



Strengthening Flood Resilience of Desa Majan through Water Infiltration Technology and Community-Based Drainage Management

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Abstrak

Desa Majan, Kecamatan Kedungwaru, Kabupaten Tulungagung merupakan wilayah dataran rendah yang rentan terhadap banjir musiman akibat kapasitas drainase terbatas, sedimentasi, minimnya sarana resapan, dan rendahnya pemeliharaan saluran secara kolektif. Kegiatan pengabdian ini bertujuan memperkuat ketahanan banjir desa melalui penerapan teknologi resapan air, normalisasi drainase berbasis asyarakat, edukasi kesiapsiagaan, dan pembentukan kelompok siaga banjir. Kegiatan dilaksanakan Juni–Agustus 2026 bersama mitra PKK Desa Majan melalui lima tahapan: sosialisasi, pelatihan, penerapan teknologi, pendampingan-evaluasi, dan keberlanjutan. Hasilnya, terpasang 29 unit teknologi resapan (9 sumur resapan dan 20 biopori) pada 19 titik, atau 145% dari target minimal 20 unit. Evaluasi pre-test dan post-test terhadap 30 peserta menunjukkan pemahaman masyarakat telah berada pada kategori tinggi sejak awal (rerata 4,13/5) dan dipertahankan pascakegiatan, tanpa perbedaan signifikan pada item sepadan (efek langit-langit). Luaran utama yang terukur adalah instalasi fisik dan pelebagaan kelompok siaga banjir.

Kata kunci: *Banjir, Teknologi resapan air, Drainase berbasis masyarakat, Kesiapsiagaan bencana, Pemberdayaan masyarakat.*

Abstract

Desa Majan, in Kedungwaru Sub-district, Tulungagung Regency, is a low-lying rural settlement exposed to seasonal flooding caused by limited drainage capacity, sedimentation, insufficient infiltration facilities, and weak collective channel maintenance. This community-service programme aimed to strengthen village flood resilience through water infiltration technology, community-based drainage normalization, preparedness education, and the establishment of a flood-alert group. Conducted from June to August 2026 with the partner PKK Desa Majan through five stages (socialization, training, technology application, mentoring–evaluation, and sustainability), the programme installed 29 infiltration units (9 infiltration wells and 20 biopori pits) across 19 locations, reaching 145% of the minimum 20-unit target. Pre-test and post-test evaluation of 30 participants showed that community understanding was already in the high category at baseline (mean 4.13/5) and was sustained afterwards, with no significant change on matched items (a ceiling effect). The principal measurable outputs were the physical installation and the institutionalization of the flood-alert group.

Keywords : *Flooding, Water infiltration technology, Community-based drainage, Disaster preparedness, Community empowerment.*



Introduction

Flooding in low-lying tropical settlements is increasingly read not as a purely meteorological event but as an outcome of altered land–water interactions. As land use intensifies and permeable ground is sealed, infiltration declines and runoff coefficients rise, so that even moderate rainfall exceeds the capacity of local drainage (Esraz-UI-Zannat et al., 2024). In the Indonesian context this mechanism is well documented at catchment and neighbourhood scale, where shrinking absorption areas translate directly into inundation and waterlogging (Apriliani, 2025; Balqis et al., 2023). Desa Majan, in Kedungwaru Sub-district, Tulungagung Regency, East Java, is a representative case: a low-lying rural settlement subject to recurrent seasonal flooding that disrupts village access and raises post-flood health risks. It was reported that Kabupaten Tulungagung experienced extreme weather 7 times, and in 2025, major flooding in Desa Majan has flooded more than a hundred hectares of field (BNPB, 2025). The position of Desa Majan near Wudhu river increases is the main factor of flooding in raining season.

Two paradigms compete in the response to this problem. Conventional grey infrastructure accelerates discharge through lined channels but often displaces flooding downstream, whereas nature-based solutions (NbS) and low-impact development (LID) work with hydrological processes to retain, absorb, and recharge water close to its source (Esraz-UI-Zannat et al., 2024). Rainwater infiltration wells (sumur resapan) and biopori infiltration pits are decentralized LID instruments well suited to the community scale because they rely on local materials, require no electricity, and can be maintained through self-help. Design and field studies report that infiltration wells reduce surface-runoff volume on the order of 50–77% depending on soil permeability and design rainfall (Balqis et al., 2023; Pamungkas et al., 2023), while biopori pits raise soil absorption and recycle organic waste in participatory programmes (Apriliani, 2025). Their low cost and technical simplicity make them theoretically appropriate for resource-constrained rural settings in which capital-intensive grey works are rarely feasible. These technologies are not new to Indonesian practice. Design and field studies across multiple provinces already document infiltration-well and biopori performance under comparable soil and rainfall conditions, so adoption of the technology by itself does not constitute this paper's central contribution. A recent review of low-impact development in Indonesia reaches the same conclusion and identifies community-based delivery, not the hardware, as the unresolved design problem (Putri et al., 2023).

Engineered measures alone, however, do not guarantee durable risk reduction. Scholarship on community-based disaster risk management holds that local participation and ownership are decisive for the sustained operation and maintenance of mitigation assets (Apriliani, 2025). This is consistent with socio-hydrology, which frames catchments and settlements as coupled human–water systems in which physical infrastructure, collective behaviour, and local institutions co-evolve rather than act independently (Sivapalan et al., 2012). Under this lens, drainage upkeep and infiltration capacity are not only technical variables but social practices embedded in habit, norms, and organization.

Two gaps motivate the present work. First, NbS and flood-resilience scholarship remains concentrated in urban and Global-North contexts, with comparatively thin evidence from rural tropical villages of the Global South (Esraz-UI-Zannat et al., 2024). Second, community flood-education studies typically presuppose a knowledge deficit and report sizeable pre–post gains in low-baseline groups such as school and vocational students (Wijayanti et al., 2026; Yildiz et al., 2023), leaving under-examined

the common situation in which community awareness is already high and the operative constraint is the knowledge–action gap rather than knowledge itself. Recent work treats this integration as an open engineering and governance problem rather than a solved one. Participatory design of infiltration-type low-impact-development networks is only beginning to be formalized as an explicit objective alongside cost and hydraulic performance (Creaco et al., 2026), and systematic evidence from the Global South still finds governance and institutionalization, not technology choice, as the binding constraint on nature-based-solution uptake (Zakaria et al., 2026). Integrating physical infiltration technology, community-based drainage management, and the institutionalization of preparedness within a single socio-hydrological programme in a rural village therefore addresses both gaps directly, and constitutes the paper's central novelty.

Accordingly, this community-service programme, conducted with the partner PKK Desa Majan, aimed to (1) reduce flood risk through water infiltration technology and drainage normalization; (2) strengthen community capacity, participation, and preparedness; and (3) institutionalize participatory flood mitigation from upstream to downstream. Beyond its local benefit, the activity contributes field evidence on how green infrastructure and community institutions, rather than awareness-raising alone, shape flood resilience in a high-baseline rural setting. It aligns with the Sustainable Development Goals on clean water and sanitation (SDG 6), sustainable settlements (SDG 11), and climate action (SDG 13).

Implementation Method

The programme was carried out in Desa Majan, Kedungwaru Sub-district, Tulungagung Regency, East Java, from June to August 2026, in partnership with PKK Desa Majan—a community group of ten members led by Sringaten, based in RT 03 RW 01, Dusun Krajan as shown in figure 1. Participants comprised PKK members, village officials, and residents. The education and training session on 18 July 2026 was attended by 40 participants; of these, 30 completed both the pre-test and post-test and constitute the sample for the quantitative capacity analysis.

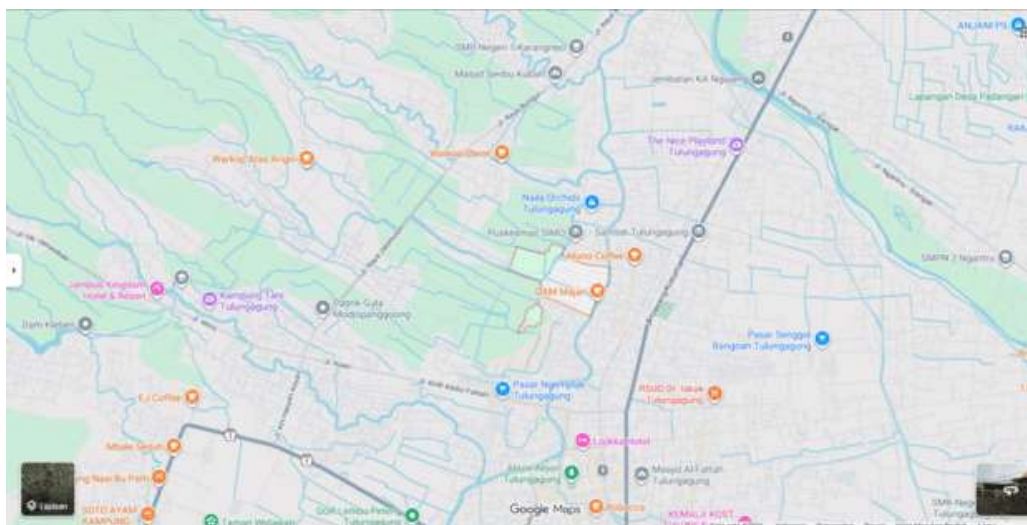


Figure 1. Implementation location

Implementation followed a community-based flood-risk-reduction approach in which residents acted as the primary actors and the team served as facilitator and

provider of appropriate technical designs. Five stages were used, summarized in Table 1.

Table 1. Implementation Method to be used

No.	Stage	Activities
1.	Socialization	Village meeting and RT/RW focus-group discussions to agree on priority locations (blocked channels, inundation points, access routes); minutes of agreement, priority-location list, and participation commitments.
2.	Training	Hands-on modules on drainage and waste management; infiltration technology (biopori/infiltration wells); environmental health and post-flood clean-and-healthy behaviour (PHBS); and flood preparedness (evacuation procedures, RT/RW emergency communication, simulation).
3.	Technology application	Normalization of priority drainage segments; installation of biopori pits and infiltration wells in household yards and public facilities; simple mapping of flood-prone points.
4.	Mentoring and evaluation	Routine team visits and coordination with village officials; monitoring by cadres/volunteers; process evaluation (attendance, training delivery) and outcome evaluation (reduced blockage points, reduced inundation, pre/post comprehension scores).
5.	Sustainability	Establishment/activation of a Flood-Alert Group (Kelompok Siaga Banjir); preparation of a maintenance SOP; cadre training; and integration into the village work plan.

Source: Field implementation records, 2026

Success indicators and evaluation method

Success was measured against five indicators agreed with the partner: installation of at least 20 infiltration units; normalization of at least 20% of the targeted drainage segments; formation of a flood-alert group; production and distribution of a preparedness booklet; and an improvement in community understanding. Achievement of the physical indicators was verified by direct counting, geotagged documentation, and a Handover Report (BAST) to the Desa Majan government.

Community capacity was evaluated with a structured questionnaire using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) organized into four constructs: knowledge of flood mitigation (B), behaviour and participation (C), preparedness and nudge (D), and programme evaluation (E). The instrument was administered before and after the 18 July session. The post-test comprised nine items common to the pre-test (B1, B3, B4, B5, C2, C4, D1, D3, D4); to preserve validity, the paired pre–post analysis is restricted to these nine matched items, while the full 21-item pre-test is used to describe the baseline. Data were analysed in Python (SciPy) using descriptive statistics with mean-score category classification, the Shapiro–Wilk normality test, paired-samples t-tests and Wilcoxon signed-rank tests at the item and construct levels, and Cohen's d for effect size. Internal consistency was assessed with Cronbach's alpha.

Result and Discussion

Green-infrastructure installation and drainage management

The programme had installed nine rainwater infiltration wells—using 28 concrete rings (buis beton) at a depth of about 1.5 m each—and 20 biopori pits at a depth of about 2 m, distributed across 10 locations as shown in figure 2. In total, 29 physical infiltration units were applied across 19 locations, comprising nine infiltration-well points and ten biopori points (Table 2). Counted by physical elements, this reaches 145% of the minimum target of 20 units. Both technologies were chosen for their low cost, ease of maintenance, and independence from electricity, matching the community's self-help capacity.



Figure 2. Rainwater infiltration wells installed

Beyond installation, priority drainage segments were cleaned and normalized through community work (*kerja bakti*), removing accumulated sediment and waste. This activity was framed not only to restore hydraulic function but to build a shared understanding that channel maintenance is a collective responsibility. Consistent with the cited runoff studies, the installed infiltration works are expected to reduce local surface runoff and support groundwater recharge; the magnitude of hydrological benefit specific to Desa Majan was not directly measured in this cycle and is recommended for post-implementation monitoring.

The normalization work also exposes the recurrent constraint on drainage performance: not hydraulic design but maintenance behaviour. Where residents dispose of solid waste into channels, cross-sections are lost and conveyance collapses well before design capacity is reached; survey evidence indicates that resident awareness of this mechanism is often below 50%, even where flooding is frequent (Atubi & Edewor, 2026). Restoring hydraulic function through *kerja bakti* is thus necessary but not sufficient—the gain reverts unless the underlying disposal and upkeep behaviour changes. This reframes channel maintenance from a one-off engineering task into a standing social practice, and motivates the institutional mechanism discussed below.

Table 2. Installed water infiltration technology

Technology	Units	Points	Depth
Infiltration wells	9	9	1.5 m
Biopori	20	10	2 m
Total	29	19	

Source: Field installation records

The selection of these two low-impact-development (LID) instruments rests on an established performance base in comparable Indonesian settings. Beyond the 50–

77% runoff reductions already noted (Balqis et al., 2023; Pamungkas et al., 2023), a fully designed communal infiltration-well system in Kabupaten Bandung achieved a modelled discharge reduction of 94.81%, and LID-based infiltration wells have been shown to lower estate-scale runoff in Bogor, both contingent on soil permeability and design rainfall (Alsadilla & Wardhani, 2024; Suprapti et al., 2024). Biopori pits complement the wells by raising soil infiltration rates while recycling household organic waste; measured infiltration gains are larger under perforated-pipe designs, and community-service programmes report improvements in both infiltration capacity and groundwater recharge (Hidayat et al., 2021; Juliandari, 2013). The nine wells and 20 biopori installed in Desa Majan therefore rest on documented mechanisms, even though the inundation benefit specific to the village remains to be measured.

Community capacity: baseline profile

Thirty participants completed both evaluations (Table 3). The sample was predominantly male (25; 83%) with a mean age of 45.6 years (range 17–64). Notably, about one-third were village officials or civil servants (kepala desa, perangkat desa, PNS), a composition that is directly relevant to interpreting the capacity results below.

Table 3. Respondent profile (N = 30)

Characteristic	Category	n (%)
Sex	Male	25 (83%)
	Female	5 (17%)
Age	Mean (range)	45.6 (17–64)
Education	Senior secondary (SMA/SMK)	21 (70%)
	Junior secondary / primary	6 (20%)
	Diploma / postgraduate	3 (10%)
Occupation	Village officials / civil servant	10 (33%)
	Self-employed / entrepreneur	9 (30%)
	Students, labourers, tailors, homemakers	11 (37%)

At baseline (full 21-item pre-test), all three capacity constructs already fell in the high category and programme appraisal in the very-high category: knowledge 4.11/5 (82.2%), behaviour and participation 4.06/5 (81.2%), preparedness and nudge 4.08/5 (81.6%), and programme evaluation 4.55/5 (90.9%). Internal consistency of the pre-test was acceptable (Cronbach's $\alpha = 0.665$ for 21 items; $\alpha = 0.829$ for the nine matched items).

Pre–post change and item-level analysis

On the nine matched items, the mean score was identical before and after the intervention (4.13/5 $\rightarrow$ 4.13/5). The difference was not statistically significant by either the paired t-test ($t \approx 0.00$, $p = 1.000$) or the Wilcoxon signed-rank test ($p = 0.946$), with a null effect size (Cohen's $d = 0.00$) and normally distributed differences (Shapiro–Wilk $p = 0.66$). Of the 30 respondents, 14 improved, 5 were unchanged, and 11 declined. No individual construct changed significantly (knowledge +0.03, $p = 0.77$; behaviour –0.12, $p = 0.42$; preparedness +0.03, $p = 0.77$). The item-level results are reported in Table 4.

Table 4. Item-level pre–post comparison (n = 30, matched items)

Item	Statement	Pre	Post	Δ	p
B1	Knows the main causes of flooding	4.10	4.00	–0.10	0.366
B3	Knows what to do during a flood	4.10	4.33	+0.23	0.222
B4	Knows what to do after a flood	3.97	4.20	+0.23	0.198
B5	Knows the importance of drainage upkeep	4.37	4.13	–0.23	0.249
C2	Does not dump waste into drains	4.10	3.97	–0.13	0.346
C4	Encourages family to protect the environment	4.23	4.13	–0.10	0.696
D1	Knows the evacuation location	4.07	4.17	+0.10	0.552
D3	WA reminders prompt joining community work	4.10	4.10	0.00	0.981
D4	Feels a key personal role in reducing floods	4.13	4.13	0.00	1.000

Two patterns are worth interpreting despite the absence of statistical significance. First, the directional gains concentrate in operational, emergency-response knowledge—what to do during a flood (B3, +0.23), what to do after a flood (B4, +0.23), and awareness of the evacuation location (D1, +0.10)—precisely the content emphasized in the training modules and the preparedness booklet as shown 3. Second, items concerning routine, habitual maintenance behaviour—the importance of drainage upkeep (B5, –0.23), not dumping waste into drains (C2, –0.13), and encouraging family (C4, –0.10)—were flat or slightly lower. The most plausible explanation is a ceiling effect: baseline agreement (scores of 4–5) already ranged from 73% to 97% per item, leaving little headroom for a self-report scale to register gains, while post-training self-assessment on familiar habits may become more critical.



Figure 3. (a) Booklet reading and (b) cover

This interpretation is formalized by measurement theory. A floor or ceiling effect is conventionally diagnosed when more than 15% of respondents select the extreme category, at which point the instrument loses the headroom needed to register change

and its responsiveness falls (Terwee et al., 2007). In the matched items, baseline agreement in the top two categories ranged from 73% to 97%—far above that threshold—so a null pre–post difference is the expected artefact of a saturated scale rather than evidence of no learning. The direction of the maintenance items, several of which fell slightly, is further consistent with social-desirability responding: on familiar, norm-laden behaviours, self-report is prone to favourable inflation at baseline and to more candid self-appraisal after training, biasing matched-item change toward zero or below (Mortel, 2008). Both mechanisms argue for objective or knowledge-test items in future cycles rather than agreement-type Likert scales.

This ceiling is consistent with the sample composition. With one-third of participants being village officials and civil servants, self-assessed awareness of flood mitigation was high before any intervention. The finding contrasts instructively with pre–post studies conducted on lower-baseline groups—school and vocational students—where flood-education programmes produced significant knowledge gains and high normalized-gain scores (Wijayanti et al., 2026; Yildiz et al., 2023). Read together, the evidence supports a socio-hydrological reading of Desa Majan: the binding constraint on flood risk is not community awareness, which is already high, but the physical infiltration deficit and the absence of a standing institutional mechanism for maintenance and response. This is exactly why the programme's centre of gravity is the installed green infrastructure and the flood-alert group rather than awareness-raising alone.

Framed socio-hydrologically, Desa Majan illustrates the knowledge–action gap that coupled human–water models are built to capture. In these models, flood risk emerges from two-way feedbacks between hydrological processes and social responses rather than from awareness alone; protection and perceived safety can even decouple behaviour from risk, the mechanism underlying the well-documented "levee" and "adaptation" effects (Di Baldassarre et al., 2013, 2015). The corollary for a high-baseline village is direct: raising stated awareness has little marginal value, whereas closing the gap between what residents know and what they routinely do—maintaining channels, sustaining infiltration assets—depends on physical capacity and a durable institutional trigger. This is the theoretical warrant for locating the programme's centre of gravity in installed infrastructure and a standing response group.

Programme reception and institutionalization

Participants' appraisal of the programme was very high (construct E, 4.55/5), indicating strong perceived usefulness and support for continuation. A flood-preparedness booklet was finalized and 40 copies were printed and distributed to participants against a documented recipient list. A flood-alert group (Kelompok Siaga Banjir) was formed at the neighbourhood level, together with a simple flood-response procedure and strengthened RT/RW communication, providing the standing institutional mechanism that the capacity analysis identifies as the missing link.

The decision to institutionalize response through a Kelompok Siaga Banjir is consistent with the weight of evidence on what sustains community-based flood mitigation. Reviews and field studies converge on participation, local ownership, and standing organization—not one-off works—as the determinants of durable risk reduction, with community members acting as first responders whose local knowledge improves both design and upkeep (Abid et al., 2024; Echendu, 2024; Evers et al., 2016). More broadly, disaster-resilience research finds that social infrastructure—networks, trust, and reciprocity—often drives survival and recovery more than physical

hardening alone (Aldrich & Meyer, 2015). A neighbourhood-level group with a simple response procedure and strengthened RT/RW communication converts these findings into a local mechanism: it assigns responsibility for maintenance, shortens response time, and gives the installed infrastructure a custodian beyond the funding period. Its effectiveness, however, will depend on formalized maintenance SOPs and integration into the village work plan, without which the same participation gap that limits many externally initiated programmes may re-emerge.

Conclusion

The programme strengthened flood resilience in Desa Majan through three interlocking outputs: 29 units of water infiltration technology (nine infiltration wells and 20 biopori pits across 19 locations, 145% of target), community-based drainage normalization, and a preparedness package comprising education, a distributed booklet, and a newly formed flood-alert group. The pre–post evaluation shows that community awareness was already high and was sustained after the activity; on matched items the change was not statistically significant, a ceiling effect attributable to a high baseline and a participant base weighted toward village officials. The novel and practically important contribution is therefore not a claimed jump in awareness but the demonstration that, in such a setting, the effective levers of flood resilience are physical infiltration capacity and a standing institutional mechanism for maintenance and response—both of which this programme delivered. For subsequent activities we recommend instruments with lower-baseline or knowledge-test items to avoid ceiling effects, direct hydrological monitoring of runoff and inundation to quantify the benefit of the installed works, and replication with formalized maintenance SOPs so that the flood-alert group sustains the infrastructure beyond the funding period.

Acknowledgments

The authors thank the Directorate of Research and Community Service (DPPM), Ministry of Higher Education, Science, and Technology, for funding under the Community-Based Empowerment (PBM) scheme (Contract No. 210/C3/DT.05.00/PM/2026).

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