

A Laboratory-Scale Rainfall Simulation of the Surface Runoff Reduction Using Biopore Infiltration Holes

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ABSTRACT

Rapid land-use changes and the reduction of green open spaces have substantially decreased rainwater infiltration capacity, resulting in increased surface runoff, elevated flood risk, and declining groundwater recharge. Biopore Infiltration Holes (BIHs) are a simple, low-cost, and environmentally friendly technique for enhancing soil infiltration by improving subsurface pore connectivity. This study evaluated the effectiveness of BIHs in reducing water surface runoff under controlled laboratory-scale conditions. A physical test model was developed using plastic containers (700 × 510 × 425 mm) filled with disturbed soil representing three land-cover conditions: open land (bare ground), semi-closed land (grass and weed vegetation), and closed land (tall tree vegetation). The semi-closed land cover was represented by grass plants, and the closed land cover by white rombusa plants. Rainfall was simulated using a calibrated rainfall simulator operating at 50% pump pressure, and infiltration performance was quantified based on outflow collected from BIHs. The results demonstrate that soil systems equipped with BIHs combined with perennial vegetation consistently exhibited the highest infiltration capacity and the lowest runoff volumes across all land-cover scenarios. These findings indicate that BIHs function as artificial macropores, while plant root systems form complementary natural macropores, resulting in synergistic improvement of soil hydraulic performance. This study highlights the potential contribution of integrating BIHs and vegetation as a laboratory-validated approach to support sustainable stormwater management strategies.

Keywords-biopore infiltration holes; rainfall simulation; laboratory scale; infiltration

I. INTRODUCTION

Floods are natural disasters caused by intense rainfall events combined with limited infiltration capacity, resulting in significant physical and material loss. In urban areas, it is challenging to reduce the risk of flooding damage and its impact on water quality [1]. In addition to high rainfall,

changes in land use and the reduction of green open spaces contribute to reduced rainwater infiltration into the soil. Consequently, surface runoff increases, the potential for flooding increases, and groundwater reserves decline [2, 3]. In addition, changes in land use can also increase water discharge and expand flood areas [4]. A land-use system with tree-type vegetation distribution is more capable of retaining rainwater

than a land-use system dominated by shrub vegetation [5]. Low water absorption into the ground is one of the causes of flooding when heavy rain occurs for a long duration [6]. If a location has poor groundwater absorption capacity, when it rains, flowing surface water creates puddles, preventing the water from properly infiltrating the ground. This can lead to flooding during heavy and prolonged rainfall. The groundwater absorption capacity can be measured by the infiltration rate test. If the ratio of rainfall intensity is smaller than the infiltration rate, then all the rainwater that falls will seep into the ground [7]. Environmentally friendly and economical mitigation efforts are needed to restore the natural hydrological function of the land.

An effective solution is the application of Biopore Infiltration Holes (BIHs), namely vertical holes with a diameter of ± 10 -15 cm and a depth of ± 100 cm, which are designed to increase the area of water absorption [8-10]. The presence of BIHs can reduce runoff by up to 50% and significantly increase the rate of soil infiltration [2]. The results of field research are often difficult to generalize due to the influence of many uncontrollable variables, such as variations in natural rainfall intensity, soil heterogeneity, and environmental conditions. Therefore, a laboratory-scale research approach is essential for obtaining more controlled and reliable data.

Authors in [9] examined the management and reduction of surface runoff at the farm level by presenting three outlet scenarios (direct, garden, and bioretention) using the Storm Water Management Model (SWMM). The results showed that the bioretention scenario consistently resulted in reduced surface runoff volume. Laboratory-scale tests have been conducted exploring the effect of bioretention surface area and media conductivity on runoff reduction by creating a rainfall simulator and bioretention prototype. It was shown that the increase in area was directly proportional to the opportunity for infiltration and inflow temporally through bioretention [10].

Although BIHs have been widely promoted as a nature-based solution for enhancing infiltration and reducing surface runoff, most previous studies have been conducted under field conditions where rainfall variability, soil heterogeneity, and land management practices are difficult to control. Consequently, the quantitative relationship between infiltration behavior, BIHs configuration, and vegetation effects remains insufficiently investigated. Laboratory-scale research allows for hydrological simulations (especially infiltration and runoff) under tightly controlled conditions, such as rainfall intensity, land slope, number of BIHs, and variations in soil texture and type. Through this approach, the correlations between these variables can be systematically analyzed, resulting in a model of water infiltration behavior that can be adapted to the field scale [11]. Furthermore, laboratory tests allow for evaluating the relationship between soil variables and BIHs design. Experimental studies focusing on the interaction between BIHs and vegetation under controlled rainfall conditions are limited. Thus, the present study aims to analyze the effectiveness of BIHs in reducing surface water flow at the laboratory scale.

II. RESEARCH METHOD

This research was conducted at the Hydraulics Laboratory, Faculty of Engineering, Lambung Mangkurat University, by creating a miniature land model in a plastic container measuring $700 \times 510 \times 425$ mm. The soil conditions used were disturbed soil taken from open land (bare land), semi-closed land (grass and weed vegetation), and closed land (tall tree vegetation). The semi-closed land cover was represented by grass plants, and the closed land cover by white rombusa plants (*Tabernaemontana corymbosa*). Tests were conducted to estimate soil properties, such as water content (w), bulk density (γ), specific gravity (Gs), and Atterberg limits (liquid limit, plastic limit, plasticity index), as well as the soil mechanical properties, namely permeability (k). Rainfall simulations were performed using a laboratory-scale rainfall simulator consisting of a 1.5-inch distribution pipe connected to a water pump operating at 50% of its maximum pressure. The water pressure was monitored using a pressure gauge to maintain consistent operating conditions throughout the experiments. Rainfall input was recorded using an ABS tipping-bucket rain gauge, which is commonly employed for automatic rainfall monitoring. In this study, a tipping-bucket mechanism was used to quantify the cumulative volume of water delivered during each simulation, with each bucket tip corresponding to a fixed volume equivalent to 0.254 mm of rainfall depth [12]. The rainfall simulator was designed to provide a controlled and repeatable water input rather than to replicate standardized natural rainfall intensity. The system included a perforated rainfall distribution unit positioned above the soil containers, enabling water to be applied consistently across the soil surface under laboratory-scale conditions.

BIHs were constructed from $\frac{1}{2}$ -inch diameter pipes measuring 37-38 cm in length. Although the diameter of the BIHs used in this experiment is smaller than the standard field-scale biopore diameter of 10 cm, this experimental setup represents a laboratory-scale physical model and not a direct replication of field conditions. The selected pipe diameter served as a macropore-scale analog of the soil, allowing for controlled observation of the infiltration behavior within the spatial constraints of the laboratory model. The dimensions of the field-scale BIHs, as regulated by Indonesian standards [11], are cited for comparative purposes only. The BIHs were also left empty and not filled with organic waste. Twelve plastic tanks were used for the four simulations. The first simulation included a plastic tank with BIHs but without plants. The second simulation included a plastic tank planted with white rombusa plants and BIHs. The third simulation involved a plastic tank planted with grass and BIHs. The last simulation entailed a plastic tank planted with plants but without BIHs. Each simulation represented a single plot of open, semi-closed, and closed land cover. The measured parameter was the volume of water absorbed through the biopore pipes and collected in the plastic tank.

In addition to laboratory measurements, this study utilizes field-measured infiltration rate data (mm/h). The field data were used to provide a hydrological context and to examine the association between laboratory-scale BIH performance and soil infiltration behavior under real field conditions. A correlation

test was conducted between the infiltration rate measured in the field and the experimental simulation. This analysis was intended to identify empirical relationships rather than test treatment effects or conduct inferential hypothesis testing. Therefore, inferential statistical analysis such as ANOVA was not applied.

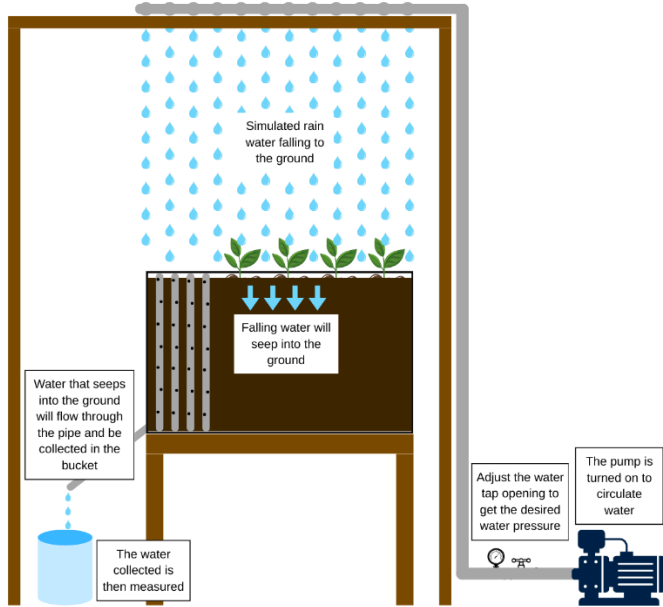


Fig. 1. Sketch of the infiltration test simulation.

Figure 1 shows the setup used for the infiltration simulations. Before the tests, the water valve is set to the desired water pressure, and then the water pump is turned on to supply water to the rainfall simulator. When the pump is operating, water falls like rain into the plastic tub containing soil and plants. The water then seeps into the soil and flows through a pipe at the bottom of the plastic tub, where it is collected in a bucket. The volume of collected water is then measured.

III. RESULTS

A. Physical Properties of Soil

In addition to measuring soil infiltration, the physical properties of the soil were tested. Soil characterization was conducted to support the analysis of hydrological behavior rather than full geotechnical classification based on the Unified Soil Classification System (USCS). Grain-size distribution tests were used to identify dominant soil fractions influencing infiltration processes. Hydrometer testing for fine-grained soils was not performed because the primary objective of this study was to compare the infiltration performance under controlled laboratory conditions rather than to establish a formal engineering soil classification.

When the pore spaces in the soil are predominantly filled with water, the soil is considered to be in a saturated condition [13]. As shown in Table I, the water content in the soil under closed land cover (54.32%) is higher than that under open (44.24%) and semi-covered land (42.22%). This indicates that

soils beneath closed land cover are closer to saturation, which can limit natural infiltration through the soil matrix and reduce the capacity of the soil to absorb incoming rainfall. The bulk density values further support these observations. Closed land cover exhibited the lowest bulk density (1.411 g/cm³) compared to open land (1.548 g/cm³) and semi-covered land (1.498 g/cm³). Although all soils can be classified as relatively dense (bulk density > 1.4 g/cm³) [14], the observed variations suggest differences in soil compaction and pore structure continuity, both of which directly influence water movement and infiltration behavior within the soil profile. The specific gravity (Gs) of soil particles across all land cover types ranged from 2.433 to 2.491. According to soil mechanics literature, quartz-rich mineral soils typically exhibit Gs values of approximately 2.65, whereas soils with high organic content generally exhibit much lower values (Gs < 2.0). Therefore, the measured Gs values indicate that the soils in this study were predominantly mineral soils, possibly containing lighter mineral constituents or minor organic matter, rather than being classified as organic soils [15]. Despite their mineral composition, the combination of high moisture content and relatively dense soil structure suggests that the effective permeability of the soil matrix remains limited. Under such conditions, BIHs play a significant role by acting as preferential flow paths that bypass the low-permeability soil matrix and enhance vertical water movement. Consequently, variations in soil water content and bulk density among land-cover types provide a physical basis for explaining the observed differences in the infiltration performances observed in this study.

TABLE I. SOIL PHYSICAL TEST RESULTS

| Parameter | Closed land cover | Open land cover | Semi-arid land cover |
|------------------------------|---------------------------|---------------------------|---------------------------|
| Water content | 54.32% | 44.24% | 42.22% |
| Volume (gr/cm ³) | 1.411 | 1.548 | 1.498 |
| Specific gravity | 2.491 | 2.433 | 2.491 |
| Sieve analysis | | | |
| Gravel | 0.07% | 0.27% | 0.17% |
| Coarse sand | 2.53% | 1.87% | 2.83% |
| Medium sand | 4.00% | 5.67% | 4.67% |
| Fine sand | 21.33% | 27.07% | 23.60% |
| Silt | 4.93% | 5.87% | 4.93% |
| Atterberg limits | | | |
| Liquid Limit (LL) | 44.2% | 44.2% | 43.0% |
| Plastic Limit (PL) | 31.6% | 27.7% | 31.7% |
| Plasticity Index (PI) | 12.5% | 16.5% | 11.4% |
| Permeability coefficient | 8.1633 x 10 ⁻⁹ | 8.4210 x 10 ⁻⁹ | 8.8485 x 10 ⁻⁹ |

Atterberg limits state that the type of soil in the 3 locations based on USCS includes the ML-OH classification, namely silt with a low plasticity value [13]. The measured permeability coefficients indicate that the soils exhibit very low permeability. The permeability values for closed, open, and semi-covered land are 8.16 × 10⁻⁹ m/s, 8.42 × 10⁻⁹ m/s, and 8.85 × 10⁻⁹ m/s, respectively. According to standard geotechnical classifications, permeability values on the order of 10⁻⁹ m/s correspond to nearly impervious or very low-permeability soils, typically associated with dense or compacted fine-grained soils, rather than being indicative of organic clay or soil plasticity characteristics [15]. Such

extremely low permeability values imply that water movement through the soil matrix is highly restricted due to the dominance of micropores and limited pore connectivity [16]. Consequently, under dense and near-saturated soil conditions, infiltration through the soil matrix alone becomes inefficient. These soil physical characteristics provide a clear physical explanation for the crucial role of BIHs in enhancing infiltration, as biopores function as preferential flow paths that bypass the low-permeability soil matrix, which is consistent with the laboratory-scale observations in this study.

B. Rainfall Simulator

A laboratory-scale rainfall simulator was developed to investigate hydrological behavior under controlled conditions. The system was equipped with a water pump and a flow-rate regulator to control the applied water input [10]. In general, rainfall simulators are designed based on rainfall characteristics, operational simplicity, and key parameters, such as droplet formation and spatial distribution. The primary function of the developed simulator was to regulate and deliver a consistent volume of water to the soil surface through a nozzle system, rather than to replicate natural rainfall events [17].

Figure 2 illustrates the setup used to estimate the rainfall generated by the rainfall simulator under each simulation condition. Two simulation settings were applied to represent different water input conditions. The first simulation was conducted using 50% pump pressure for 60 s, whereas the second simulation employed 100% pump pressure for 120 s. These settings were consistently maintained across all experimental treatments to ensure comparable input conditions among the soil and BIHs configurations. The average rainfall measurements (in mm/s) are presented in Table II.



Fig. 2. Setup for rainfall measurements.

As depicted in Table II, the average rainfall measured at 50% water pressure and 60 s time ranged between 0.08 mm/s and 0.18 mm/s, whereas the average rainfall measured at 100% water pressure and 120 s time ranged between 0.11 mm/s and 0.20 mm/s. The rainfall simulator was not intended to reproduce standardized natural rainfall intensity. Rainfall input was therefore treated as a controlled laboratory water application rather than as an absolute rainfall intensity expressed in mm/h. Variations in discharge among individual

outlets were observed. However, formal calibration of rainfall intensity and evaluation of rainfall uniformity using the Christiansen Uniformity coefficient (CU) were not conducted. As a result, rainfall intensity was considered a relative parameter, and the analysis focused on comparative infiltration responses between treatments under identical water input conditions.

TABLE II. RAINFALL DATA WITH 50% AND 100% WATER PRESSURE

| Plastic tub | Average rainfall for 50% pressure (mm/s) | Average rainfall for 100% pressure (mm/s) |
|-------------|--|---|
| Open | 0.08 | 0.13 |
| Closed | 0.13 | 0.13 |
| Semi | 0.17 | 0.13 |
| Open | 0.12 | 0.11 |
| Closed | 0.12 | 0.14 |
| Semi | 0.18 | 0.13 |
| Open | 0.10 | 0.13 |
| Closed | 0.13 | 0.14 |
| Semi | 0.10 | 0.16 |
| Open | 0.08 | 0.18 |
| Closed | 0.13 | 0.20 |
| Semi | 0.10 | 0.17 |

C. Biopore Infiltration Holes

BIHs are spaces or pores in the soil formed by living organisms, such as soil fauna and plant roots. BIHs are small, branched tunnels that are very effective in channeling water and air to and within the soil. BIHs are a water conservation (rainwater harvesting) concept that involves storing surface runoff or rainwater in the soil, especially during the rainy season. This concept constitutes a part of the same drainage system, reducing runoff quantity [18]. BIHs are cylindrical, 10-15 cm in diameter and 100 cm deep, not exceeding the groundwater level. The holes are spaced 50-100 cm apart. BIHs are typically filled with organic waste, such as leaves, lawn clippings, and kitchen waste [11, 12]. In this study, BIHs were created using 38 cm long, 1/2-inch pipes. The biopore pipes were then inserted into a 700 × 510 × 425 mm plastic tub filled with soil.

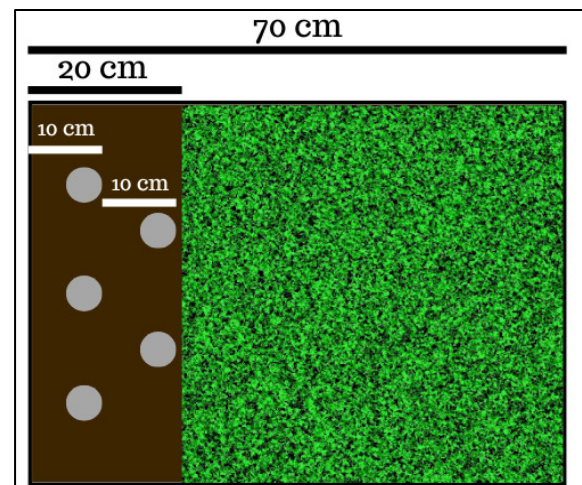


Fig. 3. Top-view sketch of BIHs.

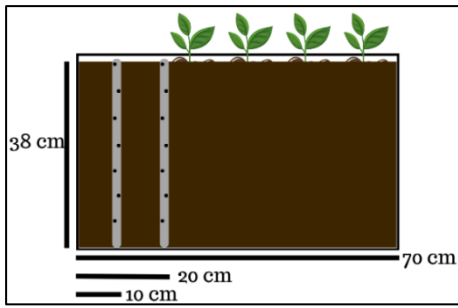


Fig. 4. Side-view sketch of BIHs.

Figures 3 and 4 show the spacing of the BIHs used in each experimental setup. Each plastic tub contained 5 BIHs, with the distances between the tub edge and pipe rows being 10 and 20 cm. Twelve plastic tubs were divided into four simulations, each containing three tubs. The plants used were grass and white rombusa. The plastic tub without plants simulates areas with open land cover, the plastic tub with grass plants simulates areas with semi-covered land cover, and the plastic tub with grass and white rombusa plants simulates areas with closed land cover.

Figure 5 displays a plastic tub with BIHs planted with white rombusa plants representing closed land cover conditions, while Figure 6 demonstrates a plastic tub with BIHs planted with grass representing semi-covered land conditions. The tests were conducted for 14 days with the water pressure set at 50% and applied for 1 min. The volume of water that infiltrated the soil and subsequently exited the plastic container through the outlet pipe was measured 24 h after water was supplied from the pump to the rainfall simulator. The results of the 14-day measurements are presented in Figures 7- 9.



Fig. 5. Plastic tanks simulating BIHs with white rombusa plants.



Fig. 6. Plastic tanks simulating BIHs with grass plants.

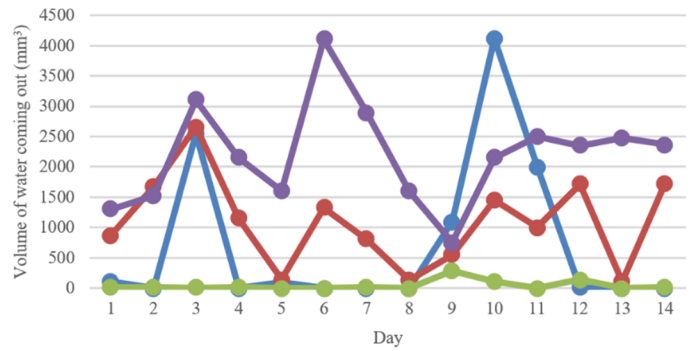


Fig. 7. Measurements for open ground conditions.

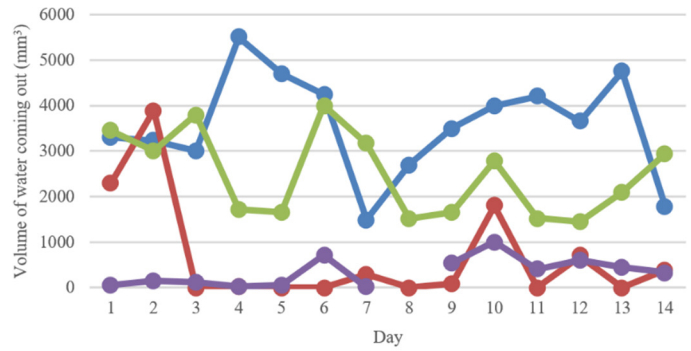


Fig. 8. Measurements for semi-soil conditions.

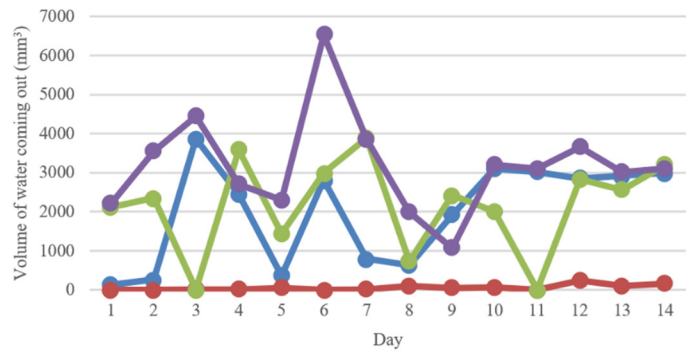


Fig. 9. Measurements for closed ground conditions.

According to Figures 7-9, the plastic tub with BIHs simulation with white rombusa plants in open, semi, and closed land cover conditions from the first day of testing until the 14th day, always absorbs well, as evidenced by the volume of water filled in the reservoir tank. This shows that with the presence of BIHs and white rombusa plants, water will be easily absorbed into the soil and reduce surface runoff. Similar to other simulations, it also helps reduce surface runoff, but in the

simulation of BIHs without plants, the value was low but remained constant. In the plastic tub with semi-covered land, the simulation without BIHs but with white rombusa plants also shows good results. The volume of the reservoir tank was always filled.

IV. DISCUSSION

The volume of infiltrated water measured in this study is expressed in mm³. All graphical and numerical results were standardized using this unit to ensure consistency and clarity in data interpretation. The results of simulation measurements using BIHs and a rainfall simulator indicate that BIHs and white rombusa plants, which are perennial plants, are very helpful in reducing surface runoff. The presence of BIHs facilitates water seepage into the soil. The results of this test were compared with the infiltration rate measurements in the field to conduct a correlation test. Infiltration rate measurements show that the soil of Datar Ajab village has infiltration rate values with different classifications. The most frequently appearing classification is very slow [19].

TABLE III. RESULTS OF THE CORRELATION TEST

| No | Without BIHs | BIHs without plants | BIHs with grass | BIHs with white rombusa | Land assumptions |
|----------------|--------------|---------------------|-----------------|-------------------------|------------------|
| Multiple R | 0.978 | 0.147 | 0.788 | 0.822 | 0.865 |
| R ² | 0.957 | 0.022 | 0.622 | 0.676 | 0.748 |

The correlation results indicate a positive association between the infiltration response observed in the laboratory and the infiltration rate measurements in the field, reflecting an empirical relationship rather than a statistically inferred treatment difference. As illustrated in Table III, the multiple R values for all simulations except the simulation with BIHs without plants ranged from 0.788 to 0.978, with a strong to very strong relationship level. The R² values ranged from 0.622 to 0.957, indicating a strong to very strong correlation. For the simulation of BIHs without plants, the level of correlation was very low. This demonstrates that the correlation between laboratory tests does not reflect the infiltration rate in the field for only one simulation. The relatively low infiltration performance observed in the BIHs scenario without plants can be attributed to the instability of artificial macropores under disturbed soil conditions. In the absence of plant roots, the macropore walls are more susceptible to partial collapse, clogging, and reduced continuity during repeated wetting cycles. Limited biological activity and poor soil aggregation further reduce pore connectivity and aeration, resulting in lower infiltration efficiency compared to BIH systems combined with vegetation. The correlation analysis presented in this study should be interpreted as exploratory. The absence of experimental replication limits inferential interpretation; however, the observed associations provide useful insights into infiltration behavior under controlled laboratory conditions.

BIHs are helpful in reducing surface runoff, which is the primary cause of flooding. In addition to surface runoff, land use influences flooding. In this test, BIHs with white rombusa plants, assumed to be perennials, had a constant water

absorption capacity. When these two factors are implemented together, they produce more permeable and fertile soil that effectively absorbs water, contributing to groundwater conservation and flood prevention. Although this study was conducted under laboratory conditions, the observed infiltration mechanisms provide insights into the potential field-scale behavior. BIHs function as preferential flow paths, analogous to natural soil macropores. At the field scale, their effectiveness depends on soil texture, vegetation type, biological activity, and maintenance. Therefore, laboratory results should be interpreted as mechanistic evidence supporting field implementation, rather than as direct predictors of field performance.

The results of this study are consistent with previous studies demonstrating the effectiveness of biopore infiltration systems in reducing surface runoff. BIHs significantly increase infiltration and reduce runoff under field conditions. The present laboratory-scale study supports these findings and further shows that BIH performance is strongly influenced by vegetation characteristics [2]. In comparison with the urban stormwater management strategies [9], which emphasize distributed outlet systems, this study focuses on the subsurface infiltration mechanism. The results indicate that BIHs combined with deep-rooted perennial vegetation, such as white rombusa, provide higher and more stable infiltration responses due to improved macropore continuity and biological stabilization. The findings are also consistent with a laboratory-based bioretention study [10], which highlighted the importance of pore connectivity in enhancing infiltration performance. Unlike engineered bioretention systems, this study demonstrates that relatively simple BIH-vegetation systems can generate preferential flow paths even in dense soils with very low permeability. This provides additional mechanistic insights into how biopore infiltration performance can be enhanced under controlled conditions.

A. Limitations of the Study

This study has several limitations that should be acknowledged to ensure the appropriate interpretation of the findings. First, the experimental design employed a single laboratory unit for each treatment, without statistical replication. Consequently, the results cannot be subjected to inferential statistical analyses such as ANOVA, and the findings should be interpreted as exploratory and comparative, rather than statistically conclusive. Second, the rainfall simulator used in this study was designed to provide controlled and repeatable water input but was not calibrated to represent standardized rainfall intensity or uniformity. Rainfall intensity was therefore treated as a relative laboratory input rather than an absolute hydrological parameter. Third, the measurements focused primarily on the infiltrated water volume through BIH systems, whereas other hydrological parameters, such as runoff volume, soil moisture dynamics, and hydraulic conductivity, were not directly measured. These limitations imply that the results represent laboratory-scale mechanistic evidence rather than direct predictors of field-scale hydrological performance. Future studies should incorporate experimental replication, standardized rainfall calibration, and additional hydrological

parameters to strengthen statistical robustness and field applicability.

V. CONCLUSIONS

Based on the results of the soil physical property tests, the soil water content for closed, open, and semi-closed land covers was already saturated, making it difficult, if not impossible, for water to penetrate the soil. The bulk density indicates dense soil, hindering water penetration. Furthermore, the very low soil permeability coefficient indicates that the small pores in the soil obstruct water penetration.

Laboratory-scale simulations demonstrate that Biopore Infiltration Holes (BIHs), particularly when combined with perennial vegetation, significantly improve infiltration capacity and reduce surface runoff under controlled conditions. Infiltration occurred most rapidly in simulations combining BIHs and perennial vegetation, followed by grass-covered soils, whereas BIH systems without vegetation exhibited slower and less stable infiltration due to macropore instability and limited biological reinforcement. These findings provide experimental evidence of infiltration enhancement mechanisms and indicate the potential contribution of BIH-vegetation systems as supportive measures for runoff reduction. However, the results should not be interpreted as direct evidence of flood-risk reduction at the field or watershed scale, and further field-based studies are proposed.

The novelty of this study lies in its laboratory-scale experimental evaluation of BIHs combined with different vegetation types under controlled rainfall conditions. Unlike previous studies that primarily relied on field observations or numerical modeling, this research provides direct mechanistic evidence of how BIH systems interact with root structures to enhance preferential flow in dense, low-permeability soils. The findings demonstrate that integrating BIHs with deep-rooted perennial vegetation produces more stable and effective infiltration pathways than BIHs alone, offering new insights into the physical mechanisms underlying BIH performance. This laboratory-based evidence complements existing field and modeling studies and contributes to a better understanding of BIH-vegetation synergy as a nature-based solution for runoff reduction.

DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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DATA AVAILABILITY

The data used in this study are available from the corresponding author upon reasonable request.

AI USE AND DECLARATION OF GENERATIVE AI USE

During the preparation of this manuscript, the authors used ChatGPT as an auxiliary tool to assist in identifying relevant scientific literature related to the research topic and to support paraphrasing for language clarity and coherence. All suggested references were independently verified through official academic databases, and the cited sources were carefully reviewed by the authors. After using this tool, the authors critically evaluated, revised, and edited the manuscript to ensure accuracy, originality, and compliance with academic standards. The authors take full responsibility for the content of this publication.

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