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Turning an Invasive Species into Rural Opportunity: A Women-Led Community Case Study for Sustainable Biomass Management and Livelihood Development in India

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ABSTRACT

Invasive species are commonly viewed as ecological threats; however, community-led approaches can transform these management challenges into opportunities for rural livelihood development. This qualitative case study examines a women-led initiative near the Beas Conservation Reserve (BCR), Punjab, India, where invasive water hyacinth biomass is managed through manual removal and value-added reuse. Semi-structured interviews, participant observations and photographic documentation of processing and production activities were conducted to understand perceived ecological changes, livelihood outcomes and social dimensions. The intervention generated supplementary household income through handicraft production while strengthening skills, participation and leadership roles among rural women. The findings demonstrate a transferable community-based approach that links invasive species management, sustainable biomass utilization and gender-responsive rural development. The study contributes to rural development scholarship by showing how institutional facilitation—rather than subsidy-driven interventions - can support locally driven environmental action and livelihood generation. The approach aligns with the Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth) and SDG 15 (Life on Land), by illustrating how women-led rural innovations can integrate community-based invasive species management with social and economic empowerment.

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1. Introduction

Water hyacinth (Pontederia crassipes, formerly Eichhornia crassipes) is one of the world's most problematic invasive aquatic weeds (Thamaga & Dube, 2018). It is spread in more than fifty countries (Villamagna & Murphy, 2010; May et al., 2022; Degaga, 2018; Harun et al., 2021). The weed proliferates rapidly in freshwater ecosystems, disrupting ecological balance. It accumulates over the water surface, reduces dissolved oxygen, suppresses plankton and fish production, degrades water quality and impairs navigation and recreational activities (Lubembe et al., 2023). The species' fast growth is linked to

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eutrophication from poor land-use practices, nutrient enrichment and climatic changes (Thamaga & Dube, 2018).

The socio-economic implications of water hyacinth are also notable. Local communities experience impacts from diminished fish catches, hindered navigation, restricted tourism access, and risks to clean water supply and human health due to nutrient release during decomposition (Degaga, 2018; Yigermal & Assefa, 2019; Reddy, 1987). The effects of these changes significantly influence rural livelihoods that rely on freshwater ecosystems.

Near the Beas Conservation Reserve in Punjab, women have organized a local initiative that combines the removal of invasive water hyacinth with small-scale handicraft production. In practice, this activity supports household incomes while contributing to riparian management. The case shows that community-based, gender-responsive approaches can play a meaningful role in addressing invasive species pressures in rural landscapes.

Unlike many water hyacinth utilisation initiatives that are externally driven or focused on large-scale bioenergy or composting, this study documents a locally initiated, women-led intervention operating at the human–riparian protected area interface. The case highlights how institutional facilitation, rather than directive management or subsidy-based programmes, can enable community-led invasive species management linked to rural livelihoods. By situating invasive species removal within everyday household economies, the study contributes empirical insight into gender-responsive rural development strategies in riparian landscapes.

This study addresses this gap through an in-depth qualitative case analysis of a women-led initiative integrating invasive species management, sustainable biomass utilization and rural livelihood development.

The objective of this study was to examine how a locally initiated women-led intervention transformed invasive water hyacinth biomass management into a rural livelihood opportunity near a riparian protected landscape.

Research questions:

How does women-led utilization of invasive water hyacinth contribute to supplementary livelihood generation?

How does institutional facilitation support community-based invasive species management?

What opportunities and limitations emerge while transforming invasive biomass into value-added products?

2. Literature review

Water hyacinth presents avenues for generating livelihoods. Its biomass can be converted into bioenergy, biofertilizers, animal feed, handicrafts, furniture and other value-added products, transforming an ecological challenge into an economic opportunity (Nega et al., 2022; Rezania et al., 2015; Nandiyanto et al., 2024; Liu et al., 2024).

Several self-help groups, spearheaded by women, have successfully harnessed water hyacinth to develop products that generate extra income, enhance skills, and foster social and women's empowerment (Mathur & Mathur, 2017; Harun et al., 2021; Sreenivasan & Soundari, 2024; Chakraborty & Kumar, 2024).

Sun-dried, minimally processed biomass serves as a resource for small-scale, cost-effective handicrafts, contributing to the strengthening of rural economies (Gunnarsson & Petersen, 2007).

Although there is considerable potential, the marketing of these products poses a challenge that restricts economic benefits for rural communities (Abba & Sankarannair, 2024; Kumari et al., 2025).

Consequently, the implementation of integrated management and inclusive governance is crucial for addressing the ecological consequences of invasive freshwater species like water hyacinth (Malik, 2007; Strayer, 2010).

Community-based approaches emphasize the role of local participation, collective action and shared benefits in natural resource management (Berkes, 2004). Gender-responsive governance further recognizes the importance of women's involvement in environmental decision-making and sustainable livelihood processes (Agarwal, 2009; Leisher et al., 2016).

This women-led initiative is a promising strategy for sustainable rural livelihood management and contributes to Sustainable Development Goals, including SDG 5 (Gender Equality), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work and Economic Growth) and SDG 15 (Life on Land) (United Nations, 2015).

While prior studies document the utilization potential of water hyacinth and women's self-help initiatives, fewer studies examine how locally initiated, institutionally facilitated interventions operate at the human–riparian protected area interface.

3. Study Area

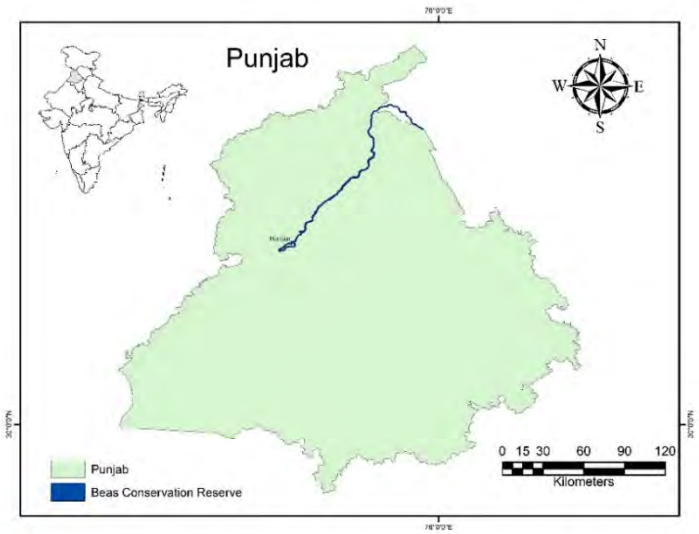

Figure 1. Location of the study area near the Beas Conservation Reserve, Punjab, India.

Source: Author's map generated using QGIS with spatial data from the Ramsar Sites Information Service (RSIS).

The study was conducted in a rural region adjacent to the Beas Conservation Reserve (BCR), close to the Harike Wetland in Punjab, India. Both BCR and Harike Wetland are Ramsar-designated sites. The area experiences seasonal monsoon flooding and sediment deposition, which influence surrounding land-use patterns and also facilitate the spread of water hyacinth.

The zone is dominated by agricultural fields, drainage channels and rural settlements and has several human-riparian interactions (Sood et al., 2025). Local livelihoods are primarily agrarian. The location within the influence zone of a protected riparian ecosystem places communities at a dynamic human–river–conservation interface. The geographical location of the study area in relation to the Beas Conservation Reserve is shown in Figure 1. Specific village names and individual participant identities are not disclosed to maintain community-level confidentiality.

4. Methodology

4.1. Study Design

A qualitative case study design was utilized to investigate a context-specific, women-led initiative for managing invasive species. This approach enabled documentation of institutional processes, social dynamics and livelihood outcomes where quantitative ecological monitoring was constrained.

4.2. Participant Selection and Data Collection

Data were gathered from March to July 2024 using the following methods: Participants were selected using purposive sampling to capture direct involvement across removal, processing and coordination roles. Interviews continued until thematic saturation was achieved

- Semi-structured interviews were conducted with 18 female participants engaged in water hyacinth removal and product processing, together with 4 key informants comprising community facilitators and municipal officials.
- Participant observation: Direct observation of extraction activities, biomass drying, braiding, mechanized processing and communal production within domestic environments.
- Visual documentation: Photographs documenting water hyacinth processing, workflow and final products were recorded.
- Informal group discussion: To understand challenges and benefits, informal group discussions were conducted.

4.3. Data Analysis

Thematic analysis was employed to examine interview transcripts and field notes. Codes were generated inductively and categorized into themes pertaining to environmental consequences, livelihood advantages, institutional assistance and gender roles. Triangulation of interviews, observations and photographic evidence improved reliability. Coding was conducted manually and iteratively, with themes refined through repeated comparison across interviews, observations, and visual records. An initial open-coding phase was followed by axial coding to consolidate themes.

4.4. Visual Documentation

Photographic documentation acted as supplementary empirical data to support participant observation, record the ongoing activities, and illustrate the value-addition process from biomass

removal to final products (Figs. 3-5). All photographs were captured following the verbal consent and agreement of the participants involved. The study design was guided by a sustainability-focused analytical approach, acknowledging connections among gender equity, water management and ecosystem restoration. Outcomes of the study were analysed for SDG-alignment. The conceptual framework illustrating the linkage between invasive biomass management, women-led participation and rural livelihood outcomes is presented in Figure 2. The study map was generated using QGIS, with BCR datasets sourced from the Ramsar Sites Information Service (RSIS) and overlaid in the UTM Zone 43N coordinate reference system.

4.5. Ethical Considerations

Informed consent was obtained from all participants prior to interviews, field observations and photographic documentation. Permission was obtained for the use of photographs for academic publication purposes. No personal identifiers are disclosed in this study. The study involved non-invasive social research based on voluntary participation and did not involve experimental procedures. Institutional ethical approval was not required; however, informed consent procedures and confidentiality principles were followed throughout the study.

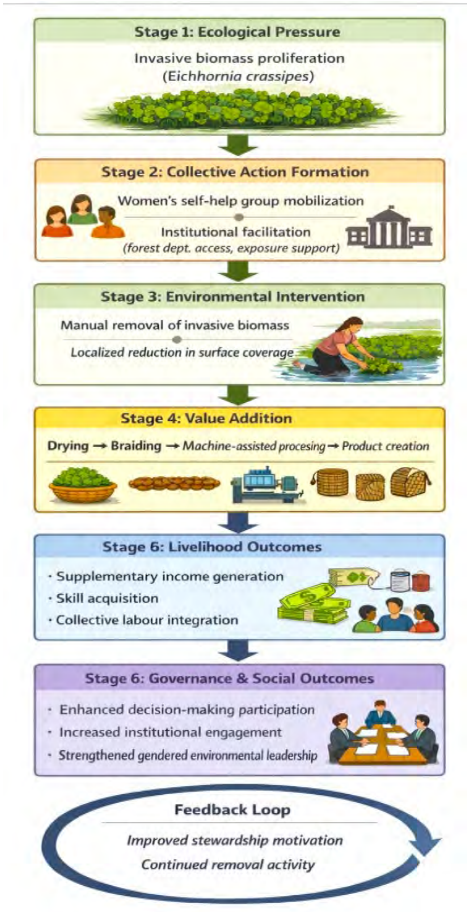

Figure 2. Conceptual framework linking invasive biomass management, women-led participation and rural livelihood development.

Source: Author's field documentation (2024).

1. Results

5.1. Organization and Implementation

Women worked as a self-help group for planning and executing water hyacinth removal activities. Removal was conducted manually, targeting a nearby river stretch with high water hyacinth biomass. Some participation was reported from their family members and community members, although the women's group took the lead.

5.2. Livelihood Transformation through Biomass Processing

Field observations documented a multi-stage processing sequence (Figure 3).

i. Harvested hyacinth was sun-dried (Figure 3a).
ii. Manually braided into fibers (Figure 3 b,c,d)
iii. Shaped into products using collective labour (Figure 3e).

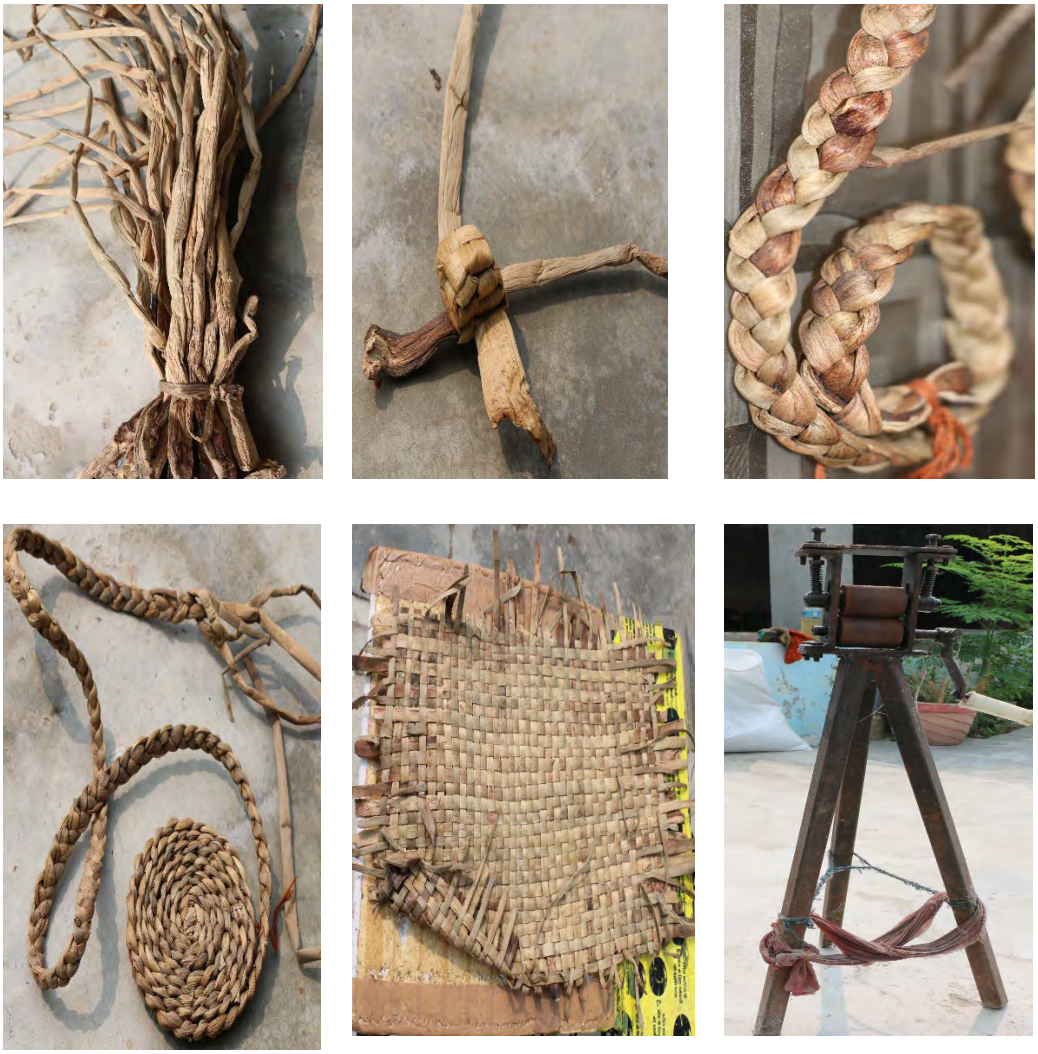

Figure 3. Different stages of water hyacinth biomass processing and value-added product preparation

Source: Author's field documentation (2024).

A small household-scale mechanical unit (Figure 3f) was used for compressing dried water hyacinth. The machine reduced manual effort and improved the consistency of the water hyacinth strips. Final products included file covers, folders, footwear and utility items intended for use in environmental meetings and conferences or for daily use. The staged transformation of water hyacinth biomass into usable products illustrates how ecological removal activities are embedded within household labour routines.

Each stage involves distinct skill acquisition, time investment and gendered labour allocation, revealing how environmental management becomes integrated into everyday livelihood practices rather than remaining an external conservation task. Women's control over processing stages - particularly braiding and finishing - enabled greater decision-making authority over production pace, product design and income use, reinforcing leadership roles within the collective.

5.3. Products developed

Figure 4. Value-added products developed from processed water hyacinth biomass

Source: Author's field documentation (2024).

5.4. Perceived Environmental Change

Community members reported a visible reduction in surface water hyacinth cover in treated sections of the river following removal activities. The observations are based on community perceptions and field narratives rather than quantitative ecological measurements.

5.5 Livelihood Diversification Outcomes

The sale of dried water hyacinth-based products generated supplementary income for women. The women's group reported limited market access and low sales, mainly due to the absence of established marketing channels and limited consumer awareness.

Detailed financial records of production volume, costs and income were not maintained by participants; therefore, economic outcomes were assessed qualitatively through participant narratives and field observations.

Figure 5. Collective braiding activities and machine-assisted finishing of water hyacinth products.

Source: Author's field documentation (2024).

5.6 Social and Gendered Shifts in Participation

Capacity building and external exposure included opportunities to display and utilize final products in wider forums, contributing to increased recognition and strengthened confidence among participants. Women's engagement in invasive species management and the product sales enhanced their visibility and leadership in the nearby local riparian governance process (Agarwal, 2010; Leisher et al., 2016). Participants described increased confidence when interacting with external institutions and reported more active involvement in discussions and decision-making linked to the initiative.

At the same time, they pointed to limited market access and uneven product demand as continuing challenges, highlighting the need for focused efforts to strengthen livelihood sustainability. A summary of the field observations, participant involvement, processing approach and livelihood characteristics documented during the study is provided in Table 1.

Table 1. Summary of field observations and livelihood initiative characteristics

Indicator	Observation
Study period	March–July 2024
Women participants	18
Key informants	4
Processing approach	Household/community scale
Products developed	Folders, footwear, utility products
Economic contribution	Supplementary income
Major constraint	Limited market linkage

Source: Author's field survey (2024).

5.7 Participant Perspectives

Participant narratives indicated that the plant was earlier perceived only as waste obstructing waterways, whereas training changed perceptions by demonstrating its potential value (Participant W3).

Participants reported that the activity improved skills and recognition, although regular market access remained a challenge (Participant W11). Collective production activities were described as improving cooperation among women (Participant W15).

6. Discussion

6.1 Community-Based Natural Resource Management and Gendered Environmental Governance

Viewed through the lens of community-based natural resource management (CBNRM), the women-led initiative documented in this study demonstrates how localized stewardship can address invasive species pressures while supporting rural livelihoods. CBNRM emphasizes the role of local communities as active managers of natural resources, grounded in contextual knowledge, collective action and shared benefits rather than externally imposed control mechanisms (Berkes, 2004). In this case, the manual removal and reutilization of water hyacinth represent a form of community-driven management embedded within everyday livelihood practices at the human–riparian protected area interface.

The initiative also reflects principles of gendered environmental governance, wherein women's participation reshapes access to resources, decision-making authority and environmental responsibility (Agarwal, 2009; Leisher et al., 2016). Women's leadership in organizing biomass removal, coordinating processing activities and engaging with external institutions highlights how gender-responsive governance can enhance both conservation outcomes and social equity. Rather than being peripheral beneficiaries, women functioned as central environmental actors whose labour and knowledge transformed an ecological intervention into livelihood value.

Importantly, the case illustrates how institutional facilitation, rather than directive management or subsidy-driven programmes, can enable effective CBNRM and gendered governance. External institutions provided legitimacy, exposure and logistical access without displacing local agency, allowing women's collectives to retain control over production processes and income use. This aligns with broader scholarship emphasizing that supportive governance arrangements are more effective when they strengthen, rather than replace, community-led environmental action.

By integrating invasive species management with livelihood generation through gendered collective action, the initiative demonstrates a governance pathway where ecological restoration and social empowerment reinforce each other.

6.2 Implications for Rural Development, Gender Equity and Sustainable Invasive Species Management

This study illustrates that the management of invasive species in riparian landscapes, when led by women, can generate interconnected ecological, social and economic benefits by integrating conservation action with rural livelihood strategies. The findings have implications for rural development planning, gender equity in natural resource governance and sustainable invasive species management in riparian systems. The combination of invasive biomass removal with income-generating

activities, such as handicraft production, demonstrates how conservation actions can become socially embedded when ecological restoration relates to local livelihood needs (Berkes, 2004; Sood et al., 2025).

The manual removal and reutilization of biomass serve as cost-effective and contextually suitable approaches for riparian ecosystems. These strategies can contribute to localized invasive biomass management while enabling productive reuse of biomass and supporting nature-based livelihood opportunities (Villamagna & Murphy, 2010; Rezania et al., 2015; Nega et al., 2022; Meinzen-Dick & Zwarteveen, 1998).

Beyond ecological outcomes, the initiative promoted women's empowerment within rural economies. Participants were involved in planning, coordination, handicraft production and market interactions, acquiring skills, confidence and leadership roles while transitioning from informal resource users to recognized economic and environmental contributors (Mathur & Mathur, 2017; Chakraborty & Kumar, 2024). Institutional support through field access, technical facilitation and external exposure created an enabling environment without imposing externally driven interventions, thereby strengthening the legitimacy and recognition of women's contributions.

A significant constraint was the restricted and inconsistent market access for biomass-derived products, which limited economic returns despite continued ecological engagement (Harun et al., 2021; Abba & Sankarannair, 2024). Strengthening value chains, improving branding strategies and developing reliable market linkages are therefore essential for sustaining both conservation and livelihood outcomes. This limitation reflects broader challenges in rural value-chain integration rather than shortcomings of community participation or environmental commitment.

The approach contributes to multiple Sustainable Development Goals (SDGs), including gender equality through women's leadership and income generation, improved ecosystem management through invasive species removal and sustainable livelihoods through nature-based economic opportunities (United Nations, 2015; UN Women, 2023). For rural development agencies and local governments, such initiatives highlight the importance of supporting women's collectives through market access, institutional facilitation and capacity building rather than relying only on subsidy-driven interventions. Beyond individual empowerment, the initiative contributes to gender equity by challenging traditional exclusions of women from environmental decision-making and public conservation spaces.

7. Conclusion

This study demonstrates that women-led management of invasive water hyacinth near a rural riparian protected area can contribute to localized invasive biomass management while creating supplementary livelihood opportunities and strengthening gender participation in conservation. By transforming invasive biomass into value-added products, the initiative connects ecosystem management with community-based rural development and supports SDGs 5, 6, 8 and 15.

Although limited in spatial scale and lacking quantitative ecological monitoring, the case highlights the potential of locally driven, institutionally supported approaches for addressing invasive species challenges. Integrating such community-based strategies into riparian governance frameworks can

strengthen biodiversity conservation, sustainable livelihoods and inclusive environmental management in similar landscapes.

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Conflict of Interest

The author declares no conflict of interest.

Author Contribution

The author contributed to conceptualization, field investigation, analysis, writing and revision of the manuscript.

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