DYNAMICS OF RURAL SOCIETY JOURNAL
Vol. 4, No. 1 January 2026, pp. 60–69
E-ISSN 2987-0844
Journal homepage: https://drsj.fis.ung.ac.id/index.php/DRSJ

Assessing economic and livelihood impacts of water hyacinth utilisation in rural India: A mixed-methods study

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Article info

Research article

Article history

Received: 18 April 2025
Accepted: 4 July 2025
Online Publication: 17 September 2025

Keywords:

Economic Impact; Handicrafts; Income Generation; Jalkumbhi; Rural Livelihood

To cite this article:

Kumari, R., Boerma, B., Ahmed, R., Suman, S., Sharma, S., & Dhawan, S. (2025). Assessing economic and livelihood impacts of water hyacinth utilisation in rural India: A mixed-methods study. *Dynamics of Rural Society Journal*, *4*(1), 60–69. https://doi.org/10.37905/drsj.v4i1.96

Abstract

Water hyacinth (Eichhornia crassipes), an invasive aquatic plant, poses a persistent challenge to freshwater ecosystems in India, contributing to clogged waterways, reduced biodiversity, and economic strain on rural populations. This study examines a community-based intervention in Meerut, supported by the Uttar Pradesh State Rural Livelihood Mission (UPSRLM) and the Meerut Institute of Engineering and Technology (MIET), which aimed to address these issues by repurposing water hyacinth into value-added products. Employing a mixed-methods research design, which included field surveys, focus group discussions, structured interviews, and socio-economic impact assessments, the study examined the environmental, economic, and social dimensions of the initiative. Preliminary findings suggest ecological improvements such as localized enhancements in water quality and reports of increased aquatic biodiversity; however, these observations require further longitudinal data to establish causality. Economically, participating women artisans reported an average income increase of approximately 35%, and profit margins for handicraft products ranged from 50% to 60%, although these figures varied based on market access and product demand. Socially, participants reported perceived gains in self-confidence, economic autonomy, and community cohesion, with 75% noting an increase in collective participation. Nonetheless, challenges persisted in areas such as scaling production, maintaining product quality, and ensuring a consistent market presence. The initiative demonstrates potential in aligning ecological management with rural livelihoods through women-led self-help groups (SHGs), contributing to broader discussions on the circular economy and community-driven development. However, sustained success will likely depend on continued policy backing, technical training, and adaptive support systems. The findings suggest a promising but context-sensitive model that warrants further study before wider replication.

Introduction

Water hyacinth (Eichhornia crassipes), locally known in India as Jalkumbhi, is widely famous/recognized as one of the world's most invasive aquatic plants (Canning, 2025). Its rapid proliferation has severely disrupted

freshwater ecosystems across tropical and subtropical regions. For instance, a study in the Kuttanad region of India documented significant ecological degradation, income loss among fishing communities, and increased health risks due to water hyacinth infestation, with the plant covering as much as 80% of surface water in some areas (Simpson et al., 2022).

Globally, the adverse impacts of water hyacinth are well documented. In Lake Victoria, its dense mats obstructed waterways, hindered fisheries and hydropower intake structures, and created ideal breeding grounds for disease vectors, leading to outbreaks of malaria and other illnesses (The Citizen Reporter, 2025). The plant's thick coverage blocks sunlight, reduces dissolved oxygen levels, and disrupts nutrient cycling—ultimately contributing to eutrophication and loss of biodiversity (Cárdenas-Cuadrado,2025).

Beyond ecological harm, water hyacinth also poses public health risks. Invasive aquatic vegetation has been associated with elevated malaria risk: dense mats of water hyacinth and other invasive macrophytes create sheltered, nutrient-rich microhabitats that can support Anopheles breeding and increase species richness (Minakawa et al., 2012; Stone et al., 2018).

To contain its spread, conventional interventions — mechanical removal, herbicide application, and biological control — often deliver only short-term relief and can be costly or have unintended ecological side effects (Portilla & Lawler, 2020; Villamagna & Murphy, 2010)

This persistent challenge has spurred interest in more sustainable and economically viable alternatives. Notably, transforming water hyacinth into biodegradable handicrafts—such as baskets, mats, and furniture—has emerged as a promising livelihood strategy. These initiatives, particularly when led by women's self-help groups (SHGs), have demonstrated potential for skill development, environmental remediation, and poverty alleviation in rural India (Simpson et al., 2022).

Despite these promising developments, empirical assessments of the long-term socio-economic and environmental impacts of such upcycling-based interventions remain scarce. Key questions around scalability, market sustainability, and ecological effectiveness remain underexplored, especially in Indian rural contexts.

This study addresses these gaps by investigating a women-led, community-based water hyacinth handicraft initiative in Meerut, Uttar Pradesh, under the support of UPSRLM and the Meerut Institute of Engineering and Technology (MIET). Using a convergent mixed-methods approach, the study examines economic outcomes, environmental effects, and social implications—aiming to offer insights into nature-based solutions, circular economy strategies, and sustainable rural development.

Methods

This study employs a convergent mixed-methods research design, integrating both quantitative and qualitative approaches to comprehensively assess the economic impact and livelihood outcomes of water hyacinth (Jalkumbhi)-based handicrafts in rural Meerut, Uttar Pradesh. The rationale for this design is to triangulate data from multiple sources, thereby enhancing validity and contextual depth. In addition, the design allowed for cross-verification of economic outcomes with social and environmental dimensions, providing a holistic understanding of the intervention.

Study area and sampling framework

The research was conducted in the Meerut district of western Uttar Pradesh, a focal site for water hyacinth-based interventions under the Uttar Pradesh State Rural Livelihood Mission (UPSRLM). The district was selected for its active participation in eco-entrepreneurship models promoted by UPSRLM in partnership with local institutions such as the Meerut Institute of Engineering and Technology (MIET). The selection criteria also considered the prevalence of water hyacinth infestation in local ponds and rivers, the active involvement of women's self-help groups (SHGs) (Karunarathne, & Praveena, 2024), and accessibility for continuous field visits. Stratified purposive sampling was used to ensure representation across different village clusters, thereby capturing variations in socio-economic conditions.

Quantitative component

Survey data collection

A structured survey was administered to 150 artisans from rural Meerut who are active members of SHGs. The questionnaire was designed to capture data related to:

1. Income generation before and after joining Jalkumbhi initiatives

2. Business sustainability and household economic change
3. Production costs, including materials, labour, and transport
4. Market demand, pricing, and customer base

The questionnaire included both closed-ended and Likert-scale questions to allow statistical comparisons as well as nuanced perceptions of change. Pre-testing of the survey was carried out with a small pilot group of 15 artisans to ensure clarity, reliability, and contextual appropriateness before full deployment.

Economic analysis

A cost–benefit analysis was performed to assess the financial feasibility and profitability of Jalkumbhi-based handicrafts. Key parameters analysed include:

1. Initial and recurring raw material costs
2. Labour and transport expenses
3. Selling price and profit margins

The analysis also included sensitivity testing to evaluate profitability under fluctuating raw material supply, seasonal demand variations, and market price changes. Break-even analysis was conducted to determine the minimum sales volume required for sustainability.

Qualitative component

Semi-structured interviews

A total of 45 semi-structured interviews were conducted with diverse stakeholders:

1. 25 artisans
2. 5 SHG (Self-Help Group) leaders
3. 10 local consumers
4. 5 UPSRLM and MIET project coordinators

These interviews focused on the following themes:

1. Skill acquisition
2. Empowerment
3. Family support

Perceived socio-economic impact of the handicraft initiative — Interviews explored themes such as economic empowerment, skill acquisition, intra-household decision-making, and market access. In addition, questions were designed to capture intergenerational impacts, such as children's education, health expenditure patterns, and shifts in women's decision-making power within households. Interviews with consumers also examined perceptions of eco-friendly products, willingness to pay, and barriers to mainstream acceptance.

Focus group discussions (FGDs)

Three FGDs (8–10 participants each) were held with SHG members to examine collective experiences, constraints in raw material procurement, design adaptation, and internal group dynamics. FGDs were audio-recorded with participant consent and transcribed for analysis. Each discussion also incorporated participatory tools such as ranking exercises (for identifying challenges) and seasonal calendars (for mapping raw material availability), thereby generating richer insights into community perspectives.

Case studies

Detailed case studies were conducted on three SHGs in Meerut. The Ruby SHG in Badam village (Rohta block) has become a platform for savings, mutual support, and small-scale livelihoods. The Krishna SHG in Rasna village focuses on skill-based handicrafts, enhancing income and social recognition. The Unnati SHG in Shyal village (Rajpura block) blends traditional skills with innovation to improve productivity and community participation. Collectively, these SHGs showcase how women's groups drive empowerment, economic resilience, and local development, while case narratives also highlight grassroots innovation, gender roles, social support networks, and adaptive practices shaped by cultural norms, leadership, and institutional

support. Figure 1 the highlighted locations—Badam, Rasna, Shyal—denote rural communities engaged in Jalkumbhi-based handicraft production under the UPSRLM initiative. This spatial context underscores the socio-economic and geographic relevance of the case study.

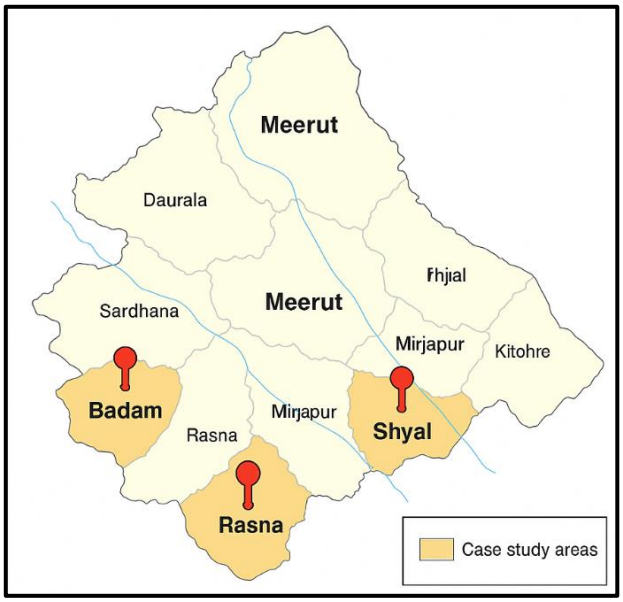

Figure 1. Map illustrating the selected study areas in Meerut District, Uttar Pradesh, India.

Data analysis and integration

Quantitative data analysis

Survey data were analysed using descriptive statistical tools in SPSS. Measures such as mean income differentials, cost–revenue ratios, and production efficiency were used to quantify economic gains and viability. In addition, frequency distributions and cross-tabulations were employed to examine demographic patterns among artisans, such as age, education, and household size, and their relationship to livelihood outcomes.

Inferential statistics, including one-way ANOVA and independent sample t-tests, were used to test the significance of income changes across different SHG sizes and between pre- and post-intervention periods. Correlation analysis was performed to assess the relationship between production volume, sales revenue, and household income, thereby identifying the strength of associations between key economic variables.

Regression modelling was also applied to predict income variability based on independent variables such as raw material costs, labour input, and marketing reach. This provided a deeper understanding of the factors most strongly influencing profitability. Sensitivity analysis was further conducted to estimate how fluctuations in input costs (transportation, raw materials) or market demand could affect long-term sustainability.

By combining descriptive and inferential statistical techniques, the quantitative analysis provided both a snapshot of current livelihood impacts and predictive insights into the future viability of Jalkumbhi-based handicraft enterprises.

Qualitative data analysis

Qualitative data (interviews, FGDs, and case studies) were analysed thematically using Braun and Clarke's (2008) six-phase framework, which provides a systematic approach to identifying, organising, and interpreting patterns within qualitative datasets. The six phases were applied as follows:

1. **Familiarisation with data** – All transcripts were read and re-read to achieve immersion in the data. Preliminary notes were made to capture initial impressions and recurring ideas from participants.
2. **Generation of initial codes** – Using NVivo 12, significant text segments were coded line by line. Codes were both descriptive (e.g., "income increase," "family support") and interpretive (e.g., "empowerment through visibility").
3. **Searching for themes** – Related codes were clustered to form preliminary themes, such as "economic resilience," "social inclusion," and "market barriers."

4. **Reviewing themes** – Themes were refined through iterative comparison across interviews, FGDs, and case studies to ensure internal consistency and external distinctiveness.
5. **Defining and naming themes** – Themes were clearly defined with scope and boundaries, supported by verbatim quotes to maintain authenticity. Each theme was aligned with the broader objectives of assessing livelihood, empowerment, and sustainability.
6. **Producing the report** – A thematic map was developed to illustrate connections between themes, showing how economic, social, and ecological factors intersect in shaping the outcomes of Jalkumbhi-based handicraft initiatives.

NVivo 12 software was utilised for systematic data management, facilitating coding queries, word frequency counts, and matrix coding to explore the co-occurrence of themes across different participant groups. Inter-coder reliability was ensured by having two independent researchers code 20% of the transcripts, with a Cohen's kappa coefficient of 0.82, indicating strong agreement.

Emergent themes highlighted five critical dimensions: economic resilience (steady income growth and risk diversification), gender empowerment (enhanced decision-making and leadership roles), skill development (capacity building in design, marketing, and financial management), market access barriers (limited exposure to larger markets and competition with synthetic alternatives), and social transformation (improved self-esteem, stronger community cohesion, and shifts in traditional gender roles).

The integration of case studies further deepened these themes by providing contextualised narratives of individual and group experiences. For example, SHG leaders described challenges in balancing traditional household responsibilities with entrepreneurial roles, while artisans highlighted pride in contributing to community-level ecological restoration. FGDs revealed collective solidarity in overcoming supply chain constraints and advocating for policy support.

Therefore, the qualitative analysis enriched the quantitative findings by uncovering nuanced socio-cultural dynamics and lived experiences that numerical data alone could not capture.

Mixed-methods integration

To enhance analytical rigour, both data streams were integrated during interpretation using a side-by-side comparison technique. Quantitative trends (e.g., income increases, profit margins, production efficiency) were juxtaposed with qualitative insights (e.g., narratives of empowerment, consumer perception, social cohesion), enabling validation and contextual enrichment.

This integration allowed the numerical evidence of a 35% rise in household income to be interpreted alongside women's testimonies of enhanced self-esteem and decision-making power. For example, statistical confirmation of higher profit margins was reinforced by qualitative accounts of artisans gaining confidence to negotiate prices and expand market linkages. Similarly, quantitative findings on cost–benefit ratios were complemented by interviews illustrating the hidden labour contributions of family members, which often remain unaccounted for in financial data.

By combining measurable indicators with lived experiences, the mixed-methods approach offered a holistic picture of the initiative's outcomes. It highlighted not only the economic viability of Jalkumbhi-based handicrafts but also the broader socio-cultural transformations, such as shifts in gender roles, intergenerational knowledge transfer, and enhanced community solidarity.

Furthermore, triangulation across methods helped to identify divergences. For instance, while survey data suggested uniform income growth across SHGs, qualitative accounts revealed that women from smaller groups faced greater struggles in accessing markets compared to larger, better-networked SHGs. Such insights underscored the importance of contextual nuances that purely quantitative analysis might overlook.

Thus, this integration strengthened the study's explanatory power by demonstrating how ecological threats like Jalkumbhi can be reframed as sustainable livelihood opportunities through women-led entrepreneurship, while simultaneously addressing environmental management, economic resilience, and social empowerment.

Results and discussion

Economic impact and viability

A structured survey of 150 women artisans revealed a substantial increase in monthly income after they engaged in Jalkumbhi-based handicraft production. The average monthly income increased by 35%, from

₹5,175 to ₹7,050. A one-way ANOVA confirmed that the differences were statistically significant ($p < 0.05$), indicating that income gains were directly associated with participation in this initiative rather than being due to external factors.

Table 1. Average monthly income increase for artisans

SHG Group Size	Average Monthly Income (Before) ₹	Average Monthly Income (After) ₹	% Increase
Group 1 (5–10)	4,500	6,100	35%
Group 2 (10–15)	5,000	6,800	36%
Group 3 (15–20)	5,200	7,200	38%
Group 4 (20+)	6,000	8,100	35%
Average	**5,175**	**7,050**	**35%**

This economic uplift highlights the commercial feasibility of eco-friendly handicrafts. The income improvement was consistent across all group sizes, with slightly higher gains observed among medium-sized SHGs (15–20 members). This suggests that collective efficiency, division of labour, and better access to markets may positively influence income growth.

The success of SHGs in leveraging local sales channels and expanding visibility through digital platforms (e.g., WhatsApp, Instagram, and Facebook Marketplace) indicates promising scalability. Artisans reported that online marketing not only helped in reaching urban consumers but also reduced dependency on middlemen, allowing them to retain a higher share of profits. Furthermore, profit margins of 50–60% underscore the financial viability of these products, aligning with those of similar rural enterprises across India.

Another noteworthy finding was the diversification of income sources. Several participants indicated that while handicraft-making became their primary occupation, the additional earnings were often reinvested into small-scale farming, children's education, or household infrastructure. This reinvestment cycle strengthened the sustainability of the initiative by creating secondary socio-economic benefits.

The results also revealed that households participating in Jalkumbhi-based enterprises exhibited greater resilience during seasonal income fluctuations. For example, when agricultural earnings declined, handicraft sales provided a steady supplementary income. This aligns with the idea of livelihood diversification as a key strategy for poverty reduction and rural resilience.

Such interventions must be embedded within a broader rural development policy framework that recognises the multi-dimensional value of linking environmental management with community livelihoods. By doing so, policymakers can promote an integrated model of development that not only addresses invasive species management but also contributes to economic inclusion, social empowerment, and ecological resilience.

As this study demonstrates, the potential of such initiatives lies in their alignment with circular economy principles, sustainable production practices, and community-led innovation. Accordingly, these insights provide a replicable and policy-relevant pathway for other regions facing similar challenges, including aquatic weed proliferation and rural unemployment (Mihai, 2023).

Social impact and livelihood enhancement

Beyond financial gains, the initiative fostered significant social transformation. The qualitative data—from interviews and FGDs—emphasized growth in self-esteem, financial autonomy, social cohesion, and inclusive participation, particularly among women previously marginalized in economic activity.

Table 2. Social impact of Jalkumbhi handicrafts on rural women

Impact Category	Percentage Reporting Impact
Increased Self-Esteem	100%
Economic Independence	100%
Strengthened Social Cohesion	75%

1. **Self-Esteem & Empowerment:** Every participant reported enhanced confidence and self-worth, citing the ability to contribute to household income and gain social recognition.
2. **Financial Independence:** Respondents highlighted new autonomy in decision-making and financial planning, particularly in children's education and household budgeting.
3. **Social Cohesion:** Approximately 75% of women noted improved community relations, teamwork, and trust through SHG collaboration.
4. **Inclusive Participation:** The initiative effectively engaged marginalised castes and economically disadvantaged women, fostering greater equity and dismantling traditional hierarchies.

These findings underscore the pivotal role of community-led, eco-centric livelihoods in promoting gender empowerment and enhancing rural resilience. The Jalkumbhi handicraft initiative exemplifies how locally available natural resources can be transformed into sustainable economic opportunities, particularly for women from marginalised backgrounds. However, the scalability of such models is constrained by factors such as seasonal variability in raw material availability, the physically demanding nature of harvesting, and emerging market competition. To overcome these barriers, there is a pressing need for targeted policy support, access to ergonomic tools, streamlined supply chains, and continuous capacity-building programs for artisans.

Figure 2 offers a visual representation of the seven-stage transformation of water hyacinth into eco-friendly handicrafts. This process not only outlines the technical steps involved—from harvesting and drying to product finishing and quality assurance—but also reflects the broader ethos of the initiative: an inclusive, sustainable livelihood model rooted in traditional knowledge and environmental stewardship.

Figure 2. Stepwise process of water hyacinth-based eco-friendly handicraft production.
Source: (Primary data collected by the study team, 2024)

A. Harvesting of water hyacinth from wetland areas by local workers.

B. Sun-drying of water hyacinth stems to remove moisture and improve durability.

C. Initial processing and cleaning of dried stems by rural women artisans.

D. Finished eco-friendly handbags made from woven water hyacinth fibre.

E. Measurement and quality checking of woven mats for uniformity.

F. Oval-shaped handwoven water hyacinth mat – a functional household product.

G. Handcrafted multipurpose tray and coasters from braided water hyacinth stems.

Figure 2 highlights the sustainable livelihood practices involving the transformation of invasive aquatic weeds into value-added handcrafted products by empowering local communities.

Handcrafted Jalkumbhi products illustrate how an invasive aquatic weed can be transformed into functional, eco-friendly goods through traditional craftsmanship and community collaboration. This adaptive reuse not only yields environmental benefits—by mitigating the invasive spread—but also supports sustainable rural livelihoods. The reported 35% average increase in household income among women artisans is consistent with empirical evidence from mixed-methods fieldwork in Kuttanad, India (Abba et al., 2025). The dependable biomass supply, minimal raw material cost, and growing consumer demand for biodegradable goods further enhance the economic appeal of these interventions (Das & Dhadse, 2023).

Social impacts were equally transformative. All participants reported enhanced self-esteem and financial independence, and 75% noted improved social cohesion through SHG engagement—findings resonant with transformative livelihood models noted in Kerala's integrated hybrid waste–livelihood initiatives (Namitha & Ramanathan, 2024) and tribal SHG enterprises in West Bengal (Chakraborty & Kumar, 2024).

Artisans also acquired skills in design, marketing, and financial management, positioning themselves as decision-makers and contributors to local governance. Although MIET's direct interventions are not yet documented in the published literature, these capacity-building outcomes reflect broader trends in rural empowerment programs across India.

Despite these successes, challenges persist—seasonal raw material scarcity, labour-intensive harvesting, and market saturation constrain scalability. Addressing these by offering ergonomic tools, bolstering supply chains, and aligning with government-led livelihood initiatives remains critical for sustained impact (Mihai, 2023). Overall, the Jalkumbhi initiative epitomises how nature-based solutions can drive inclusive rural development, environmental restoration, and women-led entrepreneurship in Indian settings.

Handmade Jalkumbhi (water hyacinth) handicrafts

The Ruby SHG in Rota Village has turned the challenge of water hyacinth infestation into an opportunity by clearing local ponds and converting the weed into eco-friendly, handmade products. This initiative supports both environmental restoration and the generation of sustainable livelihoods.

Economically, women artisans reported a 35% average increase in monthly income, driven by strong demand for their products in local markets and through platforms such as WhatsApp and Facebook. This financial uplift has enhanced household stability and empowered women through greater economic participation.

Socially, the project fostered community cohesion, skill development, and self-confidence among participants. Approximately 75% of respondents reported improved social bonds resulting from SHG collaboration. The initiative also promoted inclusion of marginalised groups, offering new opportunities for lower-caste women.

Challenges remain, including seasonal raw material scarcity, labour-intensive collection, and growing competition. However, the model demonstrates strong potential for scalable, women-led eco-entrepreneurship that benefits both people and the planet.

Integrated reflections on livelihood and sustainability

The initiative demonstrates that transforming *Eichhornia crassipes* from an ecological burden to an income-generating resource is both technically feasible and socially meaningful. However, the project's long-term sustainability depends on addressing infrastructural gaps, such as inconsistent raw material supply, market overload, and lack of formalised cooperatives.

Furthermore, the success of a few groups should not mask the fragility of grassroots enterprises operating in resource-intensive contexts. Women reported burnout during peak collection seasons and highlighted the need for ergonomic tools, childcare support, and mobility aid**,** especially for older artisans.

Recommendations and path forward

The study supports the potential of women-led SHGs in driving eco-entrepreneurship while addressing environmental degradation. To enhance impact and replication, the following are recommended:

a. Development of common facility centers (CFCs) to streamline storage and drying

b. Access to micro-credit and insurance mechanisms for SHG operations

c. Investment in branding, certification (e.g., eco-labeling), and market linkages

d. Ongoing training in inventory, logistics, and digital marketing

e. Inclusion of impact assessments at 6-month intervals to evaluate outcomes beyond income

Conclusion

In conclusion, this study highlights the transformative potential of Eichhornia crassipes (Jalkumbhi) as a sustainable resource for rural livelihoods rather than merely an ecological threat. The 35% increase in household income among SHG members underscores the economic viability of water hyacinth-based handicrafts, particularly when led by women in ecologically affected regions. To sustain and scale such initiatives, future efforts must focus on strengthening income-generation strategies through institutional

support, improving supply chains, and ensuring access to microfinance and digital markets. It is also essential to apply rigorous, validated methodologies in impact assessment and integrate ecological indicators to measure environmental benefits such as improved biodiversity and water quality. Operational challenges—such as seasonal material shortages, labour intensity, and market saturation—should be addressed through design innovation, decentralised processing, and continuous capacity-building. Promoting inclusive participation, particularly from marginalised groups, and fostering inter-community collaboration will further enhance the social equity of these models. Cross-regional studies and alignment with national schemes, such as NRLM and PMEGP, are recommended to refine and replicate this approach across India. Ultimately, the initiative presents a compelling example of how invasive species management can be integrated into broader circular economy and rural development strategies, driving both environmental restoration and socio-economic transformation.

Acknowledgment

The authors sincerely thank the Uttar Pradesh State Rural Livelihood Mission (UPSRLM), the Meerut Institute of Engineering and Technology (MIET), and the participating Self-Help Groups (SHGs) for their cooperation and contribution to this study. We also acknowledge the efforts of the field investigators and local facilitators who supported data collection and community engagement.

Statement of originality and plagiarism-free

We inform that this article is an original article and free of plagiarism

Conflict of interest

The authors declare no conflict of interest related to this study.

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