in the future.

Materials and Methods

Scope of the research

In this study, the landscape tree plant production complex was defined as "a place to cultivate and distribute plants grown for urban environment improvement and landscape improvement such as flowers, horticulture, garden plants, and sapling." In addition, for the eco-friendly maintenance of the plant production complex, the introduction of the LID facility was proposed as a way to manage environmental pollutants caused by fertilizers and pesticides, which are necessary resources for improving water circulation and plant production, and the scope of the study was limited to highly relevant LID facilities based on previous studies Ji et al. (2023).

Research methods

In order to develop an eco-friendly facility maintenance

manual for plant production complexes, this study first cataloged the types of LID by exploring prior reports on LID facilities, related laws, examples of introducing eco-friendly facilities in overseas cases, and environmental functions of agriculture (flood control effect, water resource cultivation, soil loss reduction, air purification, climate mitigation, and biodiversity). A total of 515 national policy reports on LID facilities were collected through academic research information services (KERIS 2024) and the National Assembly Library (The National Assembly Library of the Republic of Korea 2024), and related laws collected and reviewed the installation standards and management and operation standards for each LID facility of the Water Environment Conservation Act at the National Legal Information Center (Korea Ministry of Government Legislation. Water Environment Conservation Act 2024). In particular, LID facilities were selected by focusing on studies on the characteristics and functions of LID facilities suitable for introduction into plant production complexes. In particular, after focusing on studies on the characteristics and functions of LID facilities suitable for introduction into plant production complexes, LID facilities were selected.

Second, after collecting and reviewing information on maintenance methods by exploring prior manuals and similar guideline reports related to selected LID facilities, maintenance items for LID facilities were selected. The data used for the review include non-point pollution commentary and installation and management and operation manual (National Institute of Environmental Research, 2011; Ministry of Environment 2014, 2015, 2020), Korean LID monitoring and maintenance guidelines and manual (Ministry of Land, Infrastructure and Transport 2018a; 2018b), introduction of LID techniques (Korea Land and Housing Corporation 2018), manual of water treatment standards (Ministry of Environment 2013) (Table 1). Maintenance items for LID facilities were constructed by exploring the type and outline of facility, site condition, and inspection items through these documents.

Third, the maintenance work of LID facilities was classified and a manual for each LID facility was proposed. The maintenance work classification of LID facilities was made by comparing and analyzing prior maintenance guidelines, and a manual for each LID facility was proposed based on this.

Results and Discussion

Types of LID facilities suitable for plant production complexes

According to a list of the types of LID facilities through a review of previous studies, detention facility, infiltration facility, vegetated facility, equipment-based facility, and others (Table 2).

Among them, facilities that are highly related to the envi-

Table 1. List of manuals and guideline reports related to LID facilities

References	LID facilities	Contents
Korea Land and Housing Corporation (2018)	Rain garden	Facility overview
Ministry of Environment (2013)	Sand filtration system	Inspection checklist and activities
Ministry of Environment (2014)	Bio retention	Facility overview
Ministry of Environment (2015)	Bio retention, grassed swales, tree box	Site conditions, inspection checklist and activities, inspection cycle
Ministry of Environment (2020)	Bio retention, grassed swales, tree box, infiltration trench	Facility overview, maintenance overview, site conditions, inspection checklist and activities, inspection cycle
Ministry of Land, Infrastructure and Transport (2018a)	Grassed swales	Maintenance overview
Ministry of Land, Infrastructure and Transport (2018b)	Tree box, rain garden, infiltration tanks, permeable pavement	Facility overview, maintenance overview
National Institute of Environmental Research (2011)	Grassed swales, rain garden, infiltration trench, infiltration tanks, permeable pavement, sand filtration system	Site conditions, inspection checklist and activities, inspection cycle

Table 2. The types of lid facilities

Division	Detention facility	Infiltration facility	Vegetated facility	Equipment-based facility	Etc.
Type	Detention basin	Permeable block	Tree box	Sand filtration systems	Rainwater harvesting system
	Underground detention basin	Infiltration trench	Grassed swales	Manufactured filtration system	Rainwater cistern
	Constructed wetlands	Infiltration tanks	Vegetated filter bed	-	Screen facility
	Rain garden	Infiltration detention basin	Bioretention	-	Swale facility
	-	Infiltration basin	Green roof	-	-
	-	Permeable pavement	Green wall	-	-

Table 3. lid facilities suitable forlandscaping plant nurseries

Multifunctionality in agriculture	Detention facility	Vegetated facility				Infiltration facility			Equipment-based facility
	Rain garden	Tree box	Grassed swales	Vegetated filter bed	Bio-Retention	Infiltration trench	Infiltration tanks	Permeable pavement	Sand filtration systems
Flood control	○	-	○	○	○	○	○	○	○
Water resources recharge	-	○	○	-	○	○	○	○	○
Water quality improvement	○	○	○	○	○	○	○	○	○
Soil erosion reduction	○	-	-	-	○	-	-	-	-
Mitigation of heat island effect	○	-	○	○	○	-	-	-	-
Carbon sequestration	○	-	○	○	○	-	-	○	-
Biodiversity	○	-	○	○	○	-	-	-	-

ronmental functions of agriculture (Kim et al. 2017) were selected and reviewed, and the LID facilities suitable for introduction into the plant production complex were finally derived as shown in Table 3. A total of nine LID facilities were selected. Classified by facility, it is detention facility (rain garden), vegetated facility (tree box, grassed swales, vegetated filter bed, bio-retention), infiltration facility (infiltration trench, infiltration tanks, permeable pavement), and equipment-based facility (sand filtration systems).

Selection of maintenance and management items for LID facilities

As a result of classifying the maintenance items of eco-friendly facilities for the LID facility into similar contents, there were four major categories (Table 4). First, it was classified into the contents of the inspection for accumulation of sediments and waste in the facility and the periodic removal part and was named waste material management. Second, it was classified into the frequent irrigation, weed and pest control, checking the normal growth of trees, replanting, winterizing plants, lawn care, pruning, removal of dead tree, fertilization, removal of invasive species, and was named vegetation management. Third, it was divided into the ground subsidence inspection, soil replacement, checking for water pollution and improvement, and drainage inspection, and was named soil and water management. Fourth, it was divided into the ensuring the proper operation of facilities, inspecting problem areas and identifying causes when issues arise, preventing structural damage through replacement and leak prevention, and employing specialists for tasks requiring expertise, and was named repair and reinforcement management.

Table 4. Classification of LID facility management tasks

Division	Tasks of inspection and maintenance	
Waste material	Checking for waste accumulation	
	Regular removal of waste	
Vegetation	Frequent irrigation	Weed and pest control
	Checking the normal growth of trees	Replanting
	Winterizing plants	Lawn care
	Pruning	Removal of dead tree
	Fertilization	Removal of invasive species
Soil and water	Ground subsidence inspection	Soil replacement
	Checking for water pollution and improvement	Drainage inspection
Repair and reinforcement	Ensuring the proper operation of facilities	
	Inspecting problem areas and identifying causes when issues arise	
	Preventing structural damage through replacement and leak prevention	
	Employing specialists for tasks requiring expertise	

Table 5. Maintenance guideline for rain garden

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Drainage basin, inflow, and outflow litter	Removal	Once a month
Vegetation	Growth status	Poor condition of vegetation covering and growth	Replacement and reinforcement planting	Twice a year
		Dry season	Irrigation	Regular check-up
	Pests and invasive species	Appearance of invasive species such as pests and pathogens, diseased plants, etc.	Removal	Twice a year
Soil and water	Erosion	Bank erosion	Erosion prevention construction	Once a year
	Trampling	Surface soil clogging	Cleaning, especially frequent cleaning in areas with heavy traffic	Regular check-up
		Impairment of infiltration and percolation capacity of planting soil (due to soil compaction, etc.)	Replacement	Once a year
	Freezing	Soil freezing during the winter season	Maintenance to prevent runoff from flowing into the soil of vegetated areas	Twice in the winter
	Waterways	Sediment in inflow and outflow waterways	Sediment removal	Once a month
	Drainage	Drainage status within 24 hours after rainfall	Take measures to ensure smooth drainage	Immediately after rainfall
Repair and reinforcement	Equipment and structure	Rainy season, flood warning issued or completion of earthwork around the facility	Overall inspection of the facility for any abnormalities	Upon occurrence of the event
		Damage to structures such as inflow and outflow facilities	Repair	Twice a year

How to apply and maintain for LID facilities in landscaping plant nurseries

The application and maintenance plan of LID facilities in the landscaping plant nurseries was derived. Based on the characteristics of LID facilities, the application plan for landscaping plant nurseries was presented. In the case of the maintenance plan, maintenance elements were catego-

rized according to the type of maintenance, and specific site conditions to be checked for each element and the inspection cycle were presented.

Rain gardens

Rain gardens are facilities that collect rainfall runoff from impervious surfaces such as roofs and roads, infiltrate and filter it through soil and vegetation to control rainfall runoff and reduce non-point source pollution (National Institute of Environmental Research 2011; Ministry of Land Infrastructure and Transport 2018b). Rain gardens can be utilized as a decentralized stormwater management method in large drainage areas due to their functions such as pollutant treatment, groundwater recharge, habitat provision for biodiversity, and landscape improvement. Rain gardens consist of inflow areas, shallow planting spaces, mulch, gravel filtration layers, underground drainage systems, overflow systems for handling excessive rainfall, vegetation, and more. Therefore, it is essential to prioritize the management of proper drainage, healthy vegetation growth, and soil erosion prevention. In particular, the subsoil structure consists of planting soil, sand layer, and gravel layer, and attention should be paid to the filtration function and contamination of each soil layer.

Maintenance of rain gardens is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 5). Firstly, waste management involves monthly inspections to check the condition of debris in the inflow and outflow areas and to carry out removal activities as necessary.

Table 6. Maintenance guideline for tree box

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Accumulation of litter	Removal	During road cleaning
	Sediment	A decrease of more than 50% in flow capacity due to sedimentation	Removal	Regular check-up
Vegetation	Growth status	Presence of excessive growth of shrubs and presence of dead plants	Pruning of shrubs	Regular check-up
		Excessive growth of shrubs causing the roots inside the tree box to occupy the space meant for soil	Transplanting	Regular check-up
		Weed growth	Removal	Once a month
		Drought period, severe dry season	Watering	Once a month
		Exposure of soil due to lack of ground cover vegetation	Re-seeding	Once a month
		Occurrence of obstacles such as rocks and debris	Removal and cleaning	Once a month
	Pests and invasive species	Invasion of harmful vegetation	Removal	Regular check-up
Soil and water	Pollution	Soil pollution	Disposal and recharge	Regular check-up
	Erosion	Erosion and gullies	Re-vegetation to ensure a minimum depth of 7 cm when soil cover is less than 5 cm due to erosion	Regular check-up
	Stagnant water	Stagnation occurrence	Improvement of drainage	Regular check-up
		Filter media	Full drainage within 24-48 hours after rainfall	Replacement of the upper soil layer to a depth of 7 cm when blockage occurs
Repair and reinforcement	Equipment and structure	Cracks and damage to the upper part of the box, grating, and other structures	Repair	Ad-hoc inspection
		Subsidence of the facility and surrounding area	Reinforcement of subsided area	Ad-hoc inspection

Vegetation management involves biannual inspections to assess the condition and growth of vegetation, with replacement and reinforcement planting carried out as needed. Additionally, watering should be conducted as necessary during dry periods. Inspections for pests and invasive species, including checking for the presence of pests and diseases, should be conducted biannually.

In terms of soil and water management, inspections should be conducted for surface soil layer blockage, erosion, and contamination, as well as deterioration of filtration and infiltration functions of planting soil. Additionally, checks should be performed for soil freezing during the winter season. For waterways, sedimentation in inflow and outflow water should be monitored, and drainage systems should be inspected within 24 hours after rainfall to ensure proper drainage.

Repair and reinforcement management involve inspecting facilities and structures, with a recommended frequency of biannual inspections and repairs as needed for inflow and outflow structures and other facility components.

Tree box

Tree box is typically installed along roadsides for purposes such as initial runoff control, reduction of non-point source pollution, and enhancement of roadside landscaping (Geronimo et al. 2017a). Tree boxes can be installed in landscaping plant nurseries near impermeable surfaces such as roads, sidewalks, and parking lots, substituting for roadside trees.

Maintenance of tree box is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 6). Waste management involves checking for the accumulation of debris and removing waste or reinforcing erosion if sedimentation exceeds 50% of the monthly flow capacity or erosion occurs.

Tree management involves inspecting for excessive growth of shrubs and trees, presence of dead trees, weed occurrence, drought or severe watering periods, lack of ground cover vegetation, presence of debris, and other obstacles. Measures such as pruning, watering, and replanting should be taken accordingly.

Additionally, soil and water management involve inspecting for soil contamination, stagnant water occurrence, and condition of filtration materials. In case of soil contamination, waste removal and recharge should be conducted, drainage should be ensured in case of stagnant water, and in case of blockage, the upper 7 cm of soil layer should be replaced.

Finally, repair and reinforcement management suggest inspecting facilities and structures and performing ongoing maintenance as needed.

Grassed swale

Grassed swale is designed to promote water quality stabilization of nearby rivers by treating non-point source pollutants generated from agricultural areas, roads, forests, residential and commercial zones. Grassed swale can be introduced to prevent non-point source pollutants from landscaping plant nursery from entering nearby rivers. Additionally, grassed swale can be implemented in small green spaces between greenhouses, or areas facing roads and buildings, and existing concrete stormwater drains can be converted into grassed swale.

Maintenance of grassed swale is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 7). Waste management activities include inspecting the accumulation of sedimentation, and whether sedimentation exceeds 10% of the effective capacity of the channel, which involves removing and disposing of sedimentation. Additionally, it is necessary to inspect and remove waste such as garbage and rocks, accumulation at inlets and debris barrier, accumulation in sedimentation and pretreatment areas, accumulation exceeding 10% of the total effective channel capacity, and accumulation exceeding 25% of the facility surface area, and dispose of it appropriately. Furthermore, measures have been implemented to remove sedimentation that hinders vegetation growth or exceeds 25% of the treatment capacity of the grass swale floor due to sedimentation.

For vegetation management, it is proposed to inspect for damage occurrence after seeding or completion of construction, or after the first major rainfall. Maintenance includes checking the height of vegetation (grass) to be maintained between 7-10 cm, assessing if the grass cover is 90% defective, confirming the establishment of planted grass, managing excessive growth of aquatic plants, and inspect-

Table 7. Maintenance guideline for grassed swale

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Accumulation of litter	Removal	Regular check-up
	Sediment	Accumulation at the inlet and debris barrier	Removal	Twice a year
		Accumulation in the sedimentation basin and pre-treatment area	Removal	Twice a year
		Accumulation exceeding 10% of the total effective capacity of the waterway	Removal	Regular check-up
		Accumulation covering more than 25% of the facility surface	Removal	Regular check-up
		Inhibition of vegetation growth due to sediment accumulation	Removal and re-planting	Regular check-up
Vegetation	Growth status	After seed sowing and completion of construction, following the first heavy rainfall	Repair of canal sidewalls and bottom	Upon occurrence of the event
		When grass height is not between 7 to 10 cm	Use of eco-friendly fertilizer or trimming to a height of less than 10 cm (before starting the grass cutting operation, it is essential to remove any debris, and after the operation, ensure that no plant residues enter the waterway)	Regular check-up
		When ground cover grass is more than 90% inadequate	Cause investigation and replanting	After planting
		Insufficient growth of grass	Replacement with a different variety	After planting
	Pests and invasive species	Invasive vegetation cover exceeding 10% or invasion of harmful vegetation	Removal (prohibition of herbicide use) and replanting	Once a year
Soil and water	Trampling	Compaction or consolidation occurrence	Restriction of heavy equipment passage	Regular check-up
	Erosion	Formation of gullies or rills with a depth of more than 5 cm	Maintenance of facility surfaces, reinstallation of flow distribution devices, and replanting	Regular check-up
		Occurrence of erosion, flooding, and channeling in the inundated area	Repair	Twice a year (especially after rainfall)
		Erosion of the channel bed and sidewalls in dry waterways	Repair	Twice a year
		Soil erosion in the treated drainage area	Repair	Twice a year
		Accumulation of 8cm or more in the watercourse or catchment area	Removal	Ad-hoc inspection
	Stagnant water	Drainage time in the dry watercourse exceeds 48 hours	After overturning the sand and soil filtration layer, replant vegetation	Once a month
	Water ways	Channel damage	Stabilization work (such as building retaining walls or laying turf) carried out	Regular check-up

Table 7. Continued

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Repair and reinforcement	Equipment and structure	Accumulation and blockage of sediment in the inlet and flow distribution device	Removal and repair	Once a year
		Accumulation of sediment and waste exceeding 50% of the capacity of the inlet and outlet pipes	Removal and repair	Regular check-up
		Accumulation and blockage of sediment in the level spreader	Removal and repair	Once a year
		Closure of debris barriers	Removal and repair	Once a year
		Damage or breakage of inflow and outflow channels in the pretreatment facility	Repair	Twice a year

ing for invasive vegetation.

Soil and water management involves inspecting and maintaining erosion (including erosion and gullies, erosion, occurrence of flooded areas and channeling, erosion of channel floors and sidewalls in dry channels, erosion of soil in treatment discharge areas, accumulation of 8cm or more in channels or structures), drainage (drainage within 48 hours after rainfall in stagnant water, presence of ponding and stagnation), and channels (maintenance required in erosion-prone areas near channels or outlets during dry periods or for vegetation maintenance, drainage time of dry channels exceeding 48 hours).

Lastly, repair and reinforcement management require inspecting facilities and structures annually or biannually.

Vegetated filter bed

The vegetated filter bed is a facility designed to remove non-point source pollutants through plant filtration and soil infiltration, by creating a wide grassy area with dense vegetation on a uniform sloping surface. In landscaping plant nurseries, vegetative filter bed can be implemented on slopes to provide slope stabilization and perform filtration functions. Vegetative filter bed can also be installed alongside artificial wetlands to reduce stormwater runoff and provide a space for visitors to rest. Vegetative filter beds are ideally installed on gently sloping terrain, as installing them on excessively flat surfaces can lead to water stagnation. A slope of 1-2% is recommended. Slopes exceeding a 1:4 ratio or steep terrains are unsuitable. The width of the vegetative filter bed should be at least 0.6 meters, with a soil depth of at least 0.3 meters.

Maintenance of vegetated filter bed is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 8).

Waste management involves checking for sediment accumulation of 5 cm or more from the facility surface, accumulation of 25% or more of the facility surface area, and assessing whether the accumulation of sediment inhibits vegetation growth. If necessary, sediment removal and vegetation reseeding should be implemented. Additionally, sediment accumulation and closure of the inlet and outlet spreaders, distribution devices, and screens should be checked. If sediment accumulation exceeds 50% of the capacity of the inlet and outlet pipes, sediment removal and maintenance are required.

In vegetation management, an annual inspection is conducted for invasive vegetation cover exceeding 10% or invasion of harmful vegetation. This inspection also includes maintaining vegetation height between 5 to 10 cm and addressing cases where grass cover is below 90%. Actions such as vegetation removal and species replacement are part of this process.

Soil and water management involves conducting monthly inspections for soil erosion (presence of gullies or formation of rills deeper than 5 cm) and drainage (complete drainage within 48 hours after rainfall cessation, absence of waterlogging, and stagnation).

Table 8. Maintenance guideline for vegetated filter bed

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Accumulation of litter	Removal	Once a month
	Sediment	Deposition of sediment accumulating more than 5cm from the surface of the facility	Removal	
		Accumulation of sediment covering more than 25% of the facility surface	Removal	
		Accumulation and blockage of sediment in the spreader due to inflow volume	Removal and repair	Once a year (twice in the first year)
		Accumulation and clogging of sediment in the flow distribution device and screen	Removal and repair	Once a month
		Accumulation of sediment and waste exceeding 50% of the inflow and outflow or pipe capacity	Removal and repair	Once a month
Vegetation	Growth status	Invasive vegetation cover exceeding 10% or invasion of harmful vegetation	Removal (prohibition of herbicide use) and replanting	Once a year
		Insufficient growth of grass	Replacement with a different variety	Once a year (twice in the first year)
		When grass height is not between 5 to 10 cm	Use of eco-friendly fertilizer or trimming to a height of less than 10 cm	Twice in the summer
		When ground cover grass is more than 90% inadequate	Cause investigation and replanting	After planting
Soil and water	Erosion	Formation of gullies or rills with a depth of more than 5 cm	Maintenance of facility surfaces, reinstallation of flow distribution devices, and replanting	Regular check-up
	Drainage	Full drainage within 48 hours after rainfall	Replacement of the upper soil layer to a depth of 7 cm when blockage occurs	Once a month
		Waterlogging and stagnation	Inspection and restoration of downstream facilities	Once a month
Repair and reinforcement	Equipment and structure	Closure of gravel barriers	Cause investigation and repair	Twice a year
		Screen damage	Cause investigation and replace	Regular check-up

Finally, repair and reinforcement management require inspecting and maintaining facilities and structures, such as checking for the closure of gravel barriers and any damage to screens, ensuring they are properly maintained.

Bio-retention

A bioretention is a facility designed to reduce non-point source pollutants by allowing rainfall runoff to infiltrate and filter through various vegetation types such as grass, herbaceous plants, shrubs, and trees. Bioretention has the advantage of utilizing existing green spaces such as roadsides, parking lots, and agricultural areas, making site acquisition easier (Geronimo et al. 2017b). At landscaping plant nurseries, it's possible to create bioretention in existing small green spaces, enabling the creation of aesthetically pleasing landscapes.

Maintenance of bioretention is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 9). Firstly, waste management necessitates regular inspections to assess the accumulation of debris and potential blockages in the inlet and outlet. If there is a reduction of 50% or more in the inlet capacity, maintenance is necessary.

Vegetation management suggests conducting periodic inspections for excessive growth of shrubs and the presence of dead specimens, as well as monitoring areas with less

Table 9. Maintenance guideline for bio-retention

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Accumulation of litter	Removal	Regular check-up
	Sediment	Confirmation of inlet and outlet blockage if the inflow capacity decreases by more than 50%	Removal	Regular check-up
Vegetation	Growth status	Excessive growth of shrubs or presence of dead plants	Pruning of shrubs and removal of dead plants	Regular check-up
		Vegetation cover is less than 75%	Identifying the cause and replanting	Regular check-up
	Pests and invasive species	Invasive vegetation cover exceeding 15% or invasion of harmful vegetation	Removal (prohibition of herbicide use)	Once a year
Soil and water	Erosion	Soil cover is less than 5 cm due to erosion	Re-vegetation to ensure a minimum depth of 7 cm	Regular check-up
	Stagnant water	Stagnation occurrence	Improvement of drainage	Regular check-up
	Filter media	Full drainage within 24-48 hours after rainfall	Replacement of the upper soil layer to a depth of 7 cm when blockage occurs	Immediately after rainfall
Repair and reinforcement	Equipment and structure	Soil erosion due to damage to the rainwater receiver	Reinforcement of the stormwater inlet	Regular check-up
		Damage to the weir	Repair	Regular check-up
		Cracks and damage to the structure	Repair	Regular check-up
		Settlement of the facility and surrounding area	Repair	Regular check-up
		Screen damage	Repair	Regular check-up

than 75% ground cover. Additionally, it is recommended to inspect for pests and invasive species (if invasive vegetation cover exceeds 15% or there is evidence of harmful vegetation invasion) on an annual basis.

Soil and water management involves inspecting for soil erosion (when soil cover is less than 5 cm due to erosion), drainage (checking for water stagnation), and filtration material effectiveness (ensuring complete drainage within 24-48 hours after rainfall). If necessary, recommendations include re-covering soil to maintain a minimum depth of 7 cm, ensuring proper drainage of stagnant water, and replacing the upper soil layer with a depth of 7 cm.

Lastly, repair and reinforcement management suggest regular inspections of facilities and structures, including checking for soil erosion due to damaged rainwater collectors, damage to weirs, cracks or damage to structures, subsidence of facilities and surrounding areas, and damage to screens. These inspections are essential for proper maintenance.

Infiltration trench

A infiltration trench is a subsurface detention basin created by excavating a narrow and elongated trench and filling it with gravel or rocks. It functions to maintain a natural water balance and recharge groundwater to sustain base flow. Due to its narrow and elongated width, it is easily applicable in various locations within landscaping plant nurseries, such as between farms, between greenhouses, or between farms and roadside areas.

Maintenance of infiltration trench is divided into waste material, vegetation, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 10). Firstly, waste management involves inspecting for garbage (garbage accumulation on the surface of the percolation trench, in the inlet pipes, at the stormwater outfall, and within the drainage area, trench, and inlet), and proposing maintenance such as garbage removal.

Vegetation management involves inspecting sediment deposition in the vegetation zone and conducting weed control and mowing operations annually.

Soil and water management involves inspecting for soil erosion (erosion of soil around waterways, drainage outlets, and emergency spillways, as well as blockages and erosion of inlet and discharge pipes), and checking waterways

Table 10. Maintenance guideline for infiltration trench

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Generation of garbage on infiltration trench surfaces, inflow pipes, stormwater channels, inlets, catchment areas, and ditches	Removal and cleaning	Once a month
	Sediment	Sediment deposition and inflow in the treated drainage area	Removal	Once a month
		70% or more sediment accumulation in the sedimentation basin	Removal	Twice a year
Vegetation	Growth status	Overgrowth of vegetation zone	Weeding and mowing operations	Once a month
Soil and water	Erosion	Erosion of soil around the watercourse	Removal	Once a month
		Erosion of drainage outlets and emergency spillways	Removal	Ad-hoc inspection
		Blockage, closure, and erosion of inflow and discharge pipes	Removal and repair	Once a month
	Water ways	Issues with debris on the surface and filter fibers	Replace	Regular check-up
		Problem occurred on the sidewall	Excavate the existing ditch sidewall soil and replace it with new soil	Regular check-up
		Full drainage within 24-48 hours after rainfall	Cleaning or repair	Once a month
Repair and reinforcement	Equipment and structure	Damage or breakage of pretreatment facilities and flow distribution structures	Repair	Twice a year
		Closure of observation well	Observe for 3 days during the dry season and repair if necessary	Twice a year
		Closure of surface gravel	Replace	Regular check-up
		Surface contamination of crushed stone	Cleaning	Regular check-up

(occurrence of nearby vegetation, issues with upper gravel and filter fibers, problems with sidewalls, and complete drainage within 24 to 48 hours) as needed, and maintaining them accordingly.

Lastly, repair and reinforcement management suggest inspecting facilities and structures (damage or breakage of pretreatment facilities and flow distribution structures, closure of observation wells, closure of upper gravel, and surface contamination of debris) and maintaining them accordingly.

Infiltration tanks

Infiltration tanks temporarily detain rainwater collected in square or circular pits and gradually infiltrate it into the soil, serving as a facility for dispersed infiltration. This serves to reduce surface runoff volume and discharge rate of rainwater, providing effective mitigation of runoff even with small-scale facilities. Percolation trenches can be applied to the edges of drainage areas on farm cultivation sites or open fields. Maintenance of percolation trenches primarily involves checking for accumulated waste inside the facility and damage or deterioration of structures. Since vegetation is not separately cultivated, tree management and soil-water management aspects need not be considered (Table 11). For waste management, debris (such as fallen leaves, soil, and debris) within the facility and inlet/outlet areas should be removed monthly.

For repair and reinforcement management, it is essential to inspect and carry out repairs before and after periods of high risk such as monsoon, floods, or typhoons. Monthly inspections should focus on checking for any outward signs of cover displacement, structural damage or deformation,

Table 11. Maintenance guideline for infiltration tanks

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Influx of leaves, soil, debris, etc.	Removal	Once a month
	Sediment	Accumulation of sediment within the treated drainage area	Removal	
Repair and reinforcement	Equipment and structure	Before and after periods of high risk for disasters such as heavy rainfall, floods, typhoons, etc.	Inspecting and maintaining overall facility conditions	Before and after the disaster
		Inflow of surface water into the facility	Repair	Once a month
		Interlocking of covers	Repair	Once a month
		Damage or deformation of structures	Repair	Once a month
		Settling and submergence of the surface where the facility is installed	Repair	Once a month

Table 12. Maintenance guideline for permeable pavement

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Repair and reinforcement	Equipment and structure	Formation of water puddles	Removal and permeability check	Regular check-up
		Clogging of voids	Cleaning with high-pressure water spray	Regular check-up
		Impaired permeability due to blockage between the paving materials	Cleaning with high-pressure water spray	Regular check-up

as well as subsidence or sinking of the surface where the facilities are installed, followed by necessary repairs and reinforcements.

Permeable pavement

Permeable paving is a facility designed to absorb and store moisture in the voids of the pavement material. The evaporation of this stored moisture helps reduce surface temperatures and decrease heat emitted into the atmosphere, while also serving to adsorb fine particles and mitigate urban heat island effects. Permeable paving is susceptible to clogging of voids by foreign matter, so careful maintenance is necessary. Permeable paving can be applied in areas requiring parking facilities for landscaping plant distributions and sales.

Maintenance of permeable paving is divided into maintenance and reinforcement management (Table 12). It is recommended to periodically inspect for the occurrence of puddles, clogging of voids, and blockages between paving materials to assess any degradation in permeability. After inspection, if puddles occur, removal and checking of permeability function should be carried out. In case of clogging of voids and blockages between paving materials leading to a decrease in permeability function, maintenance such as cleaning with high-pressure water spraying (using a high-pressure cleaner) is proposed.

Sand filtration systems

The sand filtration systems are a facility that utilizes sand as a filtering medium to reduce pollutants. It removes large debris and particles in the pre-treatment chamber and eliminates dissolved and suspended substances in the sand filter structure. While sand filtration systems are suitable for small areas and are particularly effective within greenhouse, they are vulnerable to clogging due to the influx of large amounts of soil, making them unsuitable for areas prone to significant soil accumulation. Therefore, maintenance of sand filtration systems should focus on inspecting and managing the sand filter medium and sediment on the surface of the facility after filtration.

Maintenance of sand filtration systems are divided into waste material, soil and water, and repair and reinforcement. Inspection cycle is set based on elements and site conditions (Table 13).

Table 13. Maintenance guideline for sand filtration systems

Division	Element	Site conditions	Maintenance tasks	Inspection cycle
Waste material	Litter	Deposition of leaves, debris, and other materials outside the device	Removal	Regular check-up
Soil and water	Pollution	Severe contamination due to long-term use	Conduct contamination assessment for each layer and replace if contaminated	Every 5-7 years
	Filter media	Discharge of cloudy or turbid water	Cleaning of foreign substances attached to filter sand	Twice a month
Repair and reinforcement	Equipment and structure	Abnormalities in the subterranean catchment device	Cause investigation and repair	Regular check-up
		Malfunction of the backwash pump (flow rate, speed, time, water level, etc.)	Cause investigation and repair	Regular check-up
		Damage, leakage, or blockage	Inspectand perform maintenance on the sand filter system	Regular check-up

Firstly, waste management involves periodically inspecting for the accumulation of leaves and debris outside the device and ensuring their removal. Soil and water management entails regularly checking if the filtered water is clear and not turbid, if severe contamination has occurred due to long-term use, and if there has been any degradation in the performance of the filtration media. If contamination is detected, it is recommended to replace the media and perform backwashing to remove foreign substances attached to the filtration sand. Lastly repair and reinforcement management involve inspecting the integrity of the sub-drainage devices of the facilities and structures, checking for any abnormalities in the function of backwashing pumps (flow rate, velocity, time, water level, etc.), and investigating any damage, exposure, or blockages to identify the cause and propose maintenance actions.

Conclusion

This study aimed to enhance the environmental and landscape sustainability of landscaping plant nurseries by proposing suitable Low Impact Development (LID) facilities and detailed maintenance manuals tailored to landscape farms. The conclusions are as follows:

Suitable LID facilities for introduction to plant production complexes include detention facilities (rain gardens), vegetated facilities (tree box, grassed swales, vegetated filter bed, bioretention), infiltration facilities (infiltration trenches, infiltration tanks, permeable paving), and equipment-based facilities (sand filtration system).

Maintenance items for LID facilities were categorized into waste management, vegetation management, soil and water management, and repair and reinforcement management.

Based on this, manuals for each LID facility were proposed, presenting content on elements, site conditions, inspection activities, frequency, and notes.

This study is significant in that it selects suitable LID facilities for plant production complexes, an area where research has been limited, and provides maintenance manuals for these facilities. The results of the study can serve as reference material for practitioners in the plant production complex industry and related fields. However, since this study was literature-based, further research involving surveys, interviews, and other methods with users, managers, and experts in plant production complexes could lead to the development of more realistic maintenance manuals, thereby increasing the sustainability of the facilities.

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