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Runoff Management at Ridho Residence Using the Rain Garden

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Abstract

Namorambe Sub-district is located in a lowland area with 100 mm/day rainfall intensity. The lack of green open land exacerbates rainwater infiltration due to rampant housing developments. This problem has resulted in some Namorambe being subject to annual flooding. An inundation of 10-30 cm can damage infrastructure, disrupt economic stability, and threaten public health. To overcome this problem, the team provided socialization and training and made a rain garden at the Ridho Residence as a pilot model for the community. By looking at the social life in this very friendly housing and the people who live by having a sense of togetherness and living together, the team is confident that the program that has been implemented can be sustainable. The community is expected to feel the program's social, economic, and health benefits. It is one of the most effective ways to introduce rain gardens to the community in Namorambe District. With the provision of rain runoff management training through the application of a rain garden for residential property managers, the selling price of housing can be increased because it is equipped with facilities that make residents safer and more comfortable.

Keywords: Runoff, Property, Catchment Area, Rain Garden.

INTRODUCTION

Housing development causes changes in the landscape from its natural initial condition to be completely rigid and hard (Prayogo et al., 2020a; Yacub et al., 2022). This problem causes rainwater that falls into the pavement area to not optimally infiltrate into the soil and become runoff, harming the surrounding environment. The average rain that falls in the tropics is very heavy and high intensity, which is more than 2,000 mm/year (Prasetyo et al., 2018). Rain for just two hours can cause puddles, even flooding. It happens because the community relies on water canals as rainwater drainages (Prayogo et al., 2020b; Pasaribu et al., 2022; Prayogo et al., 2022). Drainage channels are not functioning properly due to being clogged by piles of garbage carried along with the flow of water and silting of the channel due to sedimentation. The community has been introduced to several methods of absorbing rainwater to ease the burden on downstream waterways. These methods include making bio pores (Karuniastuti, 2014), infiltration wells (Suprapto & Rachmawati, 2021), and environmentally friendly paving blocks (Yasa & Supriyadi, 2020). These methods can be applied to the house's yard but still have drawbacks. Rainwater is possible to carry several hazardous chemicals (Satriawan, 2018; Siregar et al., 2016), such as lead (Pb), cadmium (Cd), and tin (Sn), which can dissolve with rainwater due to anthropogenic sources and pollute the environment.

The rain garden is an environmentally friendly technology to support sustainable development (Zhang et al., 2020). This method can be an alternative to overcoming the problem of rain runoff and reducing harmful contaminants carried with rainwater. Its existence can also make the surrounding environment cooler and invite several biotas, such as butterflies, birds, to beetles. In its application, there is no need to worry about the presence of mosquitoes. The design and construction of the rain garden are designed to absorb stagnant water in less than 3 days, while one mosquito breeding cycle takes a total of 5-7 days from egg to adult. The construction of a rain garden is slightly different from the construction of a garden in general. Rain gardens are built according to design, location, and construction standards to function optimally.

By looking at the initial conditions, the team approached community groups and obtained information that several community groups worked independently to carry out activities with the community. In addition, several community members are self-aware in building communities and leading a group of women to care for and be aware of the importance of protecting the environment, such as making gardens in their yards or reforestation at several points around residence complexes. The activities routinely carried out are maintaining the cleanliness of rivers and drainage channels which are carried out regularly once a month, socialization of composting, and planting plants in the house yard as an eco-movement. These efforts, however, are not fully based on a form of rain runoff control. Based on observations and analysis of initial conditions, the team introduced the rain garden method through socialization and making a pilot model.

MATERIALS AND METHODS

Location and Community Overview

Namorambe Sub-district is geographically located at an altitude of 51-427 m above sea level and has a land slope of 4-7º. This region is strongly influenced by the tropical climate with an average air temperature of 18-36ºC. A rainfall of 2,256 mm/year makes the rainy season even worse if it is not managed properly, especially with the development of regional and residential development activities that are increasingly widespread. The distance is quite close to the Medan City (Figure 1), making the environmental hue of Ridho Residence also strongly influenced by dry climatology. In the dry season, the weather tends to be hot, while when the rainy season arrives, the rain lasts for a longer duration (60-120 minutes/day). The existence of housing development causes a change in the natural landscape from being natural to be completely rigid and hard (Chouinard et al., 2008). causes rainwater that falls in this area is not absorbed and becomes runoff. In other areas, water becomes expensive during the dry season from April to October. On the other hand, the soil type in Namorambe, which consists of fertile alluvial soil, makes it suitable for making a rain garden and planting various plants.

Implementation Method

Programs implemented to address problems with partners include planning approaches or changing the residential yard landscape, education and training (Mulyana et al., 2021), and mentoring. The socialization for partners is carried out at the residence of one of the residents. Implementing the landscape arrangement of the partner's residential yard is designed so that it does not interfere with the comfort and safety of the occupants of the house and can still optimize the absorption of rain runoff into the soil. For three meetings, training (partners, builders, and the community) is held every Saturday from 09.00-16.00 WIB. Monitoring activities are carried out every two weeks after the landscaping action activities, procurement of supporting facilities, and training for community until the end of this activity. Monitoring is important to ensure that partners implement the program on an on-going basis (Dyer et al., 2014; Sufri et al., 2020).

The existence of housing development causes changes in the landscape from natural to rigid and hard (Figure 2). This condition causes rainwater not to flow into the ground and becomes runoff water that will disturb the surrounding environment. One way to manage rainwater is by offering the team a rain garden pilot project in a residential complex. The building is made and does not require special preparation or treatment, so other communities easily adapt to it (Qarinur et al., 2022). This technology is made by utilizing the types of yard plants that are easily found in Indonesia. Each layer of the basin in the pond is planted with various plants that accelerate the absorption of rainwater while absorbing pollutants carried with rainwater. The planned rain garden design is added with infiltration well units that maximize water infiltration into the soil. If the rain capacity exceeds the pond's volume, runoff is channeled into infiltration wells to be accommodated and infiltrated into the ground. Making a rain garden in the yard can have several benefits, especially during the rainy season, such as (1) Reducing the volume of puddles/floods, runoff in sewers, and soil erosion. Rainwater runoff is trapped in the soil, roots, and also plant stems which causes the flow to be slower. This stream then has time to seep into the ground; (2) Can filter various pollutants carried with rainwater before they seep into groundwater or sewers

such as drainage, rivers, lakes, and/or seawater; (3) Increase the amount of rainwater that seeps into the ground to replenish groundwater; (4) Beautify the appearance of the yard of the house; (5) Provide natural habitat for insects and birds.

The construction of a rain garden is carried out at a minimum distance of 1-3 m from the house's outer wall (Asleson et al., 2009). So that the wall or structure of the house is not damaged (Figure 3). The soil is excavated at a depth of 50-100 cm. The bottom layer of the pond in the garden (about 30 cm) is filled with fill soil, and the second layer (50 cm) is filled with planting media with the ratio of soil: compost: water is 3:2:5. Plants were selected based on species that are adaptable to the climate in the Namorambe area. Several other categories can also be considered based on the color and type of rain garden maker's favorite. Plants planted in the center area towards the edge are small plants. To maintain soil moisture, the soil surface is covered with mulch (sawdust and wood chips) (McFadyen, 2012). Mulch can also function to absorb heavy metals. The best time to build a rain garden is in the dry season when the soil is moist.

RESULTS AND DISCUSSION

Program Socialization and Planning

At the preparation stage, coordination with the Village Head and observations on partners and communities will be targeted by participants. Observations were also made by looking at the condition of the housing environment against information obtained from various reference sources. Coordination explains the plans and designs of community service programs that will be carried out. The socialization and training were conducted at different times at the one of local residences in the Ridho Residence. The group of participants who are invited to this training activity follows the purpose of the activity, namely partners/workers/community who are over 17-35 years old. This group possibly has a mindset that has not been fully formed, so it is more easily influenced. In addition, this group is also felt to have the time and a high willingness to do something they think is good. Preparation of activity plans, materials, tools, and materials used in implementing activities are prepared 30 days before the day of implementation. The method used is interactive counseling by providing material and making a pilot project of one method of managing rain runoff in urban areas, namely the rain garden. The main resource persons for the training consisted of four lecturers from the Universitas Negeri Medan. Each of them was tasked with delivering material regarding the general and technical description of the activities to be carried out according to the planned timeline.

The socialization activity was held on Tuesday, April 26th, 2022. The implementing team attended it for community service activities at Universitas Negeri Medan, and property owners and staff to coordinate plans for a rain garden pilot at the Ridho Residence. In this session, the discussion was led by Dr. Ir. Putri Lynna A. Luthan, M.Sc. and Wisnu Prayogo, S.T., M.T. The total number of participants involved reached 20 people consisting of residents (13), handymen working in Ridho Residence (4), and residence managers (3). After the team has determined the placement location, the next step is to make a guidebook that contains the stages of making a rain garden that will be applied (Figure 4). This manual contains content to make it easier for the general public to understand the benefits and technicalities of making a rain garden on a home scale. The guide also provides important things that must be considered in planning and maintaining a rain garden in simple and easy-to-understand language.

Training of Rain Garden Making

Before digging, it is necessary to determine the digging depth to accommodate the inundation depth, soil mix, and runoff retaining area. Excavations are carried out on the fairly flat ground with a slope of less than 5%. The puddle's depth is 15-30 cm, and the recommended runoff retaining depth is more than 15 cm. The recommended depth of mixed soil is 30-60 cm. During the excavation process, soil compaction should be avoided. Figure 3 is a rain garden design applied to Ridho Residence. Infiltration wells here function as a complement to maximize water infiltration and reduce runoff that causes inundation/flooding (Ikhwali et al., 2022). An effective rain garden can absorb rain runoff for no more than 72 hours (less than 3 days).

Various plants are selected to be planted in each layer of the basin in the rain garden pond, which functions as an absorber of pollutants carried by rainwater and accelerates the absorption of rainwater. Nitrogen (N) and Phosphate (P) are the main contaminants absorbed by plant roots in the rain garden. Both of these components are necessary for plant growth, but if this type of pollutant is present in large quantities in water bodies, it can cause eutrophication. Eutrophication is water pollution caused by excessive nutrients entering aquatic ecosystems resulting in the enrichment of nutrients and organic matter in the water. It then encourages the growth of algae or phytoplankton. It increases water productivity, which triggers a significant decrease in oxygen concentration in the water and increases the concentration of gases and harmful compounds (cyanotoxins). Aquatic biota will die in large numbers. Plants can also filter out pollutants, including oils and fats, heavy metals, and suspended solids that are dissolved and carried away from urban roads, building roofs, and asphalt, in addition to the N and P elements. Runoff from rain is naturally cleaned by soil and plant roots before entering the groundwater system. According to Bortolini & Zanin (2019), the success of a rain garden in accommodating, absorbing, and evaporating rain runoff is also strongly influenced by the types of plants that grow. Plants can enlarge and lengthen the pores in the soil due to growth and create macro pores. Plant growth characteristics are usually associated with increased evapotranspiration rates, which will also be higher during the dry season. Some examples of recommended types of plants that are good enough based on research results to be applied in the rain garden are listed in Table 1.

The rain garden has three main zones (Syafriana & Arifin, 2020). The first zone is the part located at the bottom and is the wettest area. The second zone covers the mid-slope towards the outer part of the pond, which sometimes becomes wet. This zone requires plants to help stabilize the slope. The third zone includes the area around the rain garden and/or the embankment, where plants will grow in drier soil. Reducing the volume of rain runoff using the rain garden system by various studies gives good results in the range of 23-97%. A large number of studies have stated a reduction of 22–93% of water pollutants in Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphate (TP), and Chemical Oxygen Demand (COD). Reduction of 22-93% of water pollutants is evidenced by vegetation in the rain garden pond through assimilation, mineralization (ammonification), nitrification, and denitrification (Table 2).

Table 1. Types of plants that are recommended to be placed in a rain garden

No.	Physical Appearance	Shape	Scientific name	Local Name	High (cm)	Location	Zone
1.			Carex bichenoviana	Rumput-rumputan	40	All locations	1, 2a
2.			Goodenia ovata	-	100-250	All locations	2b, 3
3.			Ficinia nodosa	Alang-alang	20-150	All locations	1, 2a, 2b, 3
7.			Crassula helmsii	Rumput giok	50	All locations	2a, 2b, 3

No.	Physical Appearance	Shape	Scientific name	Local Name	High (cm)	Location	Zone
8.			Dichondra repens	Rumput ginjal	20	Ground cover	2a, 2b, 3
9.			Scaevola albida	Bunga kipas pucat, bunga kipas buah kecil	10-20	All locations	3
10.			Wahlenbergia stricta	-	10-90	All locations	3

Plants are very important in facilitating the removal of pollutants in a rain garden system (Brown-Fraser et al., 2015; Sharma & Malaviya, 2021). Vegetation also helps maintain soil structure in the root zone. The plant's root system continuously loosens the soil and creates macro pores that maintain infiltration capacity in the long term. Some types of plants are more effective in adapting to the conditions in the rain garden. According to Morash et al. (2019), Larger plants are more tolerant of flooding than smaller plants because the root system in larger plants is stronger. Thus, the size of the initial plant must be considered during the manufacturing stage. Planting with polyculture techniques is also another important consideration. The results showed that using various species of plants can improve the function of the rain garden. Diversification of plant proportions such as monocotyledonous and dicotyledonous groups, species that can live all year round and seasonally, and shallow-rooted and deep-rooted plants these considerations can increase nutrient absorption, biomass productivity, and stress tolerance. Plant diversity can also increase water absorption competition and sensitivity to flooding and nutrient absorption. Nutrients in the environment are released during the rainy/winter season, degradation of dead plants, and due to the presence of other tree species, such as spruce. Planting with polyculture techniques shows greater potential for removing contaminants in the water (Clive et al., 2019), such as nutrients and heavy metals. Planting with polycultures can improve the overall performance of the rain garden (Whitcomb, 2014) through greater absorption of nutrients, especially from runoff, avoiding seasonal vegetative gaps, and increasing water uptake (Table 2).

The manufacture and maintenance of a rain garden must pay attention to several things, such as: (1) The water inlet to the rain garden is not blocked by materials that can block water; (2) Avoid using chemical fertilizers, pesticides, or herbicides, which are excessive in making ponds; (3) Plants must be ensured to get sufficient water at the beginning of the time of manufacture; (4) Add mulch to a thickness of 2-3 inches across the entire pond layer to maintain soil moisture, replenish organic matter in the soil, prevent erosion, and prevent weeds from growing; (5) Consider growing a variety of plants that can live all year round; (6) Space should estimate when the plant reaches its mature size; (7) Plants that are too large may require more maintenance later on, such as pruning; (8) Avoid creating a rain garden near the roots of pre-existing trees and shrubs; (9) If the rain garden is located under power and utility lines, be sure to meet the maximum height requirements when the plants grow up; and (10) If there are utilities near the rain garden, choose plants that will not grow and damage or clog the utilities.

Table 2. Summary of percent (%) runoff and pollutant retention by rain garden

Run off	TSS	TN	TP	COD	Reference
78	-	40	65	-	Hunt et al. (2006)
97	-	-	-	-	Guo et al. (2019)
33	-	-	-	-	Hatt et al. (2009)
48-74	87-93	-	67-83	-	Chapman & Horner (2010)
23-85	-	-	-	-	Gülbaz & Kazezyılmaz-Alhan (2017)
-	22	-	74	-	Davis (2007)
-	83	62	48	-	Line & Hunt (2009)
-	93	-	90	-	Li & Davis (2009)
26	54	34	47	28	Liu et al. (2015)
23	41	29	-	-	Rezaei et al. (2019)

CONCLUSIONS AND SUGGESTIONS

The impact of urbanization results in changes in proportion to the hydrological cycle (Wisnu Prayogo et al., 2021; Subroto et al., 2022), increased concentrations of contaminants and loss of vegetation. From this problem, the rain garden is suitable for application in urban areas. Even though it looks easy like an ordinary garden, its construction requires careful planning to ensure that the rain garden can function optimally. It is hoped that socialization and training and making a rain garden pilot project at the Ridho Residence Housing can help deal with community problems from inundation/floods in the rainy season. With the provision of rain runoff management training through the application of a rain garden for residential property managers, the selling price of housing can be increased because it is equipped with facilities that make residents safer and more comfortable. This kind of program can be held again in other locations by considering the number of people as more massive participants so that more people will know the benefits and technicalities of making rain gardens.

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APPENDIX

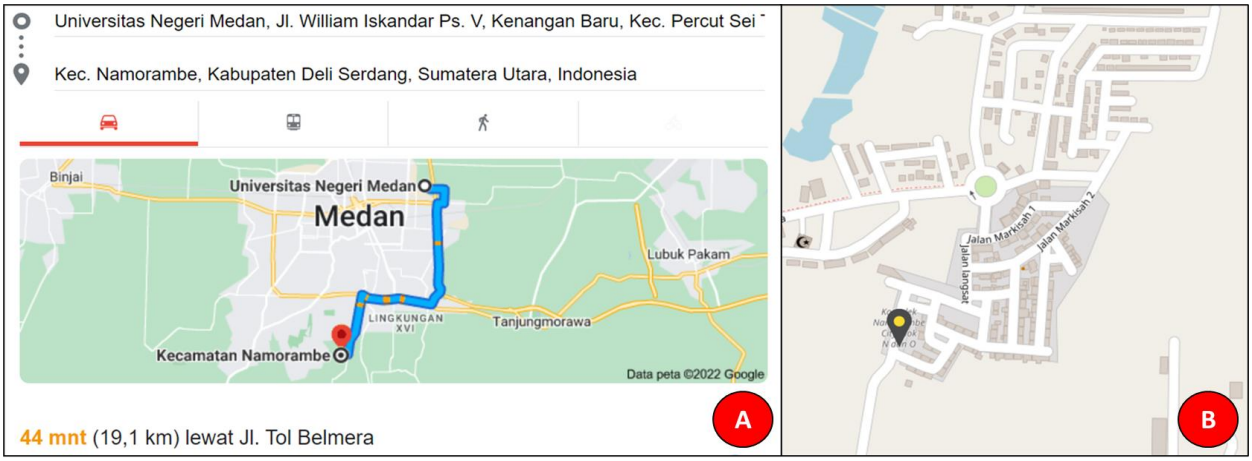

Figure 1. (A) Distance from Universitas Negeri Medan to Namorambe Sub-district (B) Ridho Residence (marked with black pin)

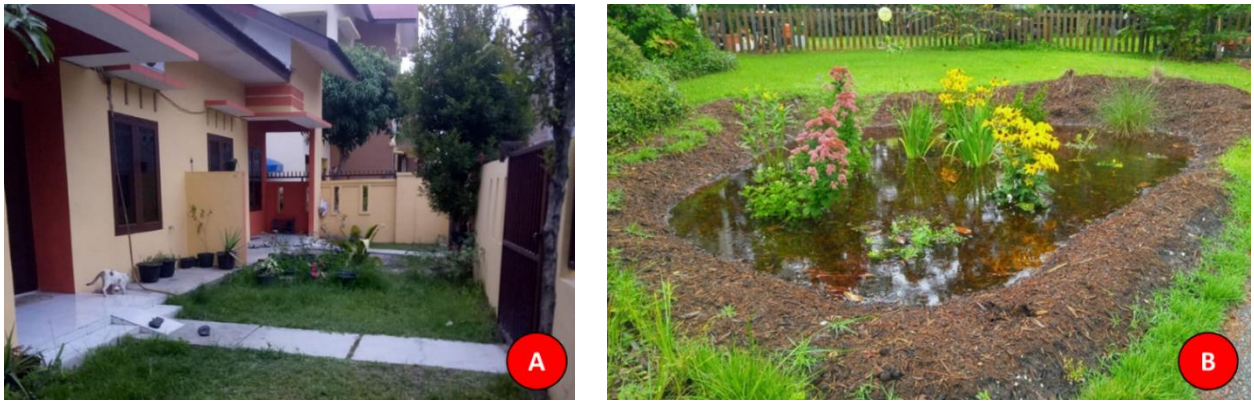

Figure 2. (A) Potential land use that has not been utilized and (B) Optimization of yard land for rain runoff management with the rain garden method

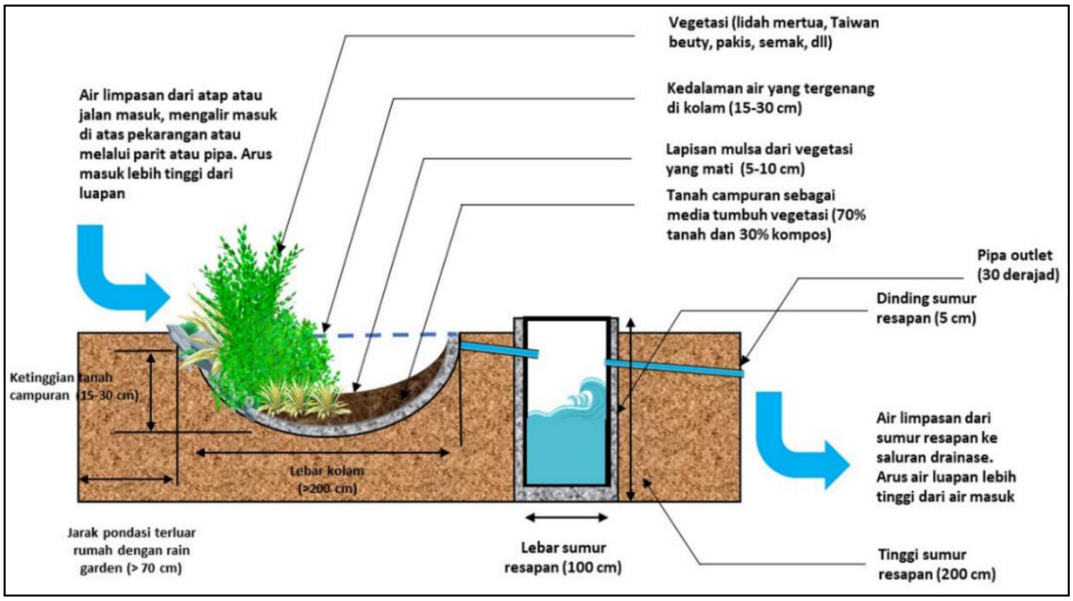

Figure 3. Rain garden design

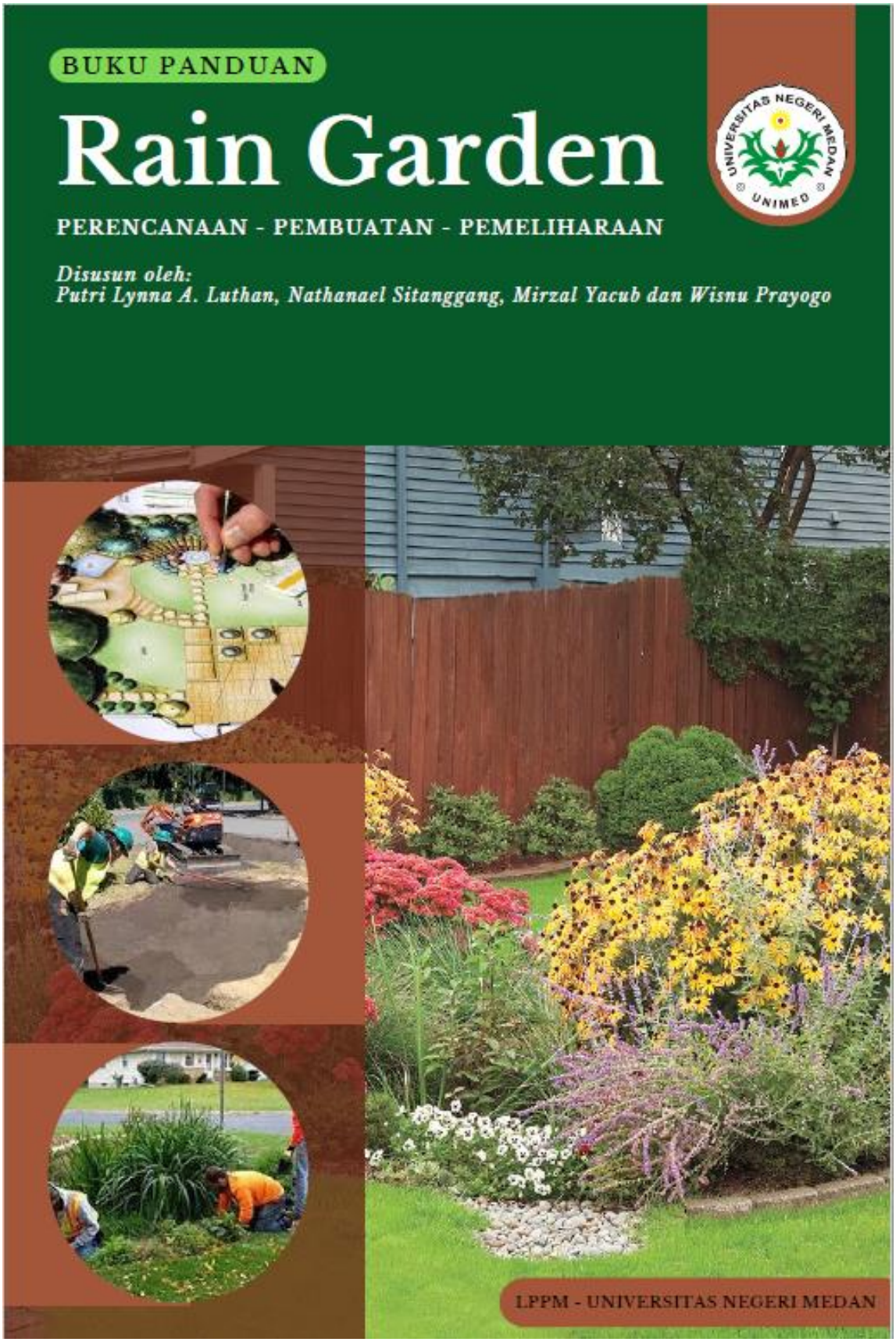

Figure 4. Cover of rain garden manual

Figure 5. Rain garden equipped with infiltration wells at Ridho Residence