Nakhara: Journal of Environmental Design and Planning (2022)
Volume 21(3), Article 222
DOI: https://doi.org/10.54028/NJ202221222
Article Type: Research Article

Rain Garden Design for Stormwater Management in Chiang Mai, Thailand: A Research-Through-Design Study

Chulalux Wanitchayapaisit[1*], Pongsakorn Suppakittpaisarn[1], Nadchawan Charoenlertthanakit[1], Vipavee Surinseng[1], Ekachai Yaipimol[1], Damrongsak Rinchumphu[2]

[1] Faculty of Agriculture, Chiang Mai University, Thailand
[2] Faculty of Engineering, Chiang Mai University, Thailand

*Corresponding e-mail: chulalux.w@cmu.ac.th

Received 2022-08-31; Revised 2022-11-15; Accepted 2022-11-30

ABSTRACT

Conventional stormwater management may cause long term environmental issues. Fortunately, Water Sensitive Urban Design (WSUD) can manage stormwater more sustainably. However, the design examples of WSUD elements, such as rain gardens within the geographical and cultural context of Thailand are lacking. This study investigated the patterns of rain garden design suitable for urban areas in Chiang Mai and developed examples of rain garden design processes and prototypes in an urban context for Chiang Mai.

This research used the Research by design Method (RDM), which has great potential in bridging the gap between research and application. The researchers selected the site at the Faculty of Agriculture, Chiang Mai University. They designed 2 schematics of rain gardens with local Lanna plants. Then, they compared stormwater capacity with the existing site via the Natural Resources and Conservation Service (NRCS) Curve Number Method. The design results were evaluated by stakeholders and design experts to bridge the gaps between international standards and local contexts.

We found that 1) the west side of the site was most appropriate to develop the pilot project. 2) Both design schematics performed better than the original site. 3) Stakeholders and design experts see the potential of the site, but had concerns regarding its actual performance, maintenance, scale, and safety. This paper offers and provides an example of the rain garden design process which can be used as a baseline for future designs of rain garden and water sensitive urban designs.

Keywords: rain garden, WSUD, stormwater management, local planting, research by design

INTRODUCTION

Overview

For settlements across Thailand, rain and fresh water are essential to their lifestyle and culture (Nimsamer & Ramasoot, 2015). Modern stormwater management may interrupt such relationships (Watson & Adams, 2010). However, a new landscape approach to stormwater infrastructure, such as rain gardens, has the potential to help reduce issues related to urban flooding and downstream erosion (Molloy & Albert, 2008). However, very few rain gardens have been implemented in Thailand, especially in Northern Thailand. Without sufficient examples of finished infrastructure and design processes, designers and planners might have a difficult time initiating and implementing infrastructure, resulting in poor performance and design, which might further discourage future implementation (Nassauer, 2011; Suppakittpaisarn et al., 2019). This study used a research through-design approach to create an example process of how one can design a rain garden within the context of an educational campus located in Northern Thailand.

Thailand and water sensitive urban design

Thai communities have established settlements along water bodies since the ancient times. In local societies and traditional cultures, people accommodated water cycles in their lifestyles, including traditional agriculture and architecture (Nimsamer & Ramasoot, 2015). Later, as the influence of westernization altered the way Thai people lived their lives and built their settlements, there were often issues regarding water management, such as flooding and sewage contamination (Thipsuwan, 2015). To exacerbate the issues, the conventional stormwater management practices aimed to only get rid of the surface water as soon as possible with heavy structures such as concrete pipes, dams, weirs, levees, and pumping stations (Foster et al., 2011). These unnatural constructions can cause water to back up and flood when there is too much as well as damage the ecosystem downstream (Nawanuch et al., 2022), especially during global climate change where rainfall patterns become even more unpredictable than before (Pour et al., 2020).Therefore, in addition to the conventional stormwater management, alternative designs that emphasized increasing the capacity of urban spaces to precipitate more water in the urban areas were explored as possibilities. Many names emerged to embrace such a concept, including “water sensitive urban design (WSUD). ” (Limthongsakul, 2018).

Many landscape elements that manage stormwater reflect WSUD principles. They vary according to the application characteristics, such as bio-retention basins, green roofs, pervious pavements, constructed wetlands and rain gardens (Public Utilities Board of Singapore, 2014; Zhang et al., 2020) (Figure 1).

Rain gardens

Among stormwater management strategies, rain gardens have been widely used (Dunnett & Clayden, 2007; Franti & Rodie, 2007; Jaber et al., 2013). Rain garden designs have started to appear in Thailand in recent years (Likitswat, 2018; Limthongsakul, 2018). Limthongsakul (2018) and Likitswat (2018) justified the choice of the rain garden as a WSUD element that could be easily applied to the general area of conventional landscapes. The installation and maintenance costs were affordable, and the details of the design and construction were usually not too complicated for the designers and gardeners to understand and implement without further training (Likitswat; Limthongsakul, 2018)”.

The design of a rain garden can blend in with a conventional design of urban elements, including street design, parking lot, residential parks, and city parks. It can also be used as a focal point, a relaxation garden, supplying wildlife habitats for the area to contribute to thermal comfort in open spaces (Coutts et al., 2014).

The key to designing a rain garden is the detailed design of the underground elements, as well as the details of the constructional properties of each layer. The patterns of rain garden area design are presented in accordance with a variety of standards, including the following.

Figure 1

Example of WSUD Strategies

Note. Examples of Water Sensitive Urban Design strategies from United States. Images in courtesy of Pongsakorn Suppakittpaisarn and Xiangrong Jiang.

- Singapore's Waters Design Guidelines: Active, Beautiful, Clean (ABC)
- Low Impact Development: Technical Guidance Manual (Public Utilities Board of Singapore, 2014) used in many cities in the United States.
- A guide presented from educational institutions such as Stormwater Management: Rain Gardens (Hinman, 2005; Jaber et al., 2013)
- Rain Gardens Book: Managing Water Sustainably in the Garden and Designed Landscape (Dunnett & Clayden, 2007).

The overall contents of each guide are quite similar. Figure 2 details the key construction elements of a rain garden via a cross-section diagram based on the combination of these guides. We have concluded all of the guides and combined them based on the Auckland Council Rain Garden Construction Guide (Auckland Council, n.d.), which balanced between having a similar climate context and more elaborate detail of the rain garden among the guides.

From figure 2, each element can be described in more detail as follows.

1) Ponding depth: The key function of a ponding depth is water collection, which slows water from flowing rapidly and also gives water a chance to seep into the ground (Public Utilities Board of Singapore, 2014). In some ways, the area is also designed to be a flat turf (Dunnett & Clayden, 2007) which can be designed in depths ranging from 0-60 cm.

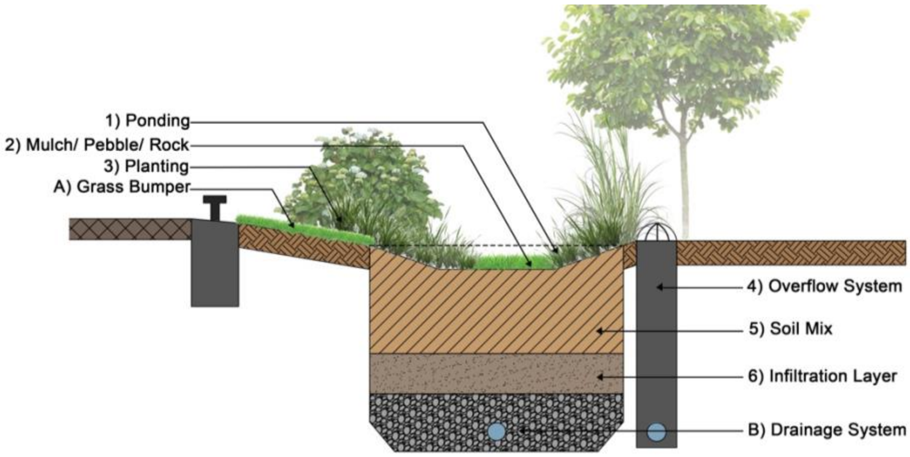
2) Groundcovers (mulch/ pebbles/ rocks): groundcovers perform in order to mitigate soil erosion and provide aesthetics of the garden and may be supplemented by gravel to reduce surface erosion. Local materials should be emphasized.

3) Planting: The surface of the soil is usually designed to grow plants or pave grass to mitigate soil erosion and provide aesthetics of the garden. Native plants are recommended to ensure that the surface of the soil is not easily blown away.

4) Overflow system: Due to the style of the design of the rain garden, the overflow system is a design that is complementary to conventional rainwater drainage. However, some manuals provide this part only as optional (Public Utilities Board of Singapore, 2014) depending on the level of rainwater in that area.

Figure 2

Cross-section of rain garden



Note. This figure illustrates examples of rainwater submerged garden areas in practical use.

5) Soil mix/media: The soil mix/media acts as a filter for debris. It is usually a mixture of sandy loam or loamy sand or loam, which also supplies food to the plants grown on top. In general, the soil properties used in such work are 25% porous and the depths of active planting soil layers are between 10-20 cm (middle average 15 cm) (Emanuel et al., 2010).

6) The infiltration layer: this layer is a very important part, designed to increase the efficiency of soil layer permeability. This layer is generally gravel or coarse sand because, in addition to being a well-drained layer, it is strong enough to support the weight of the upper activities. The porosity should be 20 – 40 percent on average (Rinchumphu & Anambutr, 2017) and the depth of the layer 5-60 cm.

7) Grass bumper (A) and drainage system (B) are optional additions depending on the designer's choice. It can supplement the design, but not necessary for most rain gardens.

The surface area of the rain garden is not dependent of the guide, but rather the volume of stormwater it needs to slow and contain. This information needs to be calculated based on the design storm (how big is the storm it needs to contain) and the area of the subcatchment (the surface of the runoff it is collecting).

The presented general guide can suggest environmental designers to begin on WSUD. However, there are still uncertainties as to whether the design of the rain garden can be applied sustainably in Thailand. Research and installation of rain gardens in Thailand may widely differ from in the West, from which most of the information has originated. For example, rainfall in Thailand is higher and more distributed throughout the year than in the United States (Gardner et al., 2000). It is characterized by a lowland, closer to the water. There is more natural diversity among vegetation, insects, soil, and ecosystems than those in the west (Ashton, 1990; Gardner et al., 2000; Suppakittpaisarn et al., 2020; Thanvisitthpon et al., 2018). There are also differences in lifestyle, culture, and expectations on what might be a rain garden (Church, 2015; Suppakittpaisarn et al., 2019). As previous research has shown, topographical, climatic, social, and cultural factors may contribute to the success of rain gardens (Ji et al., 2000; Suppakittpaisarn et al., 2019; Wells et al., 2019). Understanding, designing, and adapting the characteristics of rain gardens to different contexts in Thailand is crucial.

The cultural contexts of Northern Thailand and public spaces

If there is going to be a rain garden that is functional, recognizable, and accessible for learning, such designs should be in public spaces, such as a city square where festivals may be held. It reflects a sense of belonging and the strength of community bonds (Madanipour, 2010; Madanipour et al., 2014), and the complementary role of public spaces also represents areas that create identity for the place and create economic value for the city, such as Piazza San Marco in Venice or the Champ Elise, Paris (Nateewuttikul et al., 2008; Strauß et al., 2021).

In term of place identity, Chiang Mai city itself has public spaces that develop from the wisdom of Lanna cultures, the local culture that preceded Thailand for several centuries, running from Northern Thailand to Myanmar and Southern China. Part of Lanna vernacular villages, homes, living spaces, and social spaces are gradually continuous and are connected between groups by open spaces, also known as courtyards or khuangs (Commons) (Srisuwan, 2016). The stormwater infrastructure is designed as Lam Nam or Lam Muang *(*canals*).*

Common areas, or commons, host social activities within the city proper. The commons do not have be in geometric shapes such as squares, rectangles, circles, as in the understanding of modern public spaces (Srinurak & Mishima, 2014). These commons can appear in three main scales, listed as the following (Chumduang, 2003):

- Public commons, such as community commons, temple commons, or a cemetery.
- Semi-public commons, such as cremation commons.
- Private commons, such as palace commons, household commons.

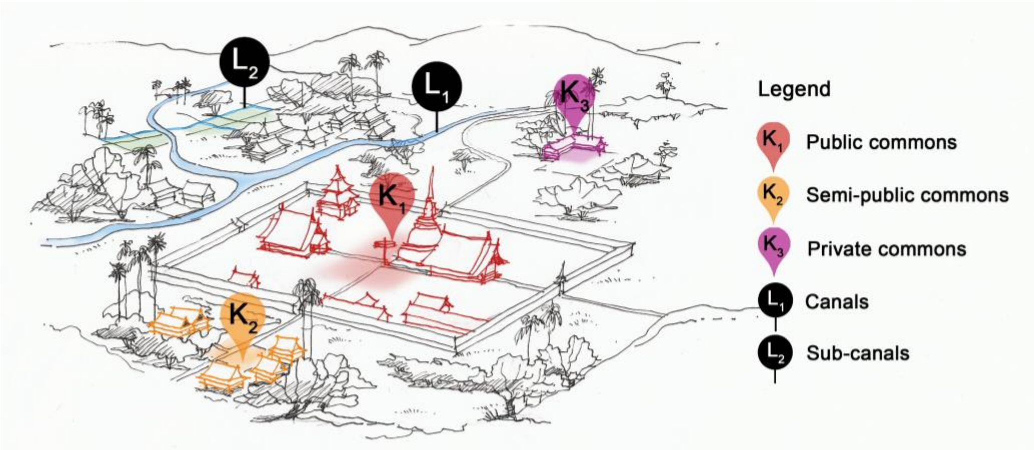
Alternatively, these commons can also be divided according to the nature of their utility. The main three categories include the following (Chumduang, 2003):

- Prominent functioning (Positive space): the activities may include singing, cremating, or a place for tombs. This characterizes activities and ceremonies related to community values, spiritual beliefs, and Buddhism in relation to the ways people live in the community.
- Informal functioning (Negative space) such as palace commons and temple commons. This type of commons supported activities that are relevant to the daily life of urban communities, which are diverse and complex including agriculture, animal husbandry, commerce, politics, and government. In addition, the use of space depends on the time of day and the season.

In conclusion, commons are central spaces that accommodate cultural activities and traditions; they are the hearth of the people, ranging from family to community. Figure 3 represents the scales and functions of commons.

Figure 3

Commons and canals in Lanna settlements



Note. This figure illustrates Khuang, Lam Muang, and Lam Nam of modern landscapes of Northern Thailand.

Canals are the ground-based systematic water management of the ancient Lanna people and are in the form of irrigation systems for the villagers. In addition to water management in the channel-weir system, they are also managed in the series of water reservoirs (Maneegorn & Panin, 2016). In some areas, the canal dry up due to concrete channels; as a result, the amount of natural water seeping into the ground is greatly reduced (Nawanuch et al., 2022; Thipsuwan, 2015).

Nowadays, Chiang Mai has undergone various developments with many factors resulting in changes in the lifestyle and structural systems of the city, including open spaces and water management system, resulting in developments that lack the uniqueness and culture of the locality.

To preserve the older tradition within new contexts, an example in a public space is needed. There is an opportunity to use educational spaces such as universities as a space to experiment with landscape patterns. University spaces are public spaces where knowledge is gathered. It has a diverse reach of researchers in both scientific and social sciences and is a place where many local curious minds come together, especially when the educational model has transformed into lifelong learning. In order to provide opportunities for the general public to seek knowledge, whether they are students or not, it is appropriate to use the university space as a model space to create a new type of landscape for future awareness and development.

The study site

In this study, we selected the Kaset Ruam Jai Commons (United Agricultural Commons) at the Faculty of Agriculture, Chiang Mai University as the study site. The research team was approached by the Faculty of Agriculture to design a sustainable site that might take into account the flooding and drainage situation, thus the site was selected from an opportunity sample, which fitted our requirement as a culturally functional public space with stormwater management issues. There were some problems in storm water management in the site, as discovered from our preliminary investigation. The team hoped that the new type of stormwater management could improve the flooding problem of the commons.

Kaset Ruam Jai Commons is a public space surrounded by academic buildings in all three directions. It contains 5,600 sq.m. of green, shady areas with many mature trees which are approximately 30–50 years old (Figure 4). The commons acted in similar ways between a household commons and community commons; the private and semi-public level open spaces that support activities are related to the daily lifestyle of the family. The area is used for a variety of activities, such outdoor classrooms, student activities, recreational activities such as music, traditional events, etc. Activities with other faculties or universities are held here, such as Si-Job League (the League of 4 Spades), which brings together agricultural faculties from all universities to engage in sports activities and agricultural-based competition together; Aggie-Nurse Night, which is a party held between the Faculty of Agriculture and Nursing; and The Northern Agricultural Fair, which is a regional agricultural fair that happens biannually. When the site were not active, it was used as a parking lot to accommodate the faculty's activities such as its monthly flea market and exhibitions.

Because of the limitation of how we can alter the space as a pilot project, while patches of Kaset Ruam Jai Commons were flooded often in rainy season, (Figure 5), the researchers took priority from those affected by the daily access to the area, such as entering the building and daily parking. Therefore, in designing a rain garden for the commons, the researchers chose the transition area from the building to the agricultural parking lot southwest of the commons, adjacent to the west side of the Animal Science Building (Figure 5) to solve the storm water runoff during the monsoon season, thus creating aesthetics and increasing environmental sustainability.

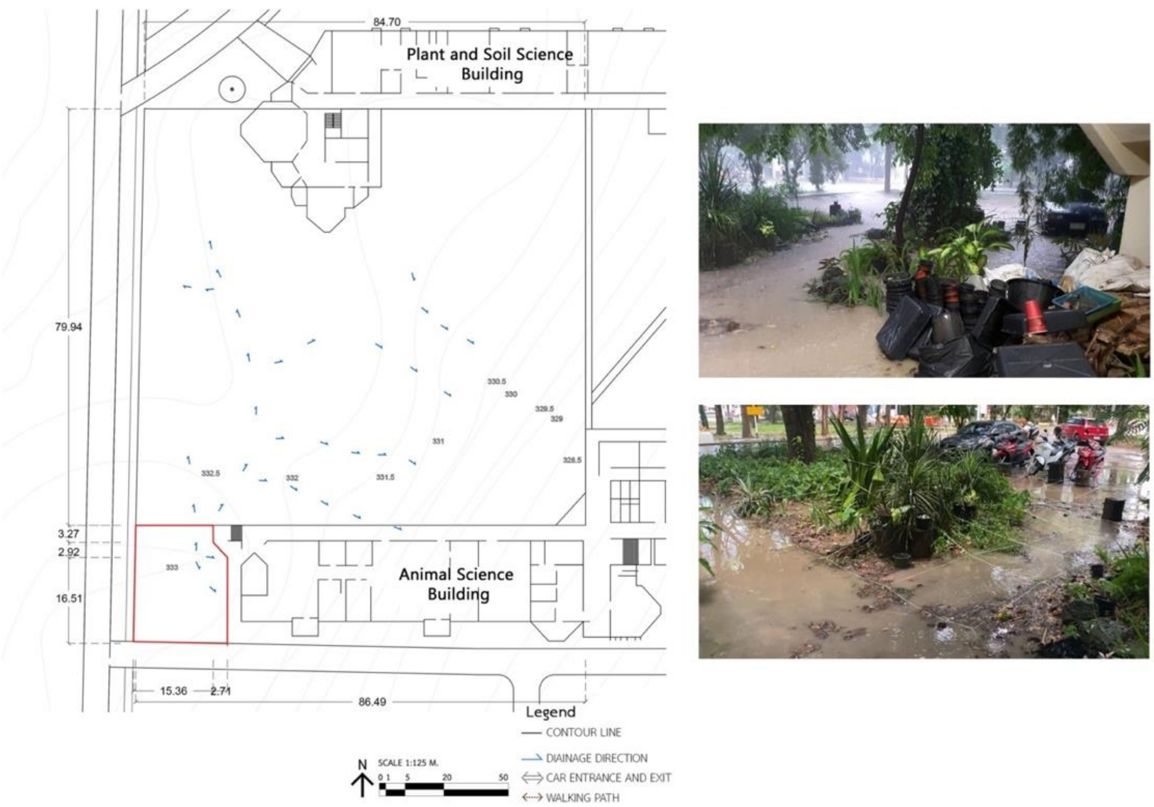
Figure 4

Kaset Ruam Jai Commons, Faculty of Agriculture, Chiang Mai University.

Note. This figure demonstrates the photo. Faculty of Agriculture, Chiang Mai University.

Figure 5

Kaset Ruam Jai Commons flood



Note. The photograph is of a flood in Kaset Ruam Jai Commons at the west entrance of Animal Science Building. The flood extended towards the sidewalks and parking spaces.

This research raises the question of how to design a rain garden in accordance with the context of Chiang Mai. The focus is on studying the design and selection of plants in rain gardens for environmental designers within the Faculty of Agriculture, Chiang Mai University by researching a design process that is suitable for the context of Chiang Mai, Thailand. This research will be beneficial for providing sustainable ways to reduce the impact of rainwater flows and to promote sustainable urban development.

The objectives of this study are:

1. To study the patterns of rain garden design suitable for Chiang Mai University area/urban use in Chiang Mai province.
2. To develop examples of rain garden design processes and design prototypes in an urban context for Chiang Mai.

METHODOLOGY

Research Methods

This study used the Research-by-Design Method (RDM), which has been used for landscape architecture research. RDM is a new way by which research and design can be developed together (Zimmerman & Forlizzi, 2014) to understand design issues in real world contexts (Charoenlertthanakit et al., 2020). RDM has great potential in bridging the gap between research and application, and the process is continuing to develop and change with the real world. In this study, we decided to use an operational approach to RDM, which focused on the knowledge learned from the entire process of the design operation (Stappers & Giaccardi, 2017).

There are three main parts in RDM: analysis, synthesis, and evaluation, which are conducted as stated by the following.

Site Analysis

The researchers approached site analysis in four ways: the physical conditions of the site, stakeholders' expectations from the site, cultural contexts, and rain garden guidelines. For the physical condition, the researchers worked with the stakeholders of the site to investigate the site during the monsoon season (September–October 2021) and the dry season (April–May 2022). The researchers moved throughout the site and recorded the physical condition of the site. Aerial photography, the estimated elevation and slope, and maps were used to construct the physical understanding of the site. We also conducted preliminary stakeholders' interviews on 10 stakeholders for the problems on the site and general expectations about the sites. The recorded interviews were then noted for emerging patterns and combined with the site observation by the design team. For cultural contexts of Chiang Mai, researchers explored the existing literature to find the cultural significances of patterns and plants to be included in the design. Furthermore, the researchers investigated the guidelines for rain gardens, both in engineering, landscape architecture, and planting design fields to consolidate the design principles and adapt them into a new, local context.

Synthesis

After the database was constructed from the field survey, observation and maps, the researchers started designing using the acquired data combined with theories and principles in rain garden guideline and design.

We designed the rain garden to hold 1-inch stormwater runoff, allowing them to perform as a first-flush system.

In a first-flush system, a rain garden will retain most of the rainfall during the course of a year. For example, according to statistics of rainfall in a 10-year period, storms with more than 3.15 inch per day happen only 10 times a year, on average, in Chiang Mai, Thailand (Mahawan et al., 2021).

For planting design on rain gardens, plants are often designed to prevent erosion and increase porosity to the soil layer (Gonzalez-Merchan et al., 2012). Native plants are recommended for biodiversity and additional ecosystem services and wildlife habitats. (Dagenais et al., 2018). Thus, aside from looking pleasant to the public eyes, the planting design adheres to the following principles:

- Tolerate flood

- Drought tolerance in the absence of rain during a dry period
- Deep roots that prevent erosion
- Can absorb water well
- Preferably native or well-adapted plants for low maintenance and resilience

Evaluation

Run off Volume Calculation

One of the missing elements for WSUD design guidelines was the calculation of runoff that the area could manage (Rinchumphu & Anambutr, 2017*)*. In this study, the researchers used the Natural Resources and Conservation Service (NRCS) Curve Number Method (Jaber et al., 2013).The method was adjusted and used in the stormwater modelling within a Thai context. We then compared the calculations with the existing site to ensure that the new design had improved in stormwater management capacity. The main information includes:

- Rain garden layer (CN) to find S value
- The total rainfall over a 10-year period for Runoff Dept (RD) calculation
- The size of the total area for Runoff Volume calculation
- Volume per square meter
- Surface area of Rain Garden sizing calculation

Stakeholder's feedback

The design was presented to stakeholders of the site and landscape design experts. The feedback was collected in a focus group, lasting about 1 hour. The data collected were then analyzed and translated for future research use, using the same methods of data collection and analysis as the interview.

RESULTS

Analysis

Site investigation

After the series of investigation containing interviews, site observation, literature review, and cultural context exploration, we concluded Khuang Kaset Rum Jai can be described in 3 concepts as follows:

1) Aesthetic potential: this open space is the visual center of plant science and animal science buildings. It resembles traditional commons in Lanna culture, yet lends some characteristics to open spaces based on western theories (Sullivan, 2005). However, some areas of the Kaset Rum Jai Commons have puddles of mud pits and debris of logs and unused materials along the edges of the building.

2) Overlapping activities and problems in Kaset Rum Jai Commons: There were educational, recreational, and public activities which overlapped. Usually, this would not be an issue, but a conflict may arise when more than one function is required at the same time. The conflict may be worsened if some areas of the space are not usable because of flooding and puddles. This is especially true in the areas that affect key users, such as the link between buildings and parking lots, walkways between buildings, etc. (Figure 6).

3) A lack of design to solve long-term stormwater runoff. The current design has no consideration for stormwater.

4) management. This means that the site was dry-looking in dry seasons and became a mud pit in wet seasons, limiting its uses along with sustainability potential.

Due to the construction site being a wide green space and a wetland, which has a steep slope from the road (west) into the building (east) (Figure 7), this area always floods, including pits and puddles. Sometimes the parked cars would be stuck in the mud, and the access to the Animal Science's west entrance would be blocked.

While the lab test for soil porosity was not available, we assumed the soil porosity is 25% based on the information provided by Rinchumphu's study (Rinchumphu & Anambutr, 2017).

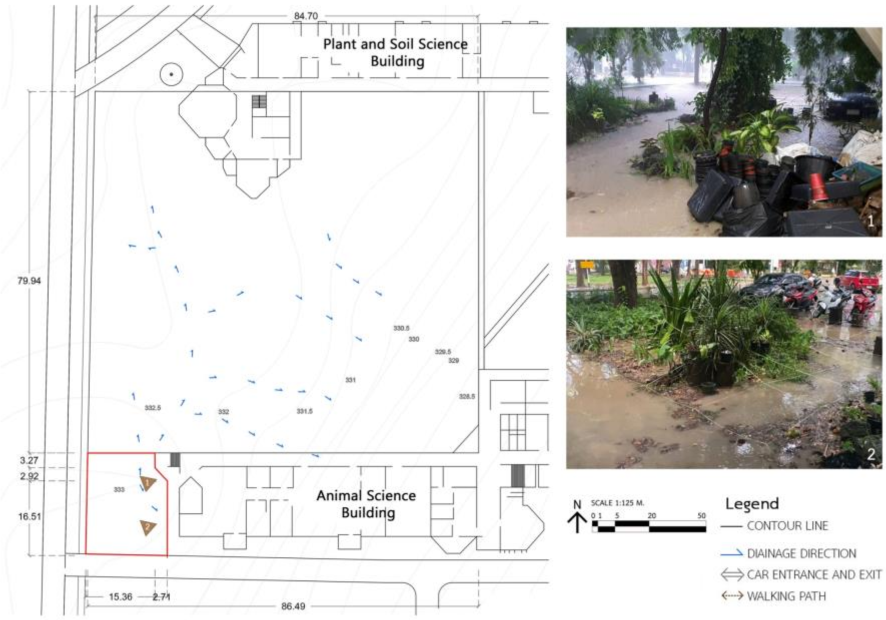
Figure 6

Kaset Ruam Jai Commons as a parking lot

Note. This figure demonstrates the functions of Kaset Ruam Jai Commons as a parking space during the monthly flea market, as well as the focal location which was the entrance and exit of the Animal Sciences Building.

Figure 7

Hydrological Analysis



Note. This figure demonstrates the direction of stormwater runoff in Khuang Kaset Raum Jai and the flooding issues in the area.

The problem of flooding had been temporarily addressed during the Northern Agriculture Fair in 2017. The organizers used coffee bean husks to reduce the puddle issue. However, the problem of flooding still persisted in later months, and the coffee bean husks also affected the soil condition of the agricultural fields, making the soil acidic and less suitable for local groundcover species (Oliveira & Franca, 2015) and affecting the nutrient absorption of vegetation within agriculture.

The area to be used as a pilot site is the area to the west adjacent to the building, as shown in (Figure 8).

The area selected for the site study is an area with a low slope, characterized by a basin tipping onto the sidewalk of the building. This causes rainwater from the surrounding area to pool together at this point, which is a regularly used area. This creates difficulties for foot traffic and may cause long-term impacts on the building structure.

Synthesis

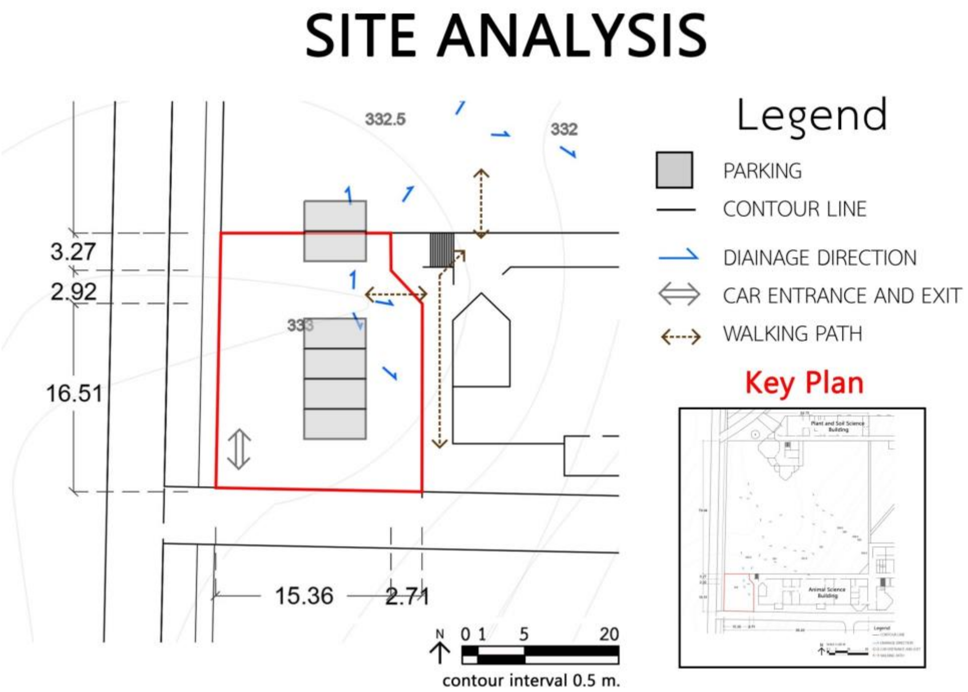
Anatomy of Rain Garden

After the design, the researchers used the following guideline (Auckland Council, n.d.; Rinchumphu & Anambutr, 2017) to construct the rain garden.

Because an important factor in the design of rain garden is the underground structure, the researchers designed two alternatives rain gardens with differences in the porosity of the soil layers and different ponding depth sizes to determine the optimal rainwater flowing efficiency based on different guidelines. In addition, we calculated the stormwater management capacity of the site without any alteration. The case is called Base Case (Bc). The comparisons between Base Case (Bc,) the Schematic Case 1 (Sc1) and Schematic Case 2 (Sc2) were designed with the depth specified in Table 1 and illustrated in Figure 9. The information regarding soil porosity is assumed based on literature (Rinchumphu & Anambutr, 2017). The groundwater table is low enough not to impact the design.

Figure 8

Site Analysis



Note. The analysis of the pilot space, including the vehicular entrance, the Animal Science Building's west entrance, and parking. This analysis includes circulation and hydrology of the space.

Table 1

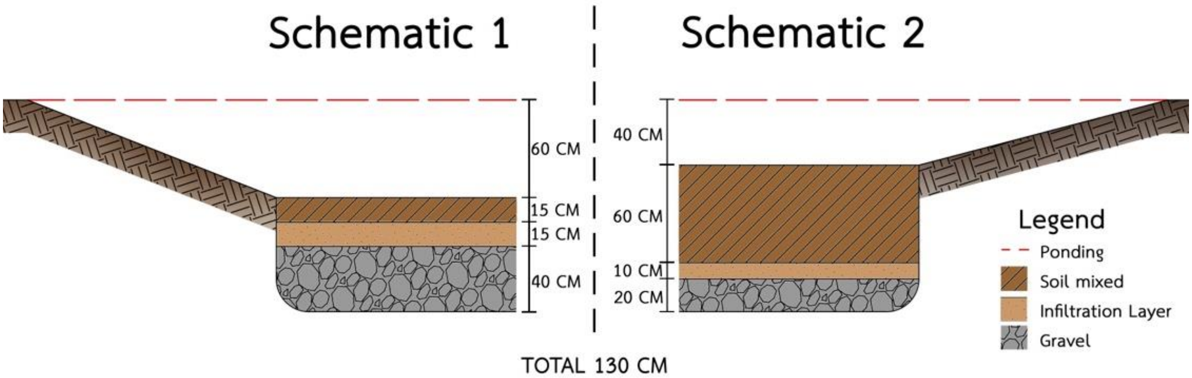
Specified depths of the Rain Garden.

variable	**kind**	**Bc** (cm)	**Sc1** (cm)	**Sc 2** (cm)
Depth of the pond (A)	-	0	60	40
Depth of planting soil layer (B)	Soil group	60 (Soil group D)	30 (Soil group A)	70 (Soil group D)
Porosity of planting soil layer (C)		25%	35%	25%
Depth of drainage layer (D)	gravel	0	40	20
Porosity of the drainage layer €		-	40%	40%
Dept of water capacity		87	66	33

Note. This table demonstrates the specified depths of the Rain Garden layer comparison for both schematics including the base case.

Figure 9

Proportions of Rain Garden layers used in both schematic designs



Note. This figure demonstrates the proportion of rain garden layers used in both schematic designs.

Plant selection

Plant diversity is prioritized over monoculture plantings which are prominent in several rain gardens (Hunt et al., 2015). The purpose of the diverse planting was to attract different species of insects into the garden for a richer ecosystem. The selected plants must withstand floods and droughts. They were mostly native with a mix of well-adapted non-aggressive imported species.

A bioretention system with a range of plant species increases the success of the system as plants are able to “self-select” suitable establishment areas within the vegetated area—drought tolerant plants will gradually replace those plants that prefer wetter conditions (Jaber et al., 2013). The plants selected for use in the recommended Rain Garden design are displayed in Table 2.

Table 2

Plant selection in the design of rainwater mop gardens in the project.

No.	Common name	Botanic name
Shrubs		
1	Walking Iris	*Neomarica longifolia* (Link & Otto) Sprague
2	Beach Spider Lily	*Hymenocallis littoralis* (Jacq.) Salisb.
3	FRAGRANT PANDAN*	*Pandanus amaryllifolius* Roxb.
4	Dwarf pandanus	*Pandanus pygmaeus* Thouars.
5	WATER CANA	*Thalia geniculata* L.
6	Parrot Heliconia	*Heliconia psittacorum*
7	AGAVE	*Agave* spp.
8	PHILODENDRON	*Philodendron erubescens* K.Koch & Augustin.
9	WEEPING WILLOW	*Phyllanthus myrtifolius* (Wight) Müll.Arg.
10	Barleria	*Barleria strigosa* Willd.
11	Yellow Sanchezia	*Sanchezia speciosa* Leonard
12	Crape ginger	*Cheilocostus speciosus* (J.Koenig) C.D.Specht
13	Greater Galangal*	*Alpinia galanga* (L.) Wild
14	Wildbetal Leafbush	*Piper sarmentosum Roxb.*
15	Giant Elephant's Ears	*Colocasia gigantean Hook.f.*
16	Taro	*Colocasia esculenta (L.) Schott*
17	Paco.	*Diplazium esculentum*
18	Ming Aralia	*Polyscias fruticosa* (L.) Harms
19	Climbing wattle	*Acacia pennata* (L.) Willd.
20	Siam Tulip	*Curcuma sessilis* Gage.
Ground covers		
21	MENTHA MINT	*Pilea nimmulariifolia* (Sw.) Wedd.
22	MONDO GRASS	*Ophiopogon japonicus (Thunb.)* Ker Gawl.
23	**Spanish Shawl**	*Heterocentron elegans* (Schltdl.) Kuntze

Table 2 (Continued)

No.	Common name	Botanic name
24	Climbing Wedelia*	*Wedelia trilobata* (L.) Hitch.
25	Plu Kaow *	*Houttuynia cordata Thunb.*
26	Kyoto Dwarf	*Ophiopogon japonicus* (L.f.) Ker Gawl.
27	Water morning glory*	*Ipomoea aquaica* Forsk.
28	Gotu kola*	*Centella asiatica* (L.) Urb.
29	Culantro	*Eryngium foetidum* L.
30	Indian borage	*Plectranthus amboinicus* (Lour.) Spreng.
Grass		
31	Citronella grass*	*Cymbopogon nardus* Rendle.
32	Vetiver grass*	*Chrysopogon zizanioides* (L.) Roberty
33	Fourtain grass	*Pennisetum setaceum* (Forssk.) Chiov.

Note. Culturally significant*
This table demonstrates the tree types used in the design of the Rain Garden in the project.

The recommended plants were then used to design into 2 schematics as follows:

Schematic 1- The stream (Figure 10): The highlight of this design is the shape of the water retention basin, which has a curve that feels like a natural water body. When the park is fully saturated, the garden resembles a small stream. The ponding area is deeper (60 cm) but smaller at the surface.

As for the vegetation used, they consist of large shrubs to groundcovers and riparian plants, including native plants of Lanna, which are durable, have a unique fragrant, and can be used for cooking.

There are two 1-meter water inlets: one from the west and connected to the multipurpose parking lot. The other is at the east, to receive rainwater that runs from the buildings and flows down the pedestrian crosswalk.

The size of the retention area is 10 sq.m., the total depth is 1.30 m. Each layer consists of 60 cm of ponding depth, 15 cm of soil mix, 15 cm of Infiltration layer, and 40 cm of gravel layer.

Schematic 2 The pond (Figure 11): The highlight of this design is a fairly wide and large retention area. When this garden is fully watered, it feels like a natural pond.

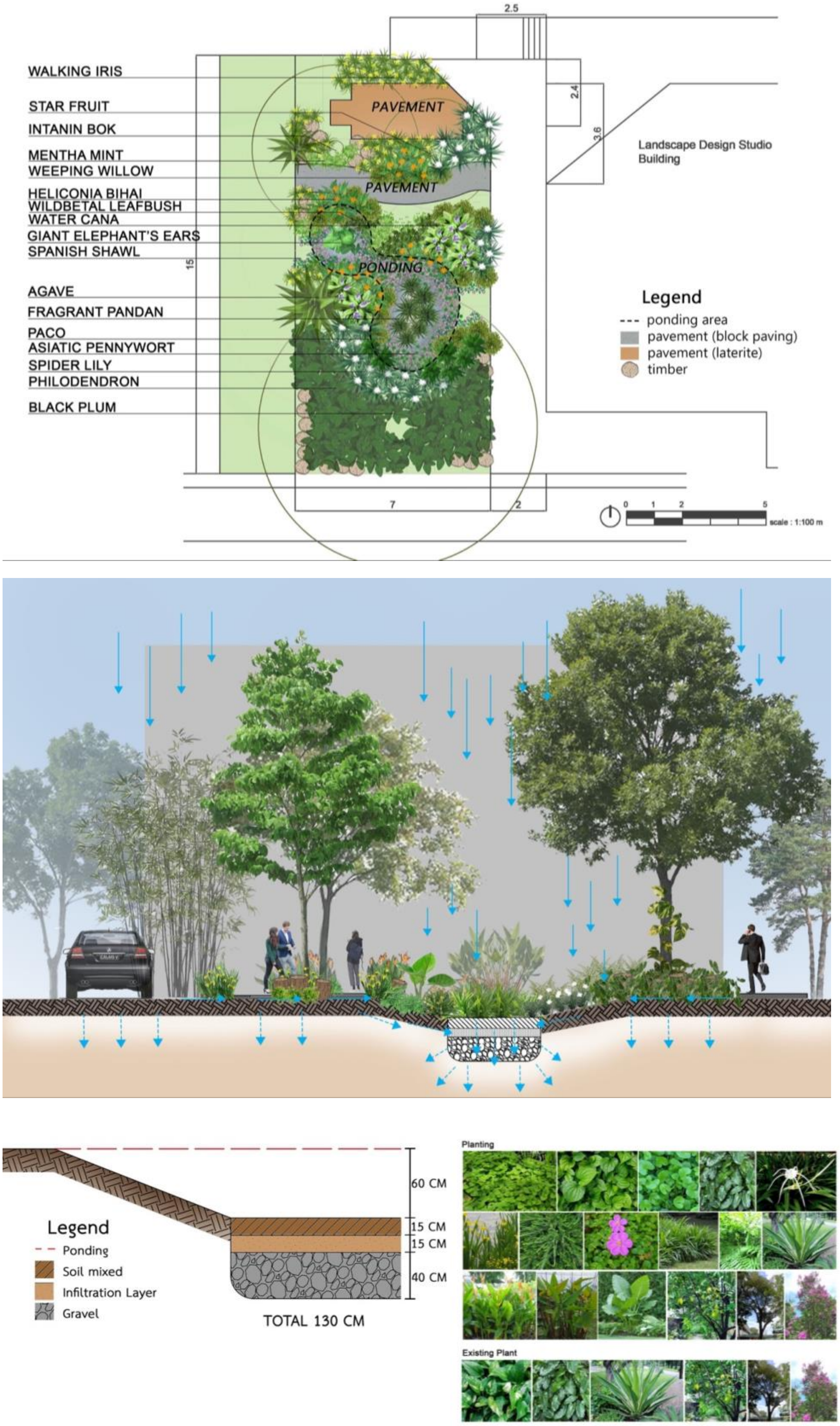
The entrances of the stormwater runoff are similar to the first schematic, but the width of the water entrance is 2 meters wide, allowing water to quickly flow into the pond area of the rain garden.

The pond size of this rain garden is 18.5 sq.m. The total depth is 1.30 m, and each layer consists of a pond of 40 cm, a soil mixture of 60 cm, a layer of infiltration of 10 cm and a gravel of 20 cm.

In both designs, the researchers kept the original vegetation, including the big tree, tall shrubs, and groundcovers such as Philodendron, Agave, and others. The walking path style retained the original direction, which reflected the habits of the users. The design of relaxing space was added, since the designs focused on the rain garden design, the schematics differed mainly on the stormwater management and engineering elements.

Figure 10

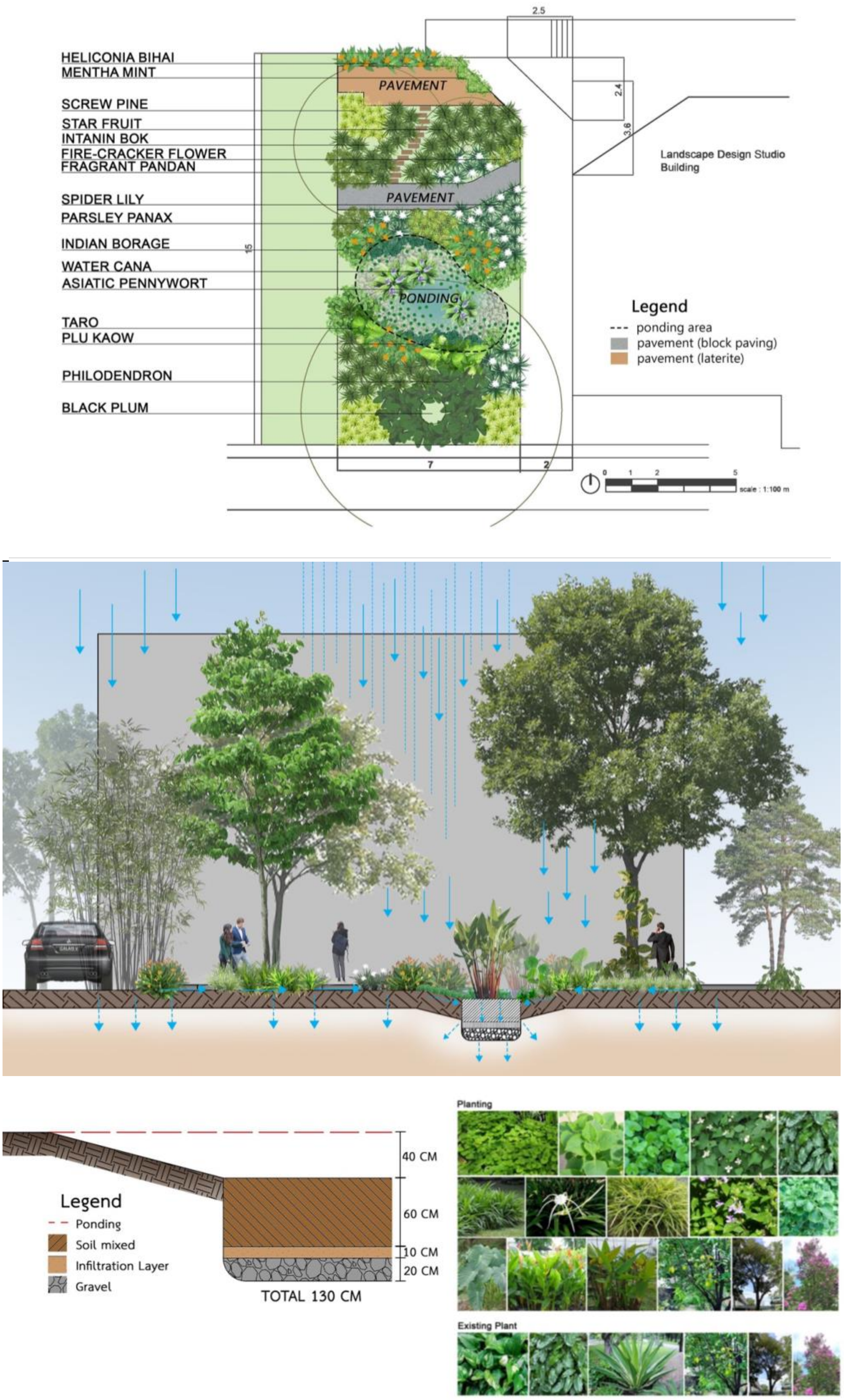
Design Schematic 1 (Sc1)



Note. This figure demonstrates the rain garden design, Sc1. Water catchment area size 10 sq.m. Depth 1.3 m.

Figure 11

Design Schematic 2 (Sc2)



Note. This figure demonstrates the rain garden design, Sc2. Water catchment area size 6 sq.m. Depth 1.3 m.

Next, the researchers calculated the rainwater absorption capacity of the proposed schematics in comparison with the base case to test whether the proposed designs had improved the stormwater situation in the area.

Evaluation

Runoff volume calculation

While the calculation for vegetation design factors is not established in stormwater management calculations, we could find partial capacity from the underground layers. First, we tested the effectiveness of stormwater management in the proposed schematics. The stormwater performance of the designs was shown as follows. By site study size 340 sq.m., the average rainfall of Chiang Mai over 10 years is 3.15 inches.

Runoff depth (m)= $\frac{\left(P-0.2\times\left(\frac{1000}{CN}-10\right)\right)^2}{\left(P+0.8\times\left(\frac{1000}{CN}-10\right)\right)}$x0.0254

= 0.049 m

Runoff Volume (m^3)= Runoff depth(inches) × Area (m^2)

= 0.049 m x 340 m^2

= 16.66 m^3

To determine the surface area of the rain garden :

Volume per square meter= Water depth (m) (from table.1)

Rain garden sizing

Surface area of RG (BC)= $\left(\frac{\text{Volume of runoff (m}^3\text{)}}{\text{Water depth (m)}}\right)$

= 16.66 / 0.33

= 51 m^3

Surface area of RG (Sc1)= 16.66 / 0.87

= 19 m^3

Surface area of RG (Sc2)= 6.477 / 0.66

= 25 m^3

It was found that Sc1 consisting of a deeper ponding depth and soil group characteristics of a soil mix with sandy loam and high porosity, resulted in infiltration potential when calculated. Sc1 had better efficiency in collecting stormwater with a ponding dept layer 40 cm than Sc2 did. However, both cases were calculated to perform better than the Bc (Base Case).

In addition to calculating the water intake efficiency of the rain gardens, we interviewed the 14 stakeholders, including 3 landscape architects, 1 engineer, 1 executive member, and 9 users, which resulted in Table 3. Overall, the interviewees were receptive because it provided a new model for education, recreation, and sustainability, but some questions were raised about performance, maintenance, and safety.

Table 3

Stakeholders' evaluation

Theme	Land. Arch.	Eng.	Exec.	User	Example quote
Education	/		/		"I'm interested if [the staff] can take care of this [garden] because it's an educational opportunity and an important role model for landscape technology."
Recreation	/			/	"This rain garden should address other functions, such as relaxation, student activities, and outdoor exhibition"

Table 3 (Continued)

Theme	Land. Arch.	Eng.	Exec.	User	Example quote
Sustainability	/	/			"In the future, the designers should focus on the system of green infrastructure instead of the elements to address the stormwater issues and provide ecological infrastructure to the campus."
Performance	/		/		"There's a good design but I wonder if a small space can really take care of the entire storm water system."
Construction		/			"Let's look at the use of materials that are used as rain garden layers. To increase the efficiency of water absorption quickly, porosity should be increased, such as adding more coarse sand to the planting soil layer."
Maintenance			/		"This looks messy. Who is going to take care of it? My staff are rather busy with the way it is, but this grass and plants look too complicated to maintain."
Ease of access				/	"The path should be an easy-to-walk because we may have to carry items or equipment entering and leaving the building."
Safety			/	/	"I am concerned about the use of large thickets of vegetation that may be home to unwanted animals such as snakes, mosquitoes, centipedes, scorpions, or other poisonous animals."

DISCUSSION

Key findings and contributions

In this study, we designed a rain garden in Chiang Mai University based on the geographical and cultural contexts of Chiang Mai, Thailand. We explored the possibilities of the planting designs, including the planting lists which are suitable and provided a wide range of ecosystem benefits. Furthermore, we found that the rain gardens had potential of absorbing rainwater better than the base case, and that there were both excitement and concern about such new types of landscape.

Those who were interested in the design of rain gardens such as landscape designers, landscape architects, engineers, and urban planners could study such a design process and see how rain gardens can reduce the urban impact of stormwater in the areas, including cities, communities, and homes, by taking this pilot to develop their own design directions of rain gardens.

Design Implications

While this study was done in the context of Chiang Mai, Thailand, some of the knowledge can be generalized. This study's results yielded a few implications for design and planning, including the following.

Underground layers

Some of the keys for rain garden performance are the underground layers and soil porosity. A deeper ponding depth and more porous soils could help manage stormwater quantity. Plants and material selection should target the porosity of the layers for optimal performance.

Public perception of rain gardens

There is a lack of understanding about rain garden designs, how they look, and what function they may perform. For example, some interviewees thought the rain garden would have standing water all year long. Information about rain gardens and WSUD should be clear and offered to stakeholders.

Planting selection

While tall grass is popular among rain garden design, in this study, tall grass is associated with the wild, messiness, and habitats for animals viewed as nuisances. Alternative planting, such as local plants and plants with a natural significance, may be offered. However, designers must be aware of the performance along with other ecosystem services regarding the plant selection.

Plan for Monitoring and Communication

Clear communication about vision, progress, and issues on the site to all involving organizations may be key to developing a site more effectively.

Budget for Maintenance or Design Landscapes with Low Maintenance

Like most places, the Faculty of Agriculture needs a garden with optimal beauty and minimal care; therefore, choosing non-invasive vegetation would be a good choice. Designers and planners should consider maintenance strategies as a part of the design procedure.

Limitations and Future Studies

This study has a few limitations. (1) the calculated numbers came only from calculations with many assumed values based on theories. The site still needs to be constructed and field tested for researchers to know the effectiveness of the design. Furthermore, the calculation method had limited variables regarding vegetation, biodiversity, species, and biomass. Future studies should take into account the effects of vegetation towards rain gardens, (2) The pilot site was small compared to the catchment area and may not alleviate the stormwater issues of the whole site. Future studies may expand upon the design that include larger areas in its fuller potential, (3) The focus group was limited and was only explored towards the qualitative end. Quantitative analysis of perceptions and preferences of the design may inform future designers more clearly on the direction of rain garden design4) The surface size of the rain garden is limited by the space given instead of the design storm. Thus, it might not have the full stormwater capacity for the entire commons. Future implications should negotiate the spaces or consider implementing more than one rain garden to address the stormwater quantity of the sub catchment.

CONCLUSION

This study aimed to explore the patterns of rain garden design suitable for Chiang Mai University campus and develop examples of rain garden design processes and design prototypes in an urban context for Chiang Mai. The researchers recorded the process of designing a rain garden within the geographical and cultural context of Chiang Mai, the process of research-by-design method, starting from site investigation, design process, and evaluations in both performance and perception dimensions. The resulting design provided two design examples, along with planting lists which could offer ecosystem services, including stormwater management and wildlife habitat. It confirmed the challenges in WSUD, including managing the expectations and concerns of stakeholders. This study is novel because it explores the new type of landscapes in the lens of engineering, vernacular culture, and planting design. Future research must explore the post-occupancy evaluation, quantitative analysis of perception and preference, and more extensive scale of stormwater management.

ACKNOWLEDGEMENTS

This research is supported by Chiang Mai University, Junior Fellowship Grant JRCMU2564_006 towards the recipient Chulalux Wanitchayapaisit. We also thank the Landscape Design and Environmental Management Studio Research Team, Faculty of Agriculture and the City Research & Development Center Team, Faculty of Engineering for their support.

REFERENCES

Auckland Council. (n.d.). *Stormwater forms and guides: Rain garden construction guide.* https://www.aucklandcouncil.govt.nz/environment/looking-after-aucklands-water/stormwater/docsconstructionguides/rain-gardens-construction-guide.pdf

Ashton, P. S. (1990). Thailand: biodiversity center for the tropics of Indo-Burma. *Journal of The Science Society of Thailand*, *16*, 107–116. https://doi.org/10.2306/scienceasia1513-1874.1990.16.107

Charoenlertthanakit, N., Wanitchayapaisit, C., Yaipimol, E., Surinseng, V., & Suppakittpaisarn, P. (2020). Landscape Planning for an Agricultural Research Center: A Research-by-Design Case Study in Chiang Mai, Thailand. *Land*, *9*(5), 149. https://doi.org/10.3390/land9050149

Chumduang, W. (2003). *Honghian supsan phumpanya lanna* [School of Lanna Wisdom Preservation] [Master's Degree Thesis, Silpakorn University]. Silapakorn University Central Library.

Church, S. P. (2015). Exploring Green Streets and rain gardens as instances of small scale nature and environmental learning tools. *Landscape and Urban Planning*, *134*, 229–240. https://doi.org/10.1016/j.landurbplan.2014.10.021

Coutts, A., Loughnan, M., Tapper, N., White, E., Thom, J., Broadbent, A., & Harris, R. (2014). *Impacts of Water Sensitive Urban Design Solutions on Human Thermal Comfort: Green cities and microclimate*. Cooperative Research Centre for Water Sensitive Coties. https://watersensitivecities.org.au/wp-content/uploads/2016/07/TMR_B3-1_WSUD_thermal_comfort_no2.pdf

Dagenais, D., Brisson, J., & Fletcher, T. D. (2018). The role of plants in bioretention systems; does the science underpin current guidance? *Ecological engineering*, *120*, 532–545. https://doi.org/10.1016/j.ecoleng.2018.07.007

Dunnett, N., & Clayden, A. (2007). *Rain gardens: managing water sustainably in the garden and designed landscape*. Timber Press, Inc.

Emanuel, R., Godwin, D., & Stoughton, C. (2010). *The Oregon Rain Garden Guide: Landscaping for Clean Water and Healthy Streams*. Oregon Sea Grant. https://seagrant.oregonstate.edu/sgpubs/oregon-rain-garden-guide

Foster, J., Lowe, A., & Winkelman, S. (2011). *The value of green infrastructure for urban climate adaptation*. Center for Clean Air Policy. https://savetherain.us/wp-content/uploads/2011/10/Green_Infrastructure_Urban_Climate_Adaptation.pdf

Franti, T. G., & Rodie, S. N. (2007). *Stormwater Management: Rain Garden Design for Homeowners*. NebGuide. http://extensionpublications.unl.edu/assets/pdf/g1758.pdf

Gardner, S., Sidisunthorn, P., & Anusarnsunthorn, V. (2000). *A field guide to forest trees of northern Thailand*. Kobfai Publishing Project.

Gonzalez-Merchan, C., Barraud, S., Le Coustumer, S., & Fletcher, T. (2012). Monitoring of clogging evolution in the stormwater infiltration system and determinant factors. *European Journal of Environmental and Civil Engineering*, *16*(sup1), s34–s47. https://doi.org/10.1080/19648189.2012.682457

Hinman, C. (2005). *Low Impact Development: Technical Guidance Manua for Puget Sound*. Washington State University, Pierce County Extension. https://kingcounty.gov/~/media/depts/dnrp/solid-waste/green-building/documents/Low_Impact_Development-manual.ashx?la=en

Hunt, W. F., Lord, B., Loh, B., & Sia, A. (2015). *Plant selection for bioretention systems and stormwater treatment practices*. Springer Singapore https://doi.org/10.1007/978-981-287-245-6

Jaber, F., Woodson, D., LaChance, C., & York, C. (2013). *Stormwater Management: Rain Gardens*. The Texas A&M Agrilife Extension Press. https://agrilife.org/watersmart/files/2013/05/Stormwater_rain-gardens_AgriLife.pdf

Ji, L.-J., Peng, K., & Nisbett, R. E. (2000). Culture, control, and perception of relationships in the environment. *Journal of personality and social psychology*, *78*(5), 943–955. https://doi.org/10.1037/0022-3514.78.5.943

Likitswat, F. (2018). *Landscape Transformations Towards Sustainable Urbanism: The Case of Rangsit, Bangkok Peri-Urban* [Conference Session]. The 9th Built Environment Research Associates Conference 2018 (BERAC 9), Bangkok Art Conpemporary Center (BAAC), Bangkok, Thailand.

Limthongsakul, S. (2018). Impediments and hindrances for urban runoff management in the context of rapid urban growth:a case study of Kasetsart University, Bangkhen Campus. *JOURNAL OF ENVIRONMENTAL DESIGN*, *5*(1), 2–19. https://so02.tci-thaijo.org/index.php/jed/article/view/136791/101950

Madanipour, A. (2010). Whose public space? In A. Madanipour (Ed.), *Whose Public Space?: International Case Studies in Urban Design and Development* (pp. 237–242). Routledge.

Madanipour, A., Knierbein, S., & Degros, A. (2014). Políticas para el espacio público en las ciudades europeas [Politics for public space in European cities]. *Gestión y ambiente*, *17*(1), 115–137.

Mahawan, C.,Jitpairod, K., & Rinchumphu, D (2021). *ANALYSIS OF STORMWATER RUNOFF ABSORPTION POTENTIAL PER CONSTRUCTION COST OF GREEN ROOF* [Conference Session]. The 26th National Convention on Civil Engineering, Online Conference.

Maneegorn, N., & Panin, O. (2016). Dynamic Aspects of Vernacular Houses at Baan Tung Tom, San Patong, Chiangmai**.** *NAJUA: Architecture, Design and Built Environment*, *30*. 214–233. https://so04.tci-thaijo.org/index.php/NAJUA-Arch/article/view/69622/56528

Molloy, J., & Albert, R. (2008). *Managing Wet Weather with Green Infrastructure* [Conference Proceeding]. Greening Rooftops for Sustainable Comminities: Conference, awards & trade show, Baltimore, MD, the United State.

Nassauer, J. I. (2011). Care and stewardship: From home to planet. *Landscape and Urban Planning*, *100*(4), 321–323. https://doi.org/10.1016/j.landurbplan.2011.02.022

Nathiwutthikun, K., Peerapun, W., & Paksukcharern, K. (2008). THE LOGIC OF MULTI-USE OF PUBLIC OPEN SPACES IN CHIANG MAI CITY. *Nakhara : Journal of Environmental Design and Planning*, *4*, 45–68. https://ph01.tci-thaijo.org/index.php/nakhara/article/view/105104

Nawanuch, P., Mairoongroj, B., Sirachockratamanee, P., & mahawajn, P. (2022). Management of Water for Argriculture by the Community. *Santapol College Academic Journal, 8*(2), 182–190. https://so05.tci-thaijo.org/index.php/scaj/article/view/257741

Nimsamer, P., & Ramasoot, T. (2015). Vernacular Houses in Riparian Community of Central Plain, Thailand and Coping Capacity of Floods in Present. *NAJUA: Architecture, Design and Built Environment*, *12*. *98–119*. https://so04.tci-thaijo.org/index.php/NAJUA/article/view/44785

Oliveira, L. S., & Franca, A. S. (2015). An overview of the potential uses for coffee husks. In V. R. Preedy (Ed.), *Coffee in health and disease prevention* (pp. 283–291). Academic Press. https://doi.org/10.1016/B978-0-12-409517-5.00031-0

Public Utilities Board of Singapore. (2014). *Active Beautiful Clean Waters: Design Guidelines (3rd Edition)*. Public Utilities Board (PUB).

Pour, S. H., Abd Wahab, A. K., Shahid, S., Asaduzzaman, M., & Dewan, A. (2020). Low impact development techniques to mitigate the impacts of climate-change-induced urban floods: Current trends, issues and challenges. *Sustainable Cities and Society*, *62*, 102373. https://doi.org/10.1016/j.scs.2020.102373

Rinchumphu, D., & Anambutr, R. (2017). Determination of stormwater runoff infiltration on rain water absorbing garden for landscape architecture. *Journal of Environmental Design*, *4*(2), 84–101. https://so02.tci-thaijo.org/index.php/jed/article/view/111299

Srinurak, N., & Mishima, N. (2014). *The impact of urban sprawl on cultivated area in river city of Chiang Mai* [Conference Session]. International Symposium on Lowland Technology, Saga University, Saga, Japan.

Srisuwan, A. (2016). Uses and Illumination in public spaces in Chiang Mai City. *JOURNAL OF ENVIRONMENTAL DESIGN*, *3*(2), 72–99. https://so02.tci-thaijo.org/index.php/jed/article/view/73087

Stappers, P. J., & Giaccardi, E. (2017). Research through design. In M. Soegaard, & R. Friis-Dam (Eds.), *The encyclopedia of human-computer interaction* (pp. 1–94). The Interaction Design Foundation.

Strauß, P., Greven, A., & Brettel, M. (2021). Determining the influence of national culture: insights into entrepreneurs' collective identity and effectuation. *International Entrepreneurship and Management Journal*, *17*(2), 981–1006. https://doi.org/10.1007/s11365-020-00645-2

Sullivan, W. C. (2005). Forest, savanna, city: evolutionarylandscapes and human functioning. In P. F. Barlett. (Ed.), *Urban place, reconnectingwiththe natural world* (pp. 237–252). The MIT Press.

Suppakittpaisarn, P., Larsen, L., & Sullivan, W. C. (2019). Preferences for green infrastructure and green stormwater infrastructure in urban landscapes: Differences between designers and laypeople. *Urban Forestry & Urban Greening*, *43*, 126378. https://doi.org/10.1016/j.ufug.2019.126378

Suppakittpaisarn, P., Surinseng, V., Wanitchayapaisit, C., Yaipimol, E., & Xu, Q. (2020). Healthy Ecosystem Services and Healthy Human Settlements: Opportunities and Challenges in Northern Thailand. *Landscape Architecture Journal*, *27*(9), 77–88. https://doi.org/10.14085/j.fjyl.2020.09.0077.12

Thanvisitthpon, N., Shrestha, S., & Pal, I. (2018). Urban flooding and climate change: A case study of Bangkok, Thailand. *Environment and Urbanization ASIA*, *9*(1), 86–100. https://doi.org/10.1177/0975425317748532

Thipsuwan, C. (2015). FACTORS OF INTEGRATED WATER RESOURCE MANAGEMENT OF MAERIM SUB WATERSHED, CHIANG MAI PROVINCE. *Journal of Social Academic*, *8*(1). https://so04.tci-thaijo.org/index.php/social_crru/article/view/80548

Watson, D., & Adams, M. (2010). The Altered Landscape. In D. Watson, & M. Adams (Eds.), *Design for Flooding: Argriculture, Landscape, and Urban Design for Resillience to Flooding and Clomate Change* (pp. 91–102). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118259870.ch5

Wells, H., Duffy, L., Nance, M., Fleming, L., Stone, G. A., Townsend, J., & Stevenson, S. L. (2019). Does Culture Matter? : An Exploratory Study of Culture in the Implementation of an Adaptive Sports Program. *Therapeutic Recreation Journal*, *53*(3), 224–243. https://doi.org/10.18666/TRJ-2019-V53-I3-9684

Zhang, L., Ye, Z., & Shibata, S. (2020). Assessment of rain garden effects for the management of urban storm runoff in Japan. *Sustainability*, *12*(23), 9982. https://doi.org/10.3390/su12239982

Zimmerman, J., & Forlizzi, J. (2014). Research through design in HCI. In Olson, J., Kellogg, W. (Eds.), *Ways of Knowing in HCI* (pp. 167–189). Springer. Springer. https://doi.org/10.1007/978-1-4939-0378-8_8