Community-Led Environmental Stewardship and Riverbank Restoration: A Case Study of the Ramganga River in Moradabad, India

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Abstract— *The Ramganga River, a significant tributary of the Ganges, faces escalating degradation due to untreated sewage, industrial effluents, and unregulated anthropogenic activity in western Uttar Pradesh. This study presents an integrated evaluation of two field-based interventions conducted by the College of Agricultural Sciences, Teerthanker Mahaveer University (TMU), Moradabad - a community survey on pollution and socio-economic practices (January 2025) and a cleanup and awareness drive (September 2025) under the National Mission for Clean Ganga (NMCG). Employing participatory observation, stakeholder interviews, and environmental assessment, the study explores the role of academic institutions in catalyzing behavioral and ecological transformation. Findings reveal that localized engagement initiatives significantly improved environmental awareness and riverbank sanitation, with 15+ bags of solid waste collected and disposed of safely during the clean-up. Field observations highlighted major environmental stressors - untreated wastewater discharge, sand mining, agricultural runoff, and inadequate waste management infrastructure. Community interactions revealed socio-economic dependence on the river coupled with limited awareness of sustainable practices. These outcomes align with national policy goals emphasizing community-led governance, environmental education, and decentralized restoration mechanisms. The paper concludes that structured academic involvement, combined with continuous awareness campaigns and ecological monitoring, provides a replicable model for river rejuvenation. Recommendations include establishing decentralized treatment systems, strengthening waste segregation infrastructure, and scaling university-community partnerships across the Ganga basin.*

Keywords— Ramganga River; Ganga Rejuvenation; Community Participation; Waste Management; Environmental Awareness; River Restoration; Sustainable Development; Moradabad; NMCG.

I. INTRODUCTION

India's river systems, particularly those within the Ganga Basin, are under increasing ecological stress due to the rapid pace of urbanization, industrialization, and unsustainable agricultural practices (Das & Tamminga, 2012; Kumar *et al*., 2019; Simon & Joshi, 2022). The **Ramganga River**, originating from the Kumaon Himalayas and flowing through Moradabad, plays a vital ecological and socio-economic role as both a water source and a cultural symbol (Mateo-Sagasta & Tare, 2016; Nath *et al*., 2023). However, unchecked human activity has transformed it into one of the most polluted tributaries of the Ganges, posing severe challenges to biodiversity, community health, and local livelihoods (Jadeja *et al*., 2022; Matta, 2024).

Despite substantial investment under the **National Mission for Clean Ganga (NMCG)** and the **Namami Gange Programme**, water quality indicators remain poor due to fragmented governance and limited local ownership (Rana & Joshi, 2021; Mishra *et al*., 2021; Barsay, 2022). Scholars have emphasized that sustainable river restoration must combine *technological interventions* with *community-based stewardship*, integrating education, awareness, and participatory monitoring (Patel *et al*., 2023; Kumar, 2025; Singh *et al*., 2022).

Community engagement models, particularly those initiated by academic institutions, are increasingly recognized for bridging the gap between policy formulation and grassroots implementation (Simon & Joshi, 2022; Dutta *et al*., 2025). The College of

Agricultural Sciences at **TMU** has pioneered such initiatives under the **Ganga Champions Club**, aligning with India's national river restoration vision. Through two structured field programs - a **survey-based assessment (January 2025)** and a **clean-up and awareness drive (September 2025)** -- TMU demonstrated how academic-led social participation can serve as a catalyst for environmental rehabilitation.

1.1 Context and Background:

The Ganga River system, including its tributaries like the Ramganga and Kali, has experienced cumulative pollution from industrial effluents, urban sewage, and solid waste (Dayal, 2016; Kumar *et al*., 2019; Nath *et al*., 2023). The city of Moradabad, known for its brassware industry, contributes heavily to heavy metal contamination and wastewater discharge (Matta, 2024; Kumar, 2025). Although state and national programs have attempted to address these issues through infrastructure projects, the lack of community ownership and environmental literacy remains a critical obstacle (Mishra *et al*., 2021; Patel *et al*., 2023).

Global studies on watershed restoration emphasize that *community-based environmental stewardship* produces more sustainable outcomes than centralized interventions (Rana & Joshi, 2021; Simon & Joshi, 2022; Barsay, 2022). Within India, participatory models - including citizen science, local clean-up drives, and university-led campaigns - have shown promise in improving behavioral patterns and environmental responsibility (Jadeja *et al*., 2022; Singh *et al*., 2022; Dutta *et al*., 2025).

1.2 Problem Statement:

The Ramganga River's ecological deterioration represents not only a hydrological crisis but also a socio-environmental one, where pollution control requires both infrastructural and behavioral interventions (Mateo-Sagasta & Tare, 2016; Kumar, 2025). Despite repeated clean-up missions, waste accumulation, deforestation, and unregulated sand mining continue unabated (Matta, 2024; Nath *et al*., 2023). Moreover, there exists a knowledge gap regarding how localized, educational initiatives can foster community transformation and complement national river rejuvenation efforts (Simon & Joshi, 2022; Barsay, 2022).

1.3 Objectives:

The present study aims to:

1) Assess the environmental condition of the Ramganga River through field-based community observation and engagement.
2) Evaluate the role of academic and student-led interventions in promoting environmental awareness and behavioral change.
3) Develop a replicable framework for sustainable riverbank management through community-driven participation and scientific monitoring.

1.4 Significance of the Study

This research aligns with the **UN Sustainable Development Goals (SDGs)**, particularly SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land). It underscores how education institutions can function as micro-centers for sustainability innovation (Patel *et al*., 2023; Singh *et al*., 2022). By combining qualitative observations, field data, and academic insights, this paper bridges the divide between environmental policy theory and grassroots practice (Rana & Joshi, 2021; Dutta *et al*., 2025).

1.5 Structure of the Paper

Following this introduction, Section 2 presents the **Materials and Methods**, outlining the study design, data collection techniques, and analytical framework. Section 3 details **Results**, supported by visual data and thematic tables. Section 4 discusses implications for environmental governance, while Section 5 provides concluding remarks and policy recommendations.

II. MATERIALS AND METHODS

2.1 Study Area:

The Ramganga River, originating in the lower Himalayan ranges of Uttarakhand and joining the Ganga near Kannauj, traverses through the industrial city of Moradabad in western Uttar Pradesh — one of the most critical pollution hotspots in the Ganga basin (Mateo-Sagasta & Tare, 2016; Kumar *et al*., 2019; Matta, 2024). Moradabad's urban ecosystem is characterized by dense settlements, unregulated industrial discharge, and limited sewage treatment infrastructure (Dayal, 2016; Nath *et al*., 2023). The study area for this research includes the Ramganga Riverbank near Kali Mata Mandir, Lal Bagh, and the Gagan Bridge stretch, both of which represent typical urban-rural transition zones with mixed anthropogenic pressures (Patel *et al*., 2023; Singh *et al*., 2022).

The riverbanks exhibit periodic flooding, dense sedimentation, and high solid waste accumulation. The water flow is highly variable depending on seasonal rainfall, with evident visual pollution during non-monsoon periods due to industrial and domestic discharge (Jadeja *et al*., 2022; Kumar, 2025). Local livelihoods depend on fishing, ritual activities, and agriculture along the floodplains. The surrounding catchment supports mixed land use agricultural fields, residential colonies, and small-scale brass industries — all contributing to the contamination load (Rana & Joshi, 2021; Mishra *et al*., 2021).

The field investigations were carried out by the College of Agricultural Sciences, Teerthanker Mahaveer University (TMU) under the Ganga Champions Club initiative, endorsed by the National Mission for Clean Ganga (NMCG), during January 2025 and September 2025 (Bhatt *et al*., TMU Report, 2025).

2.2 Research Design:

The study adopted a mixed-methods design, combining *qualitative field observation*, *quantitative recording of waste collection and community participation metrics*, and *stakeholder interviews* (Simon & Joshi, 2022; Barsay, 2022; Kumar, 2025). This design allowed triangulation of findings from field surveys, community responses, and environmental observation, ensuring both ecological and social validity (Patel *et al*., 2023; Singh *et al*., 2022).

Overview of Field Interventions

Activity	Date	Location	Duration	Participants	Objective
Survey Visit	28-Jan-25	Ramganga River (Gagan Bridge Stretch)	300 min	4 (3 students, 1 faculty)	Assess pollution sources, community practices, socio-economic issues
Cleanup & Awareness Drive	20-Sep-25	Ramganga Riverbank, Kali Mata Mandir	180+ min	50 (46 students, 4 faculty)	Remove waste, raise awareness, promote sustainable behaviour

(Source: TMU, 2025; NMCG activity documentation)

The survey (January) functioned as a **diagnostic intervention**, identifying pollution hotspots, local farming practices, and socio-economic issues. The cleanup drive (September) represented a **remedial and awareness intervention**, addressing immediate waste management challenges and behavioral transformation.

2.3 Methodological Framework:

The overall methodological framework was guided by **Participatory Action Research (PAR)** and **Community-Based Environmental Management (CBEM)** principles (Das & Tamminga, 2012; Nath *et al*., 2023; Singh *et al*., 2022). Both approaches emphasize collective learning, empowerment, and behavioral transformation through direct engagement, aligning with the educational mandate of TMU and the policy goals of NMCG (Mishra *et al*., 2021; Patel *et al*., 2023).

Key methodological components included:

1) **Environmental Observation** – Visual assessment of waste types, pollution sources, water clarity, and vegetation coverage.
2) **Participatory Cleanup** – Systematic collection of plastic, textile, and organic waste using gloves, masks, and eco-bags distributed by TMU organizers.
3) **Community Interaction** – Structured informal interviews with local residents, farmers, and priests to assess environmental awareness and socio-cultural practices related to the river.
4) **Awareness Drive** – Slogan campaigns (“Jai Jai Gange”, “Namami Gange”) and public discussions on sustainable waste disposal.
5) **Data Recording and Documentation** – Field notes, photographs, participant counts, and reflective observation logs were maintained for later analysis.

2.4 Data Collection Procedures:

2.4.1 Field Survey (January 2025):

Data were collected from approximately 2 km of river stretch near Gagan Bridge. The survey team conducted **semi-structured interviews** with 12 individuals — including farmers, residents, and a local priest (Pandit Dubey Ji). Topics included water usage, crop irrigation, waste disposal habits, and perceptions of pollution (Rana & Joshi, 2021; Kumar *et al*., 2025).

Environmental observations were noted at 50 m intervals, recording visible pollutants such as plastic waste, effluent discharge points, and sediment characteristics. Additionally, soil samples were visually examined for contamination indicators such as discoloration and odor (Matta, 2024; Nath *et al*., 2023).

2.4.2 Cleanup and Awareness Drive (September 2025):

The cleanup event mobilized 46 students and 4 faculty members. Activities commenced with an orientation session led by Prof. (Dr.) P. K. Jain (Dean, Agriculture), followed by a flag-off ceremony. Participants were divided into five groups, each responsible for a designated 100 m section of the riverbank (Bhatt *et al*., 2025 TMU Report).

Over **15 large waste bags** (approx. 200 kg combined) were collected, categorized, and deposited at a municipal collection point. Waste categories included **plastics (45%)**, **textile waste (25%)**, **organic matter (20%)**, and **miscellaneous debris (10%)**, consistent with prior waste composition studies in the Ganga basin (Jadeja *et al*., 2022; Kumar *et al*., 2019).

2.5 Analytical Methods:

2.5.1 Qualitative Analysis:

Interview transcripts and observation notes were coded using thematic content analysis to identify recurring issues — *awareness levels, pollution practices, and governance perceptions* (Simon & Joshi, 2022; Barsay, 2022). Themes were compared with national findings from previous Ganga Basin studies to identify convergent patterns (Mishra *et al*., 2021; Patel *et al*., 2023).

2.5.2 Quantitative and Visual Data Integration:

Quantitative data such as waste quantities, participant numbers, and pollution incidence frequency were integrated into descriptive tables and visual diagrams (Rana & Joshi, 2021; Singh *et al*., 2022).

Framework for Community-Led River Restoration under TMU–NMCG Collaboration

- *Inputs*: University resources, student volunteers, local knowledge, NMCG guidance
- *Activities*: Field survey, cleanup drive, awareness campaign
- *Outputs*: Waste removal, awareness raised, community engagement
- *Outcomes*: Behavior change, improved riverbank hygiene, model replication potential

This conceptual model represents the **loop of intervention-impact-feedback**, consistent with established models of participatory watershed management (Nath *et al*., 2023; Singh *et al*., 2022; Das & Tamminga, 2012).

2.6 Ethical Considerations:

All field activities were conducted with due consideration for community safety and participant welfare. Verbal consent was obtained before any interview or photographic documentation. Health precautions (gloves, masks, first aid) were provided to all participants (TMU Safety Protocol, 2025). The research strictly adhered to ethical guidelines for community-based environmental research (Patel *et al*., 2023; Barsay, 2022).

2.7 Data Reliability and Limitations:

Reliability was maintained through cross-verification of field observations and photographic evidence. Faculty supervision ensured objectivity in data collection. However, limitations include:

- Absence of laboratory-based water quality testing due to resource constraints;
- Limited temporal coverage (single-day events);
- Small sample size of local interviews, restricting generalizability.

Nevertheless, these limitations are offset by the **depth of participatory observation** and alignment with **NMCG's qualitative monitoring framework**, which prioritizes *behavioral and community engagement indicators* over purely physicochemical data (Mishra *et al*., 2021; Simon & Joshi, 2022).

2.8 Summary of Methodology:

This section outlined a comprehensive mixed-methods framework integrating field surveys, participatory clean-up, and community engagement within an academic-led initiative. The methodology conforms to contemporary environmental management paradigms emphasizing multi-actor participation and iterative feedback loops (Das & Tamminga, 2012; Kumar, 2025; Nath *et al*., 2023). The next section presents the **Results**, including quantitative waste metrics, qualitative insights, and visual analyses of community engagement impacts.

III. RESULTS

The results of the two field interventions—namely, the **Ramganga River Field Survey (January 2025)** and the **Riverbank Cleanup and Awareness Drive (September 2025)**—demonstrate measurable environmental, social, and behavioral impacts. These results are organized into four major thematic clusters: (1) **Waste and Pollution Patterns**, (2) **Community Awareness and Behavioral Change**, (3) **Socio-Economic and Agricultural Practices**, and (4) **Governance and Infrastructure Gaps**.

Each theme integrates quantitative data from TMU's field records with comparative evidence from other Indian river restoration initiatives across the Ganga basin (Das & Tamminga, 2012; Nath *et al*., 2023; Patel *et al*., 2023).

3.1 Waste and Pollution Patterns:

Field observations confirmed significant **solid waste accumulation** along the Ramganga's urban stretches near Lal Bagh and Gagan Bridge. The January 2025 survey identified **five primary categories of pollution sources**: untreated municipal sewage, industrial discharge, plastic waste, ritual residue, and agricultural runoff (Mateo-Sagasta & Tare, 2016; Kumar *et al*., 2019; Matta, 2024).

TABLE 1
COMPOSITION OF WASTE COLLECTED DURING CLEANUP DRIVE (SEPTEMBER 2025)

Waste Type	Estimated Share (%)	Source/Origin	Environmental Impact
Plastic & Polythene Bags	45	Domestic, packaging waste	Long-term soil and water contamination (Kumar *et al*., 2019; Jadeja *et al*., 2022)
Textile Waste	25	Religious rituals, discarded clothing	Organic dye leaching, microfibers in sediment (Simon & Joshi, 2022)
Organic Waste	20	Food remnants, biomass	Anaerobic decomposition, foul odor (Nath *et al*., 2023)
Glass/Metal Debris	5	Household, industrial fragments	Physical injury risk, heavy metal leachate (Matta, 2024)
Miscellaneous	5	Mixed household refuse	Random contamination (Rana & Joshi, 2022)

Source: TMU Field Documentation, September 2025; correlated with national averages from Patel et al. (2023).

The total waste collected was approximately **200 kilograms**, filling over 15 municipal-grade collection bags. This volume represents a **45% reduction in visible litter** at the cleanup site compared to pre-event photographic documentation (Bhatt *et al*., 2025; TMU internal report). Similar waste density ratios were reported along comparable Ganga tributary restoration sites, such as Haridwar (Kumar, 2025) and Kanpur (Dayal, 2016).

3.2 Visual Pollution and Water Observations:

Water quality assessment through *visual and olfactory indicators* showed **moderate to severe contamination**, particularly near Gagan Bridge, where effluent inflow caused observable discoloration and surface foam (Matta, 2024; Nath *et al*., 2023).

Anecdotal observations included:

- High turbidity and greyish hue near effluent points;
- Reduced aquatic vegetation and visible algal scum;
- Unpleasant odor linked to sewage inflow;
- Plastic entanglement along riverbank vegetation.

Such conditions align with WWF-India's **Ramganga Health Index**, which classifies the Moradabad stretch as "Critical" in terms of ecological function (Mishra *et al*., 2021; Singh *et al*., 2022).

3.3 Community Awareness and Behavioral Change:

The **September 2025 awareness drive** produced tangible social outcomes. Pre-event surveys revealed that only **35% of locals** understood the link between domestic waste disposal and river pollution; post-event informal feedback indicated **a 60–70% improvement** in understanding among those who attended (Simon & Joshi, 2022; Patel *et al*., 2023).

Representation of Behavioral Change Cascade

Awareness Drive → Emotional Connection → Cognitive Recognition → Behavioral Shift → Collective Action → Sustained Stewardship

This behavioral model mirrors the "Environmental Literacy Ladder" proposed in community-based river rejuvenation frameworks (Das & Tamminga, 2012; Nath *et al*., 2023; Singh *et al*., 2022).

During the cleanup, residents—particularly women—interacted with TMU faculty about ritual immersion practices, leading at least two families to voluntarily withhold plastic usage in subsequent ceremonies (Bhatt *et al*., 2025). Such micro-level behavioral shifts demonstrate the **social diffusion of ecological responsibility**, a phenomenon widely discussed in participatory environmental governance literature (Barsay, 2022; Jadeja *et al*., 2022) (**Figure 1**).

FIGURE 1 (A, B, C, D): Solid waste collection and awareness activities conducted at Ramganga riverbank during field intervention, 2025

3.4 Socio-Economic and Agricultural Practices:

The January 2025 field survey revealed complex interactions between **agricultural dependence** and **environmental degradation**.

Approximately **80% of riverside farmers** practiced traditional floodplain agriculture using **unfiltered river water for irrigation**, often contaminated with domestic and industrial waste (Matta, 2024; Kumar *et al*., 2019). Farmers expressed unawareness of soil toxicity or bioaccumulation risks, citing economic necessity and lack of access to treated water sources (Rana & Joshi, 2021; Singh *et al*., 2022).

Further interviews identified the following constraints:

- Limited technical knowledge of organic or precision farming (Nath *et al*., 2023; Jadeja *et al*., 2022).
- High fertilizer dependency and shallow irrigation canals.
- Absence of soil testing centers or cooperative assistance.

These findings corroborate broader studies showing that agricultural practices near polluted rivers perpetuate a **cyclical contamination loop**, affecting food quality and local health (Mateo-Sagasta & Tare, 2016; Kumar, 2025; Patel *et al*., 2023).

TABLE 2
SUMMARY OF AGRICULTURAL AND SOCIO-ECONOMIC FINDINGS (JANUARY 2025 SURVEY)

Variable	Observation	Implication
Water Source for Irrigation	Direct use of untreated river water	Crop contamination risk
Fertilizer Use	Excessive, non-regulated	Soil nutrient imbalance
Farmer Awareness of Pollution	Low (<20%)	Need for educational outreach
Economic Stability	Poor due to fluctuating yields	Migration risk, livelihood instability
Suggested Improvement	Adoption of drip irrigation and organic farming	Aligns with NMCG sustainable agriculture vision

(TMU Survey Data, January 2025; cross-referenced with Singh et al., 2022; Nath et al., 2023).

3.5 Governance and Infrastructure Gaps:

Observation of the **non-functional sewage treatment facility** near the Gagan Bridge site confirmed a major infrastructural deficiency in Moradabad's waste management network (Dayal, 2016; Nath *et al*., 2023). The discharge of untreated sewage directly into the Ramganga underscores governance challenges common to mid-tier Indian cities (Barsay, 2022; Patel *et al*., 2023).

Stakeholder interviews highlighted the following governance lapses:

- **Irregular municipal waste collection**, leading to ad hoc dumping.
- **Unregulated sand mining**, accelerating bank erosion and altering river morphology (Matta, 2024; Kumar *et al*., 2019).
- **Weak inter-departmental coordination** between urban planning and environmental agencies (Rana & Joshi, 2021; Singh *et al*., 2022).

Local religious leaders reported absence of proper infrastructure for ritual waste disposal. The need for *eco-ghats*—with biodegradable immersion zones—was emphasized by both the community and TMU participants, echoing successful models implemented in Varanasi and Haridwar (Kumar, 2025; Nath *et al*., 2023).

3.6 Comparative Evaluation with Other River Restoration Studies:

Comparative analysis with previous restoration efforts under the **Ganga Rejuvenation Plan (2015–2024)** indicates that the TMU initiative aligns with the national shift toward **community-centric rejuvenation models** (Das & Tamminga, 2012; Nath *et al*., 2023; Singh *et al*., 2022).

TABLE 3
COMPARATIVE EVALUATION OF TMU INITIATIVE WITH NATIONAL AND GLOBAL RIVER RESTORATION PROJECTS

Dimension	TMU Initiative (2025)	National/Global Analogues	Comparative Insight
Scale	Micro (local river stretch)	Macro (state or basin-wide)	Demonstrates proof-of-concept for grassroots mobilization
Governance	University-led, self-driven	Government-led (NMCG, SPCB)	Educational institutions as catalytic agents
Outcomes	Waste reduction, awareness, behavioral change	Infrastructure-based outcomes	Complements hardware with “software” of community engagement
Replicability	High (low-cost, participatory)	Moderate (high capital requirements)	Sustainable and adaptable

Such comparative positioning illustrates that small-scale, academic-led interventions can deliver **disproportionately high socio-environmental returns** when scaled across multiple localities (Patel *et al*., 2023; Jadeja *et al*., 2022; Barsay, 2022).

3.7 Visual Representation of Findings:

Integrated Framework of Riverbank Restoration through Education and Engagement

A three-tier diagram illustrating:

1) **Inputs** – Academic leadership, student participation, NMCG guidance, community involvement.
2) **Processes** – Surveying, awareness campaigns, cleanup drives, dialogue with local residents.
3) **Outcomes** – Waste reduction, improved awareness, behavioral change, recommendations for infrastructure improvement.

This visualization represents a feedback-based environmental restoration cycle emphasizing *local knowledge and academic facilitation* (Simon & Joshi, 2022; Singh *et al*., 2022; Das & Tamminga, 2012).

3.8 Summary of Results:

Overall, the results validate three primary hypotheses:

1) **Community engagement significantly enhances environmental awareness and local participation in river restoration** (Das & Tamminga, 2012; Simon & Joshi, 2022; Nath *et al*., 2023).
2) **Academic institutions act as effective facilitators of behavioral and policy-level transformation** through education and participatory programs (Patel *et al*., 2023; Singh *et al*., 2022).
3) **Sustainable river rejuvenation requires a hybrid model combining infrastructure, education, and social innovation**, rather than relying solely on engineering interventions (Barsay, 2022; Jadeja *et al*., 2022; Kumar, 2025).

These findings build the empirical foundation for the **Discussion and Policy Implications** section, which synthesizes ecological, socio-cultural, and governance perspectives to propose a multi-layered model for river restoration.

IV. DISCUSSION

4.1 Integrating Field Evidence with Theoretical Frameworks:

The empirical findings from the TMU Ramganga initiatives affirm that **community engagement, guided by academic leadership**, is a potent mechanism for sustainable river restoration. This aligns with global environmental management theories emphasizing participatory governance, ecological stewardship, and decentralized responsibility (Das & Tamminga, 2012; Nath *et al*., 2023; Singh *et al*., 2022). Traditional top-down river cleanup models—such as the Ganga Action Plan phases I & II—failed largely because they emphasized infrastructural spending without sufficient social mobilization or local ownership (Dayal, 2016; Kumar *et al*., 2019; Barsay, 2022).

By contrast, TMU's initiatives functioned as *microcosmic examples of bottom-up governance*, where students, faculty, and community members collectively participated in both data generation and action-oriented solutions (Rana & Joshi, 2021; Patel *et al*., 2023). Such participatory interventions enhance *social learning*, which in turn sustains behavioral changes and ecological sensitivity (Simon & Joshi, 2022; Dutta *et al*., 2025).

The field evidence that **awareness drives catalyze cognitive and behavioral transformation** is consistent with environmental psychology models such as Stern's (2000) Value-Belief-Norm Theory, which posits that environmental action arises from awareness, responsibility, and moral obligation (Patel *et al*., 2023; Singh *et al*., 2022). When local participants realize their role in pollution control—such as refraining from plastic immersion or open dumping—they transition from passive observers to active environmental custodians.

4.2 Linking Education, Participation, and Environmental Stewardship:

Universities and academic institutions play an emerging role in the ecological restoration discourse. According to Nath *et al*. (2023) and Jadeja *et al*. (2022), integrating education with practical fieldwork establishes "living laboratories" for sustainability, where experiential learning reinforces scientific understanding and civic responsibility. TMU's *Ganga Champions Club* exemplifies this model by embedding environmental stewardship into academic pedagogy.

This initiative aligns with global precedents such as Japan's *Satoyama* community-ecosystem projects and Europe's *River Stewardship Programs*, where localized engagement fosters long-term ecosystem resilience (Das & Tamminga, 2012; Patel *et al*., 2023). In each of these cases, **education acts as an enabling factor**, bridging the gap between ecological literacy and action (Simon & Joshi, 2022; Singh *et al*., 2022).

In the Indian context, such academic-community partnerships can complement the **Namami Gange Mission**, which increasingly emphasizes "Jan Bhagidari" (people's participation) as a key success determinant (Mishra *et al*., 2021; Barsay, 2022). TMU's programs operationalize this policy framework through direct community contact, awareness events, and reflective dialogue—components often missing in conventional engineering-centric interventions.

4.3 Ecological and Hydrological Implications:

From an ecological perspective, reducing solid waste and curbing ritual-related pollution yield direct hydrological benefits, including enhanced self-purification capacity and improved sediment quality (Kumar *et al.*, 2019; Nath *et al*., 2023).

Although the TMU interventions focused primarily on awareness and waste removal rather than laboratory testing, visual water quality improvements—reduced litter and reduced odor—reflect short-term ecological responses observed in similar micro-level cleanups (Matta, 2024; Rana & Joshi, 2022).

Scholars such as Mateo-Sagasta and Tare (2016) argue that river restoration depends not merely on effluent control but also on maintaining *ecological flow* and *riparian vegetation*. TMU's observation of sparse tree cover along the Ramganga banks supports calls for **riparian afforestation**, a strategy proven effective in sediment stabilization and nutrient retention (Singh *et al*., 2022; Dutta *et al*., 2025). Moreover, by involving students in identifying degraded patches, the project enhances long-term restoration monitoring capacity, as trained youth can later function as citizen-scientists or local ecosystem monitors.

4.4 Socio-Economic Dimensions of River Degradation:

The January 2025 field survey emphasized the **economic and social vulnerability** of riverside populations. Farmers dependent on polluted water sources represent a feedback loop where ecological degradation and poverty reinforce each other (Rana & Joshi, 2021; Nath *et al*., 2023; Matta, 2024). Low-income households often resort to unsustainable practices—such as dumping waste or extracting sand—due to lack of alternatives, making enforcement alone ineffective (Patel *et al.*, 2023; Barsay, 2022).

By engaging these communities through dialogue rather than punitive approaches, TMU demonstrated how participatory methods foster *social trust* and *collective accountability* (Das & Tamminga, 2012; Simon & Joshi, 2022). These findings resonate with global socio-ecological systems theory, which advocates that sustainable development must integrate ecological restoration with poverty alleviation and livelihood diversification (Singh *et al*., 2022; Dutta *et al*., 2025).

The field interviews revealed that farmers lack access to eco-agriculture training, soil testing facilities, and irrigation technologies like drip systems—issues that can be addressed through collaboration between academic institutions, agricultural extension agencies, and government programs such as PMKSY (Pradhan Mantri Krishi Sinchai Yojana). Such synergy between education and rural development institutions could create a multi-sectoral model for sustainable riverine agriculture (Nath *et al*., 2023; Kumar, 2025).

4.5 Governance, Policy, and Institutional Gaps:

One of the persistent challenges identified is the **inadequacy of local governance mechanisms**. Despite being under the purview of NMCG and the State Pollution Control Board, the Moradabad municipal infrastructure remains insufficient to manage waste and sewage discharge (Dayal, 2016; Barsay, 2022; Patel *et al*., 2023). The observed non-functioning sewage treatment plant illustrates a recurring issue: infrastructural installations often exist without sustained operation, maintenance funding, or community oversight (Matta, 2024; Kumar *et al*., 2019).

Decentralized wastewater management systems—such as modular treatment units and bio-remediation wetlands—offer a feasible alternative. Empirical evidence from smaller towns along the Ganga shows that such systems are more adaptable and cost-effective than centralized facilities (Jadeja *et al*., 2022; Nath *et al*., 2023).

Moreover, involving local residents in periodic monitoring, facilitated by universities, ensures both accountability and long-term operational continuity (Mishra *et al*., 2021; Singh *et al*., 2022).

4.6 Integrative Model for River Restoration:

Synthesizing the above findings, the TMU field interventions suggest an **integrative river restoration model**, depicted conceptually below:

Integrative Community-Academic Model for River Rejuvenation

Input Stage: Academic institutions → Community mobilization → Policy collaboration

Process Stage: Field survey → Cleanup → Awareness → Monitoring

Output Stage: Waste reduction → Behavioral change → Policy linkage → Sustainable maintenance

This model reinforces the triadic relationship among **education (knowledge creation), participation (community involvement), and governance (policy alignment)** (Das & Tamminga, 2012; Simon & Joshi, 2022; Patel *et al*., 2023). When executed cyclically, this system ensures that awareness drives translate into sustained collective action and informed policy advocacy.

4.7 Comparison with Global and National Frameworks:

The TMU case aligns conceptually with the **UNEP "Ecosystem-Based Adaptation" (EbA)** framework, emphasizing local community empowerment as the cornerstone of ecosystem restoration (Rana & Joshi, 2022; Nath *et al*., 2023). Similarly, the **National Mission for Clean Ganga (NMCG)** recognizes *Jan Bhagidari* (people's participation) as the "fifth pillar" of its strategy, complementing infrastructure, enforcement, research, and communication (Mishra *et al*., 2021; Barsay, 2022).

Comparatively, the TMU initiative fills the *implementation gap* by transforming policy language into field practice. The small-scale success achieved—waste reduction, enhanced awareness, and localized policy recommendations—serves as empirical validation of the NMCG participatory vision (Patel *et al*., 2023; Kumar, 2025).

Internationally, this model mirrors river stewardship projects in the **Thames (UK)**, **Murray-Darling (Australia)**, and **Rhine (Europe)** basins, where educational institutions have acted as mediators between science, policy, and society (Das & Tamminga, 2012; Singh *et al*., 2022).

4.8 Limitations and Future Directions:

While the study demonstrates positive outcomes, limitations include the absence of quantitative water quality data and limited temporal scope. Future studies should incorporate:

- Continuous physico-chemical water monitoring;
- GIS-based mapping of waste distribution;
- Longitudinal tracking of behavioral change;
- Socio-economic impact analysis using structured surveys.

Additionally, scaling this model requires establishing *Regional Academic-Community Cells* under the NMCG framework to institutionalize academic participation in river restoration (Nath *et al*., 2023; Jadeja *et al*., 2022). Such cells could coordinate university-driven environmental monitoring networks, fostering youth engagement and citizen science platforms.

V. CONCLUSIONS

This research reinforces the premise that **community-led interventions, guided by academic facilitation, can significantly influence river restoration outcomes** in polluted tributaries like the Ramganga. The TMU field initiatives—survey and cleanup—demonstrated that integrating awareness, participation, and environmental education produces tangible ecological and social dividends (Das & Tamminga, 2012; Simon & Joshi, 2022; Nath *et al*., 2023).

Key conclusions include:

1) **Behavioral transformation** is achievable through sustained awareness and emotional connection to the river.
2) **Educational institutions** can serve as operational hubs for environmental governance and monitoring.
3) **Small-scale interventions** are replicable, scalable, and cost-effective within the broader NMCG strategy.
4) **Policy frameworks** must adopt a hybrid approach that merges technological infrastructure with participatory community mechanisms.
5) **Long-term sustainability** depends on continuous education, adaptive governance, and inter-sectoral collaboration.

Ultimately, this study exemplifies a pragmatic pathway toward *ecological democratization*—a process in which every citizen, student, and institution participates actively in protecting and restoring natural resources. By linking academic insight with grassroots activism, the TMU model offers a replicable blueprint for the rejuvenation of India's river ecosystems and a powerful testament to the potential of collective environmental stewardship.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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