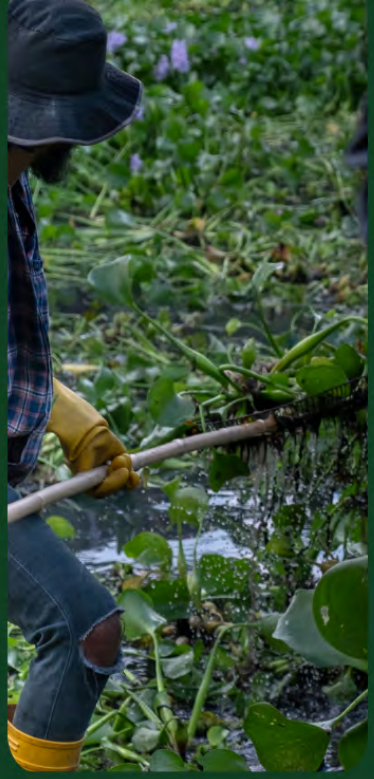

HYACINTHESIS

SCOPING STUDY

UNLOCKING THE CIRCULAR POTENTIAL OF WATER HYACINTH IN SRI LANKA

LANKA ENVIRONMENT FUND | THE FOUNDATION FOR A GOOD LIFE | GOOD LIFE | CONSERVATION COLLECTIVE | Scott Dunn

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The Conservation Collective comprises a global network of locally-focused environmental foundations, emerging from the natural instinct of all people to protect what they love. The Conservation Collective facilitates funding for the most effective grassroots environmental initiatives, with world-class oversight, management and programme aid.

The Foundation For A Good Life (Guarantee) Limited is a foundation that enables innovative, life-enhancing initiatives through business, innovation and culture with the intention of creating a significant shift towards a regenerative economy and conscious society in South Asia at large. The Foundation for a Good Life (Guarantee) Limited creates an ecosystem that encourages impact-driven innovation, creativity, and experimentation, including facilitating partnerships with research institutions and universities.

Lanka Environment Fund, established in 2019 is a Not-For-Profit Organization that supports existing conservation initiatives in Sri Lanka with their work by providing grant funding and acting as a conduit for international funding to have an impact locally. As conservation administrators, the cornerstone of our mission is the empowerment of local communities, backed up by investment in the local environment.

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EXECUTIVE SUMMARY

This scoping study explores the potential of water hyacinth (WH) as a circular solution in Sri Lanka, focusing on its business and market demand, economic viability, environmental impact, social implications and material innovation models required. The study aims to assess current business and its practices, identify opportunities for sustainable utilization, and provide strategic recommendations for scaling WH-based initiatives into a business accelerator programme.

Water hyacinth, while invasive, presents significant potential for transformation into value-added products such as handicrafts, compost, bioenergy, biochar, substitution to single use plastics, building materials and fiber applications of multiple designs. WH can also be used to create opportunities in all ESG thrust areas based on global and local experience in which applications could be in line with handicrafts; furniture; yarn and clothing; paper and board products; livestock feed; soil amendments and soil fertility enhancement; bio char and biomaterials and bioplastics. This study has taken into consideration, an analysis of the circularity of water hyacinth through the lens of material innovation, environmental safeguards and a business strategy analysis, while also examining the existing market demand, technological capabilities, and policy frameworks, alongside stakeholder perspectives from government, community groups, and private sector actors. This summary highlights the key findings and recommendations under each thematic chapter of: Material Innovation, Environmental Context and Ecosystem Impacts and Business and market analysis.

Material Innovation Findings

1. Local communities harvest and convert water hyacinth into handicrafts, compost, biogas, and agricultural inputs which is a **Community-Centric Circular Model (Low-Tech)**, turning waste biomass into valuable livelihood resources, which promotes income generation. In addition, opportunities to mitigate local food security through composting.
2. As a **Medium-Tech Cooperative Model, cooperatives or small enterprises** aggregate hyacinth from multiple areas, with the production of **biofertilizer, fiber-based paper, pellet fuel, and decorative goods** for local markets, which strengthens **economic**

sustainability and regional value chains, embedding nutrient and energy recovery within community networks

3. **Industrial / High-Tech Integrated Model**: Integrates **industrial-level technologies** with community-based biomass collection. This model converts hyacinth into **bioethanol, biohydrogen, biochar, and advanced carbon products** for energy and material markets, and ensures **large-scale circularity** through upstream (community supply) and downstream (industrial reuse and carbon sequestration) linkages, contributing to national sustainability goals.

Environmental Governance and Safeguards

1. The environmental analysis identified that water hyacinth (WH), though an invasive alien species, can function as a regenerative natural resource when managed within a controlled framework.
2. Field engagements and stakeholder consultations indicate recurring issues of eutrophication and reduced aquatic biodiversity across tanks and canal systems.
3. WH demonstrates capacity for phytoremediation by absorbing heavy metals and excess nutrients such as nitrogen and phosphorus, improving water quality and restoring ecological balance.
4. There are several agencies that need to come together to ensure a consistent supply of WH material and to ensure governance. However, there is an absence of clear regulatory guidance for harvesting, transport, and utilisation has led to ad hoc practices that create potential ecological risks, and there exists coordination challenges between local authorities, limited community awareness, and weak environmental monitoring constrain sustainable WH management.
5. WH value chains provide multiple blended financing approaches that may enhance livelihood opportunities and quality of life at community level, products that could help in import substitution and export promotion and earning exchange to the country.
6. As we are dealing with an Invasive Alien Species (IAS) it requires extensive environment management and monitoring in each step in the WH processing, value chain applications and marketing.

Business and Market Analysis

1. Funding gaps persist at the community level, where most small and medium enterprises (SMEs) depend on short-term grants or personal savings. Access to structured financing for equipment, R&D, or product scaling remains limited. Limited awareness among financial institutions about water hyacinth as a viable resource has resulted in low confidence in extending credit or green financing to enterprises in this sector.
2. High cost of transport and processing continues to constrain profitability for water hyacinth-based products. Absence of subsidized logistics or local aggregation hubs increases per-unit production cost and reduces competitiveness. However, opportunities exist to integrate carbon financing mechanisms, such as concessional green loans, carbon credit-linked funding, and performance-based incentives to support community-level collection and processing.
3. Value addition remains undercapitalized, with communities primarily focused on low-return handicrafts and compost rather than mid- to high-value applications (biofertilizer, paper, biogas, packaging).
4. Export potential is currently untapped due to lack of certification pathways, compliance costs, innovative products to suit export markets like fiber applications; SUP substitutions; mixing with other fiber types in nano-scale towards new designs including applications in line with "Design for Environment", and missing partnerships with large private-sector buyers or intermediaries who can meet international quality standards.
5. Private and public sector partnerships with established fiber, packaging, or bioenergy companies show strong potential to unlock larger market entry, technology transfer, risk-sharing models that can strengthen investment confidence, and for policy work.

To address these, the study proposes the following recommendations according to the areas of technical, environment, and business.

Technical:

1. Establish **pilot plants and demonstration centers** to test medium- and high-tech valorization pathways and encourage **technology incubation hubs** to assist startups focusing on bio-based products.
2. Mobilize **climate and biodiversity funding,** and **technology co-operation** through international collaboration and donor partnerships with brands like Nike for innovative products and work with government to generate substitute for SUPs.
3. **Research and Community Engagement:** Strengthen partnerships with universities and research institutions to conduct further studies on phytoremediation and long-term ecological effects of WH removal and use.

Environment:

4. **Regulatory and Institutional Strengthening:** Develop a structured environmental management and regulatory framework for WH utilisation aligned with national biodiversity and water resource policies.
5. Promote community-based harvesting models to prevent regrowth, ensure local participation, and support the maintenance of healthy aquatic ecosystems.
6. Develop an Environmental and Social Management System (ESMS) related to WH product development and marketing using the guidance provided in the scoping. Also develop regulations and standards to use the IAS in industry under controlled conditions.
7. **Integrate Environmental and Social Safeguards:** Implement **monitoring systems** to prevent overharvesting or ecological imbalance and an Environmental and Social Management System (ESMS) with defined standards for pollution control and effluent discharge to ensure safe utilisation.
8. Promote **safe disposal and post-processing guidelines** to manage residual biomass.
9. Establish a permitting and compliance process through key agencies such as the Central Environmental Authority (CEA), Sri Lanka Land Development Corporation (SLLDC), and the Irrigation Department.

Business:

10. **Strengthen Community Participation and Capacity Building** through Public-Private-People Partnerships (PPPP) where financial entities play a key role by providing green bonds/loans and financial or cooperatives to manage collection, processing, and marketing. In addition, provide **training and awareness programs** on safe harvesting, product development, and small-scale entrepreneurship. In addition, to further support the community model, encourage men's engagement to support **women's and youth** livelihood creation and optimisation of skill-set when appropriate.
11. Include **social impact assessments** to ensure equitable benefit-sharing among all stakeholders.
12. Develop **value chain networks** connecting rural producers to regional and industrial buyers, and with brands, green productions as solutions to microplastic and other packaging products utilizing WH as a viable pathway to Single Use Plastics (SUPs) and alternatives to plastic sheets, bags etc.
13. Ensure **quality standards and certification** to increase consumer trust and export potential.
14. Offer cross subsidies, export incentives and tax benefits (e.g., tax relief and equipment grants) for machinery imports, technical knowhow, and for enterprises adopting circular technologies. This can be also combined with international research partnerships and business collaborations with tax benefits.
15. Proposal on **Payment for Ecosystem Servies** and **Carbon/Biodiversity Financing** to increase the funding gap to deliver community benefits, enhance irrigation efficiency, and reduce water pollution which needs to be in line with policies and sector integration. This can also include the **integration of circular financing mechanisms**.
16. **Long-Term Investment and Financial Mechanisms:** Encourage **green finance instruments** (e.g., microcredit, revolving funds, or carbon finance) to support project scalability.
17. Develop **cost–benefit frameworks** to attract investors by demonstrating economic and environmental returns.

18. Develop and operationalize a Public-Private Partnership with the Irrigation Department, Department of Agrarian Development, Sri Lanka Land Development Corporation, Industries and Export-related organizations, and Ministries of Finance and Environment as key agencies, combined with private sector finance, equipment and machinery, transport, and other service providers.

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ABBREVIATIONS

BOD: Biochemical Oxygen Demand (Oxygen Needed by Microorganisms to Decompose Organic Matter)
CTF: Carbon Trading Framework
CH_4: Methane Gas
CO: Carbon Monoxide
CO_2: Carbon Dioxide
CO_2Eq.: Carbon Dioxide Equivalent
COD: Chemical Oxygen Demand (Organic Matter in Water);
CNF: Cellulose Nanofibers
DAD: Department of Agrarian Development
DO: Dissolved Oxygen
EPL: Environment Protection Licence
E&S: Environmental and Social
GEDSI: Gender Equality, Disability and Social Inclusion
GHG: Green House Gas
GPS: Global Positioning System
GS: Gold Standard
IAS: Invasive Alien Species
ID: Irrigation Department
IoT: Internet of Things
KPI: Key Performing Indicator
LCA: Life Cycle Analysis
MET: Management Effectiveness Tracking
MRV: Monitoring Reporting and Verification
NO_x: Nitrous Oxides
OHS: Occupational Health and Safety
PM: Particulate Matter
PPE: Personal Protective Equipment
PPPP: Public-Private-People Partnerships
R&D: Research and Development
SDGs: UN Sustainable Development Goals
SLLDC: Sri Lanka Land Development Corporation
SUP: Single Use Plastics
tCO_2: Tons of Carbon Dioxide
VOC: Volatile Organic Carbon
VCS: Volunteer Carbon Standards
VERA: Verified Carbon Emission Scheme
WH: Water Hyacinth

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1 BACKGROUND

Water hyacinth (WH), also known as Eichhornia crassipe, is an invasive aquatic species, renowned for its rapid growth. It can double its numbers vegetatively within one to three weeks, and its seeds can remain viable for over 15 years (Zulkeflee, 2021). Originally from the Amazon basin of Brazil, it has aggressively spread across tropical, subtropical, and warm temperate regions globally. Initially introduced as an ornamental plant to Sri Lanka in 1904 by the British Governor's wife at the time, the plant rapidly spread in waterbodies, profusely, threatening the natural aquatic ecosystems in Sri Lanka (Perera, 2019).

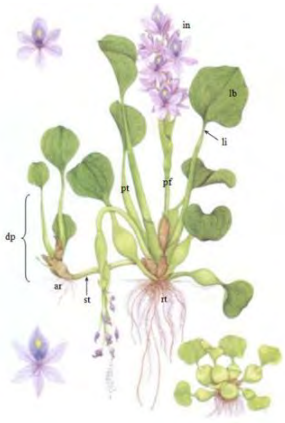


Figure 1: Water Hyacinth plant demonstrating its main contents

Despite this, the plants' abundant biomass has increasingly been recognised for its potential as a valuable resource, such as handicrafts, paper, furniture, or livestock feed, offering avenues for sustainable development and economic benefit.

2 LITERATURE REVIEW

2.1 EXISTING GLOBAL AND REGIONAL METHODS OF USING WATER HYACINTH AS A CIRCULAR SOLUTION

This section highlights countries that are using Water Hyacinth (WH) to develop circular solutions. It explores the types of products created, innovations in technology and design, the process and access to local and export markets, if applicable.

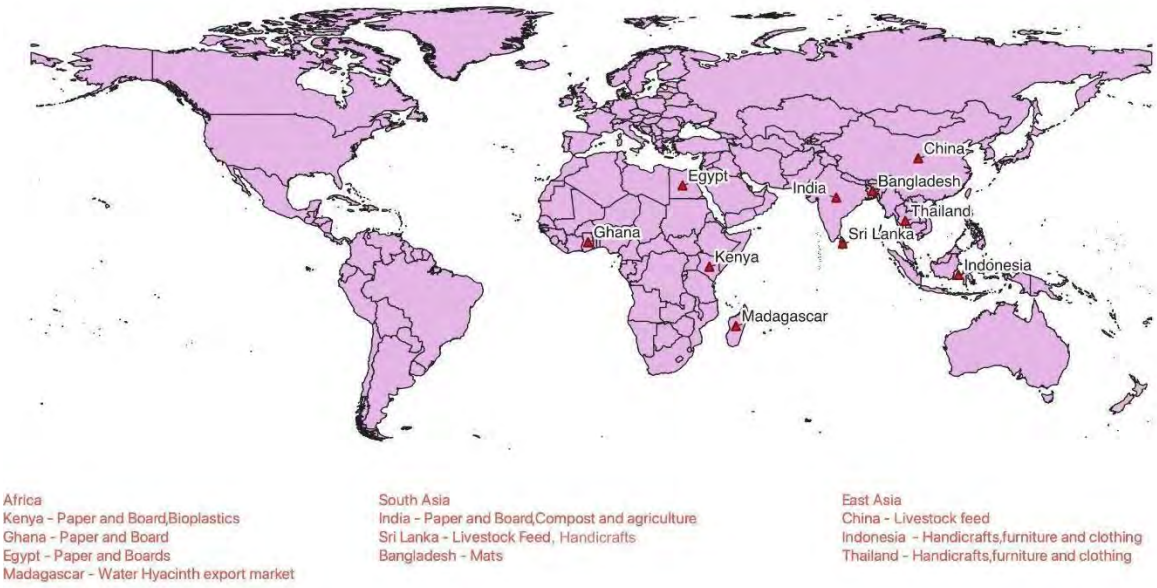


Figure 2: Global Water Hyacinth based products spread

2.1.1 PAPER AND BOARD PRODUCTS

Several countries have developed innovative best practices for utilising water hyacinth in paper and board production. Growing in abundance along the Volta River, **Ghana**, a local organisation named “Global Mamas” created an economic opportunity for their community. They have created five co-ops aimed at helping harvest the plant, using it to weave and make paper at the FairTrade Zone in KPong, transforming the plant into a new natural fibre home goods line. With

support from their neighbours in Kenya, Global Mamas are making a range of handmade paper products, coasters, runners and trivets. (Global mamas, 2022).

In Egypt innovative applications of water hyacinth have included its use in the production of fish feed from its leaves, collagen extraction from its stems, and its sale to local factories as a raw material for paper manufacturing (Gyuse, 2024).

In India, a team funded by WWF developed a range of products from the pulp of WH leaves and stems, mixed with small amounts of used newspaper and appropriate binders; these paper-based products included: disposable plates, ready-to-plant biodegradable nursery pots, egg and fruit trays, cartoon models, toys, file boards, multi-purpose boards, special canvas for paintings, etc (Warrier, S. G., 2024).

Figure 3: Disposable plates made out of Water Hyacinth pulp

Photo by G. Nagendra Prabhu.

In Kenya, Takawiri Craft was founded by Michael Otieno, aimed at creating paper-based products from WH. After completing his high school degree in 2010, he launched his business following a skills development training facilitated by a non-governmental organisation in Kisumu Enterprises (farmbiz, 2017). With an initial capital investment of KES 10,000 (Under USD 80), he acquired a pulping machine to begin operations. Currently, he employs between five to ten casual workers who manually harvest water hyacinth from the shores of Lake Victoria. The collected material is transported to his facility, where it is chopped manually and sun-dried with the assistance of five

permanent staff members. **Drying typically takes 8 to 12 hours, although adverse weather conditions can extend this process to two days** (Farmbiz, 2017).

Once dried, the plant is processed using the pulping machine, mixed with water, and filtered through a wire mesh to extract pulp. The resulting sheets are then dried and passed through calendaring machine to achieve a smooth finish (Farmbiz, 2017).

2.1.2 LIVESTOCK FEED

Water Hyacinth has been used to complement existing livestock feed, adding layers of nutrition. In **China**, pig farmers have practised feeding boiled and chopped water hyacinth mixed with rice bran, vegetables, copra cake, and salt, creating a well-established feeding protocol that maximises nutritional value while ensuring food safety through proper preparation methods. **Research by Ndimele et al. (2011) confirms that water hyacinth becomes a valuable feeding material for pigs, ducks, and pond fish** when properly cooked with complementary ingredients like rice bran, fishmeal, and copra meal, demonstrating the importance of processing techniques in optimising feed quality.

Sri Lanka has conducted extensive research on water hyacinth integration into poultry systems, where studies revealed that ducks fed 50 grams of fresh water hyacinth daily for one month showed significantly improved daily feed intake, higher egg-laying capacity, enhanced eggshell thickness, and increased feed digestion efficiency compared to control groups (Aziz, 2023).

2.1.3 HANDICRAFTS, FURNITURE AND CLOTHING

Handicraft producers in **Indonesia** have established production systems that **utilise both stems and dried petioles** (the stalk that joins a leaf to a stem) to create an extensive range of products, including household accessories such as baskets, tissue holders, coasters, placemats, and tray boxes, as well as interior furniture items like carpets, furniture sets, lamps, wall clocks, and rope.

In **Indonesia**, SMEs (Small and Medium Enterprise) from Lake Rawapening have established online home-based enterprises that manufacture bags, sandals, baskets, chairs, and tables from water hyacinth before marketing them through internet platforms, demonstrating that digital

commerce expansion supports market reach for traditional handicraft production. The Bangkit Bersama Cooperation in Indonesia has also developed empowerment programs to train individuals, particularly housewives, in water hyacinth craft production (Harun, I., Pushiri, 2021).

Women from **Thailand's** Bueng Kho Hai have been recognised for sophisticated wickerwork products including furniture, bags, tablecloths, and curtains, while pioneering eco-friendly fabric production from water hyacinth fibers that transforms what was once considered "natural rubbish" into valuable commodities, providing income for rural communities. They received support from the Government of Thailand (Sirisoda, 2023). For more information, refer annex below.

The technical aspects of water hyacinth handicraft production have evolved to incorporate modern equipment including sewing machines, cutters, punching machines, flattening machines, handlooms, and standard moulds, enabling consistent quality and increased production efficiency. Advanced applications include combining water hyacinth fibres with complementary materials like cotton yarn to create hybrid, eco-friendly fabrics. The plant's stretchy yet sturdy qualities make it ideal for textile applications (Febin, F, 2023).

Furthermore, in terms of WH quantity required for production, a single chair design utilizing water hyacinth fabric requires 10 tons of water hyacinth stems (Sirisoda, 2023), and for general craft production, it is estimated that five items per day can be produced from 1 kg of fresh water hyacinth stems and eight hours of manual work (Harun, I., Pushiri,, 2021). These regional case stories demonstrate that successful water hyacinth handicraft industries require systematic processing techniques, appropriate technology integration, market development, capacity development, and community-based production models that can generate sustainable income while contributing to invasive species management and environmental sustainability objectives.

2.1.4 COMPOST AND AGRICULTURE

In an article by Warrier for Mongabay, the author highlights how Lake Kapra in **Hyderabad, India** was made anew. A project funded by the WWF used Accelerated Anaerobic Composting (AAC) technology to transform WH into compost. The WH leaves, stems, and roots are converted to

'green waste' - good quality organic fertiliser within 28 days. The roots and stems are separated and chopped before pushing through the AAC process. The plant is then mixed with anaerobic culture, resulting in organic fertiliser, and dried to marketable fertiliser. The roots, used through the AAC process, can generate organic fertiliser, which can then be used as compost. A bulk of **400 kg** of fresh water hyacinth was chopped into small pieces for chemical analysis and compost production (Amarasinghe, S. R., 2021).

Figure 4: Mushroom grown on a bed of Water Hyacinth in India

In another instance, researchers from India mentioned that three types of technology was developed to use WH in mushroom cultivation, which were bred on specially prepared WH 'beds' consisting of modified biomass briquettes and pulp-based products from WH and other hydroponics or floating agriculture. Researchers leading the project had created technology specifically for the assignment - ***"We developed three such major technologies for mushroom cultivation on specially prepared 'beds' made from the aquatic weeds, modified biomass briquettes, pulp-based products from water hyacinth and modified hydroponics or floating agriculture. Our research has proved that Eichhornia, Salvinia and Pistia could be used as bedding material for mushroom cultivation."*** Three different species of mushrooms were cultivated in these weeds under different conditions: oyster mushroom (*Pleurotus florida*), pink mushroom (*P. eous*) and white elm oyster mushroom (*Hypsizygus ulmarius*). The leftover bedding material after the harvest of the mushrooms can be used as organic manure. Further studies are needed to undertake this at a larger scale (Warrier, S. G., 2024).

2.1.5 BIOPLASTICS

In **Kenya**, a company named HyaPak Ecotech Limited creates bioplastics from dried water hyacinths by mixing them with adhesives and additives. These bioplastics are used for seedling bags (which can be planted directly, degrading and releasing nutrients) and packaging (biodegradable alternatives to single-use disposable plastic products like wrappers, straws, tumblers, and party plates)

Figure 5: Seedling wrappers made of Water Hyacinth in Kenya

The harvested biomass often undergoes processing such as harvesting with the support of affected fishermen and community members, drying of WH, fibres are extracted and converted into biodegradable alternatives and are thereby converted using a patented process, where the fibres are moulded into biodegradable alternatives for single-use plastic products. **To ensure quality, the company creates its bioplastic material that biodegrades from 3 to 12 months** (HyaPak, 2025).

2.1.6 BIOMATERIALS

WH has the potential as a sustainable alternative to conventional building materials, positioning it alongside other sustainable options including hemp, kenaf, jute, bagasse, coir, flax, bamboo and characteristics it shares with banana fibre, making both materials highly accessible for large-scale biomaterial production (Febin, F, 2023). Research has highlighted that water hyacinth fibre boards possess reliable physical characteristics that make them highly suitable for construction

industry applications, particularly as **thermal insulators and concrete mixture additives that enhance building performance while reducing environmental impact (Pichardo, 2025).**

2.2 EXISTING APPROACHES AND TECHNOLOGY TO PROCESS WATER HYACINTH

Managing and processing WH employs several physical removal methods with varying degrees of effectiveness and sustainability considerations.

- **Manual harvesting** represents the most basic approach, relying on human labour to remove plants from water bodies, making it suitable for small-scale applications but highly labour-intensive (Yao, 2018).
- **Mechanical harvesting, though costly,** offers a more scalable solution through the deployment of specialised equipment, including weed cutters, harvesters, chaining devices, shredder boats, and dredging systems that can retrieve significant biomass quantities while simultaneously removing nutrients and pollutants (Ayana, 2021).

2.2.1 CHALLENGES

As demonstrated in Lake Tana, Ethiopia, where four procured harvesting machines became non-operational due to technical problems, insufficient operator skills, poor operational management, and lack of spare parts, highlighting the method's limitations including high costs, slow processing speeds, substantial energy requirements, and unsuitability for very large hyacinth mats (Gezie, 2020).

A critical gap in current harvesting practices is the lack of proper post-harvest processing, with collected biomass often dumped at lakeshores, leading to re-colonisation of the plant (Gezie, 2020). This highlights the importance of pre-treatment processing steps that involve washing, cutting into pieces, and drying (using sunlight or electrical furnaces) to reduce high water content.

A key challenge faced by the enterprise is **limited capita**l, which restricts the mechanisation of production processes. Despite this, the business has secured a steady clientele, including the Kenya Climate Innovation Centre (KCIC), gift shops, and book publishers, with monthly orders

reaching up to 2,000 units. Products are customised to client specifications, with A4-sized gift bags retailing at KES 150 (approximately USD $1.50) and A5-sized bags at KES 7 (under USD $1)

2.2.2 SOCIO-ECONOMIC IMPACT

Highlighting the impact from Lake Tana in Ethiopia, fishing communities noted the impact WH had on their local livelihoods. While obstructing waterways, this hinders transportation on the lake and affects local fishing activities. It also reduces the water available for irrigation. “In Lake Tana, the extent of the problem necessitated close to 800,000 person-days of hand weeding from 2012 to 2016, incurring an estimated labour cost exceeding $2.1 million USD”. In addition, human health concerns are documented as WH serves as a breeding ground for vector-borne diseases such as dengue.

2.2.3 MARKET OPPORTUNITIES

In an article that highlights the success of Water Hyacinth handicrafts in Bangladesh, the author highlights that the global market for biodegradable packaging is expected to reach $27.5 billion by 2027, with a compound annual growth rate (CAGR) of 9.4% from 2020 to 2027. Furthermore, the author states that this trend is driven by increasing environmental awareness and stringent regulations against plastic use. Eco-friendly handmade products, particularly those made from water hyacinth, are well-positioned to benefit from this growing demand (Elma, 2024).

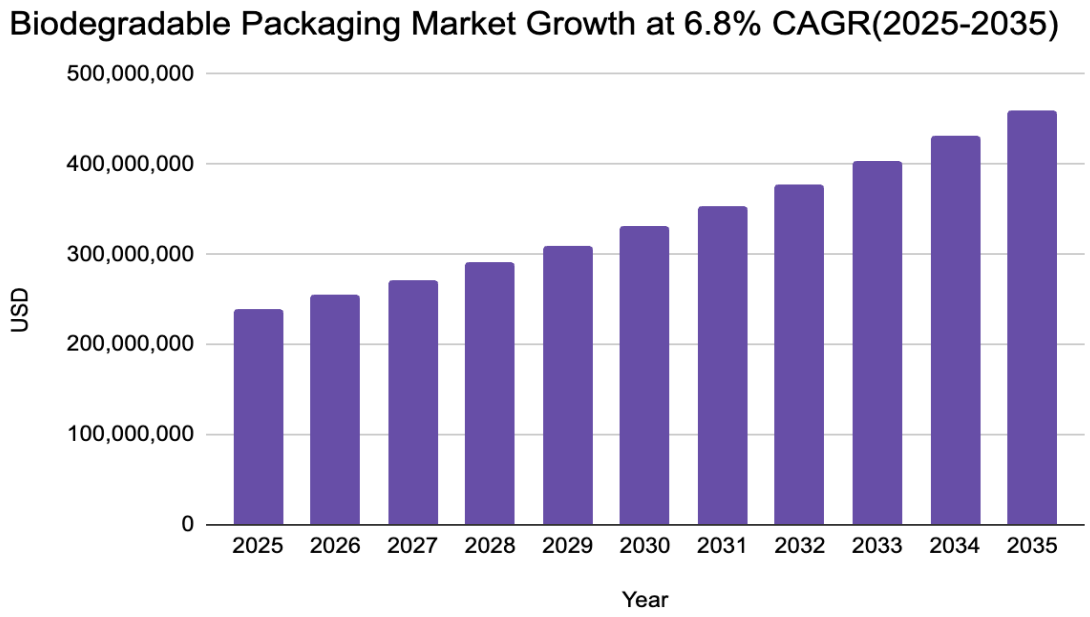


Figure 6: Biodegradable Packaging Mark Market Growth at 6.8% CAGR (2025-2035)

Furthermore, water hyacinth products are demonstrating significant commercial viability in in-country and international markets.

In Indonesia and Thailand, producers are provided opportunities to sell their products are local and regional craft fairs. In addition, basic 'DIY' websites help local household-level producers create products from Water Hyacinth at home – this was further validated through a field discussion while speaking with Imalka, owner of IMA Water Hyacinth Products in Tangalle, Sri Lanka. Further, in Indonesia, entrepreneurs have launched online home-based businesses that sell water hyacinth chairs, tables, baskets, and accessories through internet platforms.

In **Assam, India,** local artisans have marketed water hyacinth crafts to customers worldwide through television ads, social media campaigns, and online stores. In addition, these Indian entrepreneurs have attended trade shows in Bangkok to showcase their water hyacinth creations and learn from global markets (Buragohain, 2021).

Meanwhile, communities in **Madagascar** have exported their WH handicrafts. Paper, made from WH in **Egypt** has been sold to local factories. In **Bangladesh**, several multinational companies source water hyacinth from various districts, particularly Noakhali, and transport it to Nilphamari

for the production of biodegradable mats. The entire process is manual, with no machinery involved. Occasionally, international buyers visit the production sites to observe the traditional mat-making techniques. Artisans are paid a minimum of 30 Taka (USD $0.25) per mat, with higher rates awarded based on skill level. This industry has become a significant source of income for many local women, who earn between 20,000 to 25,000 (~ USD$200) Taka per month, contributing to their economic independence. Additionally, school-going students participate in the production, making 8 to 10 mats daily to support their educational expenses (Elma, 2024).

However, further research is needed to understand how small and medium enterprises can optimise their access to both local and international market systems to fully realise the commercial potential of water hyacinth-based products and scale these promising circular economy solutions.

2.2.4 Gaps and Limitations in Utilizing Water Hyacinth

A key fundamental challenge stems from water hyacinth's high moisture content, reaching up to 95.5%, which significantly complicates harvesting, transportation, and processing operations, particularly for energy production applications (Harun,I.,Pushiri,2021). This challenge necessitates the development of mobile, fast, and efficient specialised equipment for harvesting, transportation, and drying processes that can handle the plant's water-heavy characteristics while maintaining economic viability. In addition, research mentions new technology developed to process WH into a sustainable resource; however, further expansion of the referenced technology is limited. Furthermore, companies like Biofuel Lanka in Sri Lanka have converted waste or biomass into renewable energy sources; however, further scoping of the technological process is required to understand if those technologies can be adapted for use in the context of Water Hyacinth.

Quality control and safety concerns present another limitation, as water hyacinth's potential for heavy metal accumulation and other toxicity issues becomes particularly problematic when biomass is harvested from polluted waters (Amarasinghe, S. R., 2021). Furthermore, research states that handicraft production faces insufficient ventilation systems, unreliable electricity

supply, and poor storage facilities that low dried materials to absorb moisture during rainy seasons, compromising product quality and shelf life (Buragohain, 2021).

2.3 POLICY AND SYSTEM STRENGTHENING EFFORTS

Based on research into global best practices, several countries have developed comprehensive laws and policies that effectively manage water hyacinth while incorporating circular economy solutions.

In **Kenya**, two policies outline transforming water hyacinth into biodegradable products to tackle both plastic pollution and invasive plant overgrowth, promoting materials that support a circular economy and reduce environmental impact – The Kenya Vision 2030 and the National Water Resources Strategy (2020-2025) (Bureau of standards, Kenya, 2021)

Thailand's Pollution Control Department has created an innovative policy model that transforms water hyacinth management from environmental burden to economic opportunity by partnering with major companies like Thai Post, Kerry Express, Lazada, and the Thai Retailers Association (postal service, delivery companies, and online shopping platforms) to replace plastic packaging with ecofriendly packaging created with water hyacinth-based. Furthermore, the Thai government provided technical expertise to companies on water hyacinth production for packaging, supporting green economy objectives through government-facilitated market transformation that provides technical expertise to private sector partners, thereby supporting invasive species control and contributing to the economy (Nation Thailand, n.d).

In **Sri Lanka,** a comprehensive policy framework for containing water hyacinth was established, starting with the Water Hyacinth Ordinance No. 4 of 1909, which was specifically enacted to prevent the introduction and dissemination of water hyacinth within the country. This early recognition of the plant's invasive potential was further reinforced when water hyacinth was subsequently incorporated as a prohibited weed under the Plant Protection Act in 1924, providing broader regulatory mechanisms for controlling invasive plant species.

In 2016, the National Policy on Invasive Alien Species (IAS) (The National Policy, 2016) was approved by parliament and it establishes a comprehensive framework aimed at preventing the

introduction and spread of invasive species while controlling existing populations through coordinated and efficient systems with necessary legal environments to protect aquatic, marine, and terrestrial ecosystems. Implementation guidance and mechanisms have been established, however information on monitoring its progress remains scattered. The policy, allows for declaring noxious plants or weeds illegal for import and destruction by the Customs Department if detected during importation. It also aims to deal with real or potential invasives already in Sri Lanka or likely to be imported.

Additionally, disaster management policies contribute to water hyacinth control through the Disaster Management Act No. 13 of 2005) and the National Disaster Management Plan 2023-2030 which mandate the cleaning of disaster-prone waterways, including canals, lakes, and water bodies affected by water hyacinth, as part of comprehensive disaster risk reduction strategies.

Other policies pertaining to IAS include the Fauna and Flora Protection Ordinance No. 2 of 1937 (as amended), Fisheries and Aquatic Resources Act, No. 02 of 1996 (as amended), Plant Protection Act No. 35 of 1999, Prevention of Mosquito Breeding Act No. 11 of 2007 and Marine Pollution Prevention Act No. 35 of 2008.

However, despite this extensive policy architecture spanning over a century, **the Irrigation Department still spends more than 55**% (Liyanage, 2018) **of their annual budget removing aquatic invasive species from irrigation systems,** indicating that while the legal framework exists, implementation challenges and the lack of integrated approaches combining control measures with economic utilization opportunities continue to limit the effectiveness of water hyacinth management in Sri Lanka.

2.3.1 TABLE OF LAWS AND LEGAL FRAMEWORKS PERTAINING TO IAS IN SRI LANKA

Table 1: Laws and legal frameworks relevant for IAS in Sri Lanka

Policy in Sri Lanka	Notes in relation to Water Hyacinth or IAS
Plant Protection Act in 1924	Water hyacinths was categorised as a prohibited weed.
Water Hyacinth Ordinance No. 4 of 1909 (and No. 9 of 1909):	This is a direct legal instrument specifically addressing water hyacinth. It allows for declaring noxious plants or weeds illegal for import and destruction by the Customs Department if detected during importation. It also aims to deal with real or potential invasives already in Sri Lanka or likely to be imported.
Fauna and Flora Protection Ordinance No. 2 of 1937	Wetland conservation ordinance. It protects fauna in the immediate limits of any water body. It requires a permit to import animals, their spawn, eggs, or larvae, which helps control the entry of invasive species
Fisheries and Aquatic Resources Act, No. 02 of 1996	Regulates the import of aquatic resources
Prevention of Mosquito Breeding Act No. 11 of 2007	This Act mandates the removal and destruction of plants like Water Lettuce (Pistia stratiotes) and other IAS.
National Invasive Alien Species (IAS) Policy of 2016	This policy aims to prevent the introduction and spread of IAS and to control them. It provides a necessary legal structure to

	protect ecosystems and biodiversity from IAS risks. It's intended to provide a base for an IAS Act and consistent guidance to the Government and stakeholders.
Disaster Management Act No. 13 of 2005	Mandates comprehensive disaster management regulations, including the cleaning of disaster-prone waterways, which are often home to water hyacinth.

**Sources have been mentioned in this review.*

Updates against policy implementation: Following the IAS Policy of 2016, several strategies of implementation have been suggested, including the appointment of a national focal point on IAS at the Biodiversity Secretariat of the Ministry of Environment is intended to facilitate monitoring of IAS entry and control at the national level. In addition to these, the policy outlines several other recommendations. However, as of 2020, reports state that though several legislative actions have addressed the IAP problem in Sri Lanka, the laws have failed to address the problem of poor implementation of control policies and procedures (Ekanayake EMBP, Xie, 2020).

Following a paper submitted to the Parliament, asking for the development of new act to prevent entry of and control of IAS and establish effective institutional coordination mechanism.

2.3.2 A Review of Local Sri Lankan Markets That Promote Water Hyacinth as a Circular Solution

Water Hyacinth (WH), also known as Japan Jabara, is an invasive aquatic plant which is widely present in the water bodies of Sri Lanka. According to Queene (Queene, A., Safeena, 2016), and Amarasinghe and Labrada (Labrada, 2025), it has been reported that 45% of waterbodies in Sri Lanka are covered with water hyacinths.

Due to a prolific growth of water hyacinth, this plant is widely present in a large number of freshwater bodies in Sri Lanka, such as wetlands, tanks, canals, marshes, lakes, streams, and

ponds etc. Table 1 below shows some locations where water hyacinths are present in Sri Lanka and Figure 7 shows a graphical illustration of these locations in which water hyacinths are present.

Table 2: Typical locations where Water Hyacinth is in present in Sri Lanka

	District	Waterbody
1	Kurunegala (North)	Small tanks (Nishantha, 2019)
2	Kegalle (Anguruwella)	Tanks cascade (Kariyawasam, G., Erandika, 2021)
3	Gampaha (Moragoda)	Canal
4	Galle	Canal (Amarasinghe, S. R., 2021)
5	Anuradhapura (Wilpattu National Park)	Natural lakes
6	Anuradhapura (Hunuwilagama)	Tank (50% covered with water hyacinth) (MAS Holdings, 2022)

Figure 7: Graphical illustration of locations of businesses that work with Water Hyacinth

Pool of current Water Hyacinth based businesses

Listed below are some of the locations in Sri Lanka where businesses that produce water hyacinth based products are located in terms of types of businesses, years of operation and scale, and the products made using water hyacinth:

- Madadenigama Village, Ehetuwewa, Kurunegala District (Kariyawasam, G., Erandika, 2021)
  Entrepreneur: Udeni Dhammika
  A small-scale women-led business established in 2018. Initially skilled in sewing and knitting garments for the community, Udeni shifted to producing water hyacinth handicrafts after a transformative training. She leads a network of five women-led enterprises. Handicraft products through her business includes handbags, pouches, baskets, mats, file covers, and hats.

- Habarana (Khan, M., 2022)
  Entrepreneur: Ganga
  Small-scale business producing handbags, bags, hats, and purses from water hyacinth.

- Rajanganaya, Anuradhapura District (Malinda, P, 2024)
  Entrepreneur: Mana Ceylon
  A small-scale women-led business that focuses on sustainability and takes an innovative approach to handmade paper. Their produce includes eco-friendly paper products like notebooks, gift boxes, and bags.

- Kadawatha (Natures Paper, 2019)
  Entrepreneur: Priyantha Gamini AlaxznderA small-scale business called Nature's Papers led by a male entrepreneur since 2015 that produces handmade papers, notebooks, papers, wedding cards, and cake boxes through removed banana trees and water hyacinth.

- Battaramulla
  Entrepreneur: Saubhagya Development Bureau (Made by Her, 2022)
  A government entity that runs The Saubhagya Production Village Programme (Japan Jabara Handicrafts, 2023) as a bigger-scale venture with a production house in Ehetuwewa since 2021 with an aim to promote home-based products, raise the income level of the rural community and uplift the rural economy. Their produce based on their website mainly includes handmade handbags.

- Anuradhapura District (Invasive to Inclusive, 2021)
  Entrepreneur: Anuradha Nisansala
  A small-scale women-led business involved in making usable goods through water hyacinth plants. Their produce includes pencil cases, handbags, purses, shoulder bags, hats, and table mats.

- Tangalle (Pieres, C, 2025)
  Entrepreneur: Imalka
  A woman entrepreneur who produces goods using water hyacinth. She is a registered business owner and has obtained small grants from the Chamber of Commerce.

The following section covers information on market access, supply chain, tools, training, and technology used, and also the challenges encountered by the water-hyacinth based business mentioned above.

Market access (local, tourism, export)

- **Udeni Dhammika:** Primarily local market that include schools, government offices, and private companies. She is supported by the Divisional Secretariat Office and the Samurdhi Bank.

- **Ganga:** Primarily village customers and sales of her products are to the local market.

- **Mana Ceylon:** Online sales via Made by Her, Facebook, and Instagram. Primarily local market access and potential for export is under review.

Supply Chain

- **Udeni Dhammika and Ganga:**

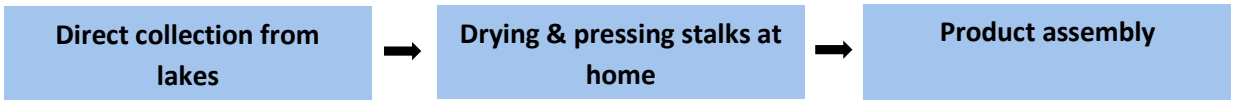


Figure 8: Supply chain process by Udeni Dhammika and Ganga

- **Anuradha Nisansala:**

Figure 9: Supply chain process by Anuradha Nisansala

2.3.3 TOOLS, TRAINING, AND TECHNOLOGY

- **Udeni Dhammika:** Received a new sewing machine and a de-watering machine from the Climate Resilient Integrated Water Management (CRIWMP) in 2020 that helped her in speeding up the production of goods.
- **Ganga:** Uses a sewing machine at her home to produce the goods.
- **Mana Ceylon:** Upcycle invasive plants like water hyacinth, guinea grass, cogon grass and agricultural by-products like banana stems to make their products.
- **Anuradha Nisansala:** Connected with other female entrepreneurs through 'Sithamu' Women's organization and the Govi Jana Sewa Center where she underwent a 3-day training.

2.3.4 CHALLENGES

- **Udeni Dhammika:** She mentioned that initially she used to struggle to de-water the plants and to press the stalks due to an old machine that she was using.
- **Ganga:** Her village people used to tease her for doing such a business and challenge her as to how she will make handicraft products from water hyacinth. Also, the economic crisis in 2022 affected her business by resulting in a decrease in the sale of her products.
- **Anuradha Nisansala:** Post training she had a task to make a product but as she didn't have a sewing machine, she had to use her sister-in-law's sewing machine to make a bag. Besides, she also faces challenges in getting raw materials as she has to look after her little kid while her husband serves the forces. She waits for her husband to return home, and upon his return he does the harvest and takes the finished products made out of water hyacinth into the town for sale.

2.3.5 CONCLUSION: WATER HYACINTH AS AN ALTERNATIVE

Some studies have stated that water hyacinth can be used as a source for animal feed with comprehensive scientific experimentation and that it can also be used as a compost for field applications. In terms of field application, water hyacinth can be mixed with cattle manure, poultry litter, wood ash and dry leaf litter (Amarasinghe, S. R., 2021). Moreover, water hyacinths can also be used for usage of making urban grow bags for urban gardening (Anuruddi, H. I. G. K. ., K. P. Samarasinghe, L. M. Rifnas and S. S. Weerasinghe, 2021).

In terms of local context, the above analysis shows that water hyacinth is widely present in the majority of waterbodies in Sri Lanka. Speaking of businesses that utilise water hyacinth for commercial purposes, it has been identified that there are quite a few small-scale businesses that make usable products out of water hyacinth.

The products that are made out of water hyacinth include shoulder bags, paper bags, cards, notebooks, hats, pencil cases, cake boxes, paper and etc, which are sold to the local market. This may also include tourists who visit Sri Lanka for tourism purposes and are interested in eco-friendly products. However, further research is needed to analyse this further. Furthermore, these businesses are predominantly women-led, where it is run by a single woman at her home.

In terms of technology, there is no high-end technology or machinery that is being used in the production of goods, while the raw materials, that is,the sourcing of water hyacinth, is manually done by these women.

Based on the findings, it can be understood that these businesses operate in diverse demographics including Sinhala and Tamil communities in North Central and North Western provinces. This gives the opportunity to intervene and assist these existing players to develop their businesses based on their needs that are context specific and/or identify businesses that make products for urban gardening or animal feed, which are already using water hyacinth as one of the ingredients.

This literature review concludes that water hyacinth presents significant circular economy opportunities for Sri Lanka, where 45% of water bodies are affected by this invasive species, yet

current utilisation remains limited to small-scale handicraft production despite successful global models from Kenya, India, Thailand, China, and Bangladesh demonstrating diverse applications across multiple sectors.

The study identifies handicrafts and textiles as the highest priority sector for immediate implementation, building on existing entrepreneurs like Udeni Dhammika's women-led group in Kurunegala followed by paper and board production, which shows proven local viability through businesses like Mana Ceylon and Nature's Papers.

Medium-term opportunities include compost, mushroom cultivation and organic fertiliser production using established technologies like India's Accelerated Anaerobic Composting process, and livestock feed supplements that could reduce expensive commercial feed costs while supporting Sri Lanka's agricultural sector. In addition, there is potential of creating pathways for WH as a circular solution by partnering with similar circular solution businesses in Sri Lanka; one such organisation is Cane Cult or BioFuel Sri Lanka.

Long-term development potential exists in bioplastics and construction biomaterials, though these require substantial infrastructure investment and policy support similar to Thailand's successful government-industry partnerships.

The review recommends prioritizing interventions in **Northern Sri Lanka**, **Anuradhapura**, **Battaramulla**, and **Gampaha** based on waterway congestion levels and existing women-headed businesses However, it’s imperative that this support be extended considering pathways to address the critical implementation challenges, which has been evidently reported across WH products as seen in Kenya, India and Egypt. These include navigating around the plant's 95.5% moisture content, quality and safety control for heavy metal contamination as seen in WH clean ups or collection points, inadequate drying infrastructure as women SME’s in Sri Lanka have highlighted and limited market access in country that currently prevent small and medium enterprises from scaling operations. In addition, analysis of current government budgets and policies indicate that Sri Lanka's costly control approach of invasive species prioritises clean-ups rather than prevention or mitigation strategies and these strategies should focus on integrating economic utilisation strategies that aim to convert the invasive species into a circular economic

solution which could reduce government expenditure while creating sustainable rural incomes and contributing to national environmental objectives.

3 RESEARCH METHODOLOGY

The scoping study was carried out through a qualitative research approach supported by selected quantitative insights from the Needs Assessment. The process began with desk-based research and a review of literature on water hyacinth utilisation, circular economy practices, and community-based resource recovery. This desk review helped establish the analytical framework and identify key policy and knowledge gaps relevant to Sri Lanka.

A global scan of case studies from India, Thailand, Kenya, and other countries was conducted to understand tested models of water hyacinth management, livelihood creation, and product innovation. These global references provided direction for identifying what could be adapted within the local context.

Secondary research on Sri Lanka focused on the existing legal, institutional, and policy environment governing invasive species management, ecosystem restoration, and comunity enterprise development. The environmental expert led an in-depth review of policy alignment and regulatory pathways related to harvesting and utilisation of water hyacinth. Five key informant discussions were held with the Sri Lanka Land Development Corporation, Department of Agrarian Development, Central Environmental Authority, and relevant local authorities. These discussions provided clarity on operational challenges, policy bottlenecks, and institutional readiness for programmatic interventions.

The technical component involved consultations with academic and research institutions to assess innovation readiness and material transformation potential. Eight experts were engaged from the University of Kelaniya, Open University of Sri Lanka, University of Moratuwa, University of Jaffna, Sri Lanka Institute of Nanotechnology, and the International Water Management Institute. These interactions contributed to mapping the technological capacity, gaps in research application, and the potential for cross-institutional collaboration to develop new products.

Primary data collection was conducted through field visits, community interviews, and direct observation of ongoing production and harvesting activities. The main field visit was undertaken in Ehetuwewa, which was selected for its matured ecosystem of water hyacinth utilisation and

active government and community involvement. Two women's groups comprising 13 members aged between 20 and 60 were engaged. One group had been trained by the National Enterprise Development Authority, while the other represented an operational enterprise, Japan Jabara Products. Supplementary visits included discussions with small-scale producers such as Imalka in Tangalle and meetings with institutions including NEDA Colombo, SLDDC, and local authorities to understand the broader institutional and logistical environment.

The business expert and programme team integrated findings from the Needs Assessment to identify priority areas for intervention, drawing on both qualitative evidence and quantitative measures such as production rates and income estimates. The data from field visits and interviews were compared with literature findings to ensure triangulation and reduce bias.

Data analysis was conducted through environmental, technical, and business lenses to build a comprehensive understanding of the water hyacinth ecosystem. The findings were categorized under market opportunities, environmental safeguards, research and development readiness, and regulatory pathways. Quantitative inputs were used to substantiate observed trends rather than to establish statistical generalizations.

While the study covered a wide range of stakeholders, limitations included restricted access to some government data and logistical challenges due to institutional overlaps and competing local priorities. Despite these constraints, the mixed qualitative approach produced strong contextual insights that inform the recommendations and the design of the subsequent accelerator programme.

3.1 Data Collection Methods and Triangulation

The study used a mixed qualitative approach combining interviews, surveys, and field visits to capture perspectives from government institutions, technical experts, community groups, and private sector partners. The team applied a participatory method to ensure inclusivity and contextual accuracy.

Structured questionnaires were designed for each stakeholder category based on the framework developed collaboratively with the expert team. The questionnaires were translated into Sinhala

to improve accessibility and understanding. Printed copies were distributed during field visits, with participants given the option to complete them independently or through guided discussions.

In several community settings, participants expressed hesitation or found written responses challenging. In these cases, the team used a conversational format, structuring the discussion verbally around the same questionnaire themes. Notes were taken by program associate to preserve the accuracy of responses.

Interviews were conducted both in person and online, depending on the stakeholder's location and availability. Field visits took place at key sites identified during the scoping phase, including Ehetuwewa and Colombo, where the team directly observed harvesting, processing, and market linkages.

All participants were briefed on the purpose of the study and provided informed consent through printed forms before participation. This flexible data collection approach allowed the team to adapt to varying field conditions while maintaining consistency and reliability across all stakeholder inputs.

All data gathered through interviews, surveys, and field observations were compiled into a unified Needs Assessment for review by the program team and the three thematic experts. Each set of responses was categorized under the technical, environmental, or business domains, and patterns were cross-checked across sources to ensure consistency.

Triangulation was achieved by comparing primary field data with secondary literature, stakeholder inputs, and expert analyses. This process helped verify assumptions, identify overlaps, and highlight gaps requiring further validation. Qualitative notes from field visits were coded thematically, and recurring issues such as regulatory challenges, material access, and product quality were traced through multiple stakeholder perspectives.

Regular internal review sessions were held between the program team and experts to validate findings before inclusion in the final scoping study. Through this iterative process, the study

ensured that all conclusions were evidence-based, contextually grounded, and aligned with both community realities and policy frameworks.

4 ASSUMPTIONS AND GUIDING PRINCIPLES

The Water Hyacinth Circularity Scoping Study has been guided by a shared understanding that the invasive nature of water hyacinth presents both ecological risks and regenerative opportunities. The study adopts a balanced lens, integrating environmental stewardship, technical innovation, and business feasibility within a circular economy framework. The following assumptions and guiding principles outline the foundation upon which the study's assessments and recommendations have been developed.

4.1 BUSINESS ASPECT

4.1.1 GUIDING PRINCIPLES

The proposed program is anchored in community ownership, environmental integrity, and circular value creation. Activities prioritize livelihood gains for local groups while restoring waterways and biodiversity. The approach is market led and evidence based, using demand signals to shape product choices, quality systems, and investment pacing. Governance emphasizes transparency, fair contracts, safe working conditions, and traceability from harvest to dispatch. Partnerships with local authorities, producer groups, and buyers are structured to share risks and benefits clearly. Interventions aim to be light on fixed costs, modular, and replicable with common facility centres providing shared services that reduce barriers to entry. Gender inclusion, youth engagement, and accessibility for low-income households remain explicit design requirements throughout implementation.

4.1.2 ASSUMPTIONS

Adequate biomass is available for legal and sustainable harvest without degrading aquatic ecosystems and environmental and occupational safety standards can be met with low-cost controls and routine supervision. Communities participate when incentives are predictable and fairly distributed through transparent contracts and local authorities cooperate on permits, access to water bodies, and transport. Demand for natural low plastic materials remains stable

or grows and buyers accept verified conservation and circularity claims. Producer groups meet baseline specifications with short training and simple tools and common facility centers operate reliably for preprocessing, drying, quality control, and storage. Seed funding and working capital are available on reasonable terms and simple financial management practices can be adopted with light coaching. Transport and storage remain serviceable at current cost levels and basic utilities are sufficient to maintain product quality. Digital tools for record keeping, traceability, and payments can be adopted with minimal training. Weather variability, price movements, and regulatory changes remain within historically observed ranges and phased targets and contingency plans are sufficient to manage foreseeable disruptions.

4.2 TECHNICAL ASPECT

4.2.1 GUIDING PRINCIPLES

Promote small industry development by supporting small and medium enterprises and local entrepreneurship. Focus community level Low-tech product lines event though we have also proposed Medium to High-tech involved on the document. This focal lens primarily revolves around eco product innovation that substitutes unsustainable materials and foster skill development through vocational training in water hyacinth based manufacturing.

Transform water hyacinth waste into high value materials or energy and promote a circular bioeconomy that replaces fossil resources with renewable biomass. Emphasize research and development-driven innovation through partnerships with academia and industry while ensuring techno economic feasibility for scale up and cost-effectiveness.

4.2.2 ASSUMPTIONS

Small scale machinery is available and local artisans or entrepreneurs are willing to engage in production. Policies or incentives exist to support green businesses and encourage sustainable practices. A steady supply of water hyacinth feedstock is available with feasible pre treatment options. Necessary processing infrastructure such as fermentation units, pyrolysis systems, or

reactors exists along with trained personnel and funding. End markets for products like biofuels and carbon materials are accessible.

For community scale applications the principles emphasize sustainability, practicality, and community empowerment with a circular economy and local value creation approach using low tech solutions that can scale as capacity and demand grow. Assumptions include reliable access to harvested biomass, existence of local markets for outputs, and basic training and organizational structures such as cooperatives or community-based organizations in place or readily established.

4.3 ENVIRONMENTAL ASPECT

4.3.1 GUIDING PRINCIPLES

These applications are anchored in Nature Based Solutions which replicate natural processes of purification, nutrient uptake, and cycling within aquatic ecosystems. The approach emphasizes low-cost water management that relies on plant-based mechanisms rather than energy intensive or mechanically complex technologies, making it suitable for low resource settings and community led water purification initiatives.

At the initial stage of the process or acceleration the invasive alien species principles may not be critical as water hyacinth is already spread around the country. As management and control improve the invasive alien species management principles can be applied gradually. Alongside this there needs to be a management board to oversee policy and implementation of ecosystem and environment governance and benefit sharing of water hyacinth operations. Payment for Ecosystem Services and carbon and biodiversity related financing can empower communities beyond livelihood benefits. Technologies for environmental governance from harvesting to air pollution, land management, waste and wastewater management, water and energy efficiency, and use of renewable energy can be enhanced from current levels. Water hyacinth also has a climate prosperity element where products can use carbon finance to ease working capital and enhance community benefits. Investor and donor interest can be enhanced by aligning the

accelerator with the Global Biodiversity Framework, the Sendai Framework, and Nature based Solutions.

4.3.2 ASSUMPTIONS

It is assumed that water hyacinth species are effectively managed so they do not regrow uncontrollably or spread beyond designated areas. Local stakeholders including municipalities and community groups are expected to take responsibility for ongoing maintenance and monitoring. Adequate land or water space is available for system installation and there is general acceptance of nature based slower treatment methods that prioritize ecological balance over rapid processing.

4.4 SYNTHESIS OF ASSUMPTIONS AND GUIDING PRINCIPLES

Across the three expert areas there is clear alignment on a community first pathway that can scale. All agree that water hyacinth must be managed, not encouraged, and that any utilisation sits within restoration and compliance. The environmental frame prioritises nature-based approaches and gradual application of invasive species controls as management improves. The technical frame favours practical processing routes that local producers can run now, with clear upgrade paths to mid and higher tech. The business frame centres on market led choices, traceable value chains, and fair contracts that keep community ownership intact.

Taken together, the assumptions are workable if we hold to a few conditions. Biomass access needs to be legal and consistent. Common facility services for drying, quality control and storage need to run reliably. Local permits and transport need early coordination. Product choices should be based on buyer demand and quality that communities can meet with short training. The near term focus is on low and mid tech lines with steady buyers, while the study keeps space for higher value materials if partners and capital line up. This gives the accelerator a practical starting point with a path to scale, without losing sight of environmental safeguards or community benefit.

5 LIMITATIONS OF THE SCOPING STUDY

The business stream notes that some foundational data remain uneven across districts, particularly in terms of unit costs, seasonality, and the true scale of informal activity, so early forecasts and comparisons carry uncertainty. Short pilot windows may not capture price swings, extreme weather, or abrupt shifts in local administrative enforcement, and findings may not fully generalize beyond the sites observed. In addition, export compliance, sustainability verification, and retail onboarding can take longer than planned and require investments that some groups may not meet immediately; transport reliability, biomass quality variation, and group-level governance issues can also slow scale-up, even when demand signals are positive.

From the environmental lens, performance of nature-based applications can vary with climate, pollutant loads, and hydrology, and systems require regular harvesting and careful biomass handling to avoid secondary pollution. Where land or water rights are contested, siting becomes slower and riskier. Critically, hyacinth from contaminated waters can accumulate heavy metals, limiting safe use pathways or forcing additional post-treatment and disposal steps that are not always feasible for community actors during a short scoping window.

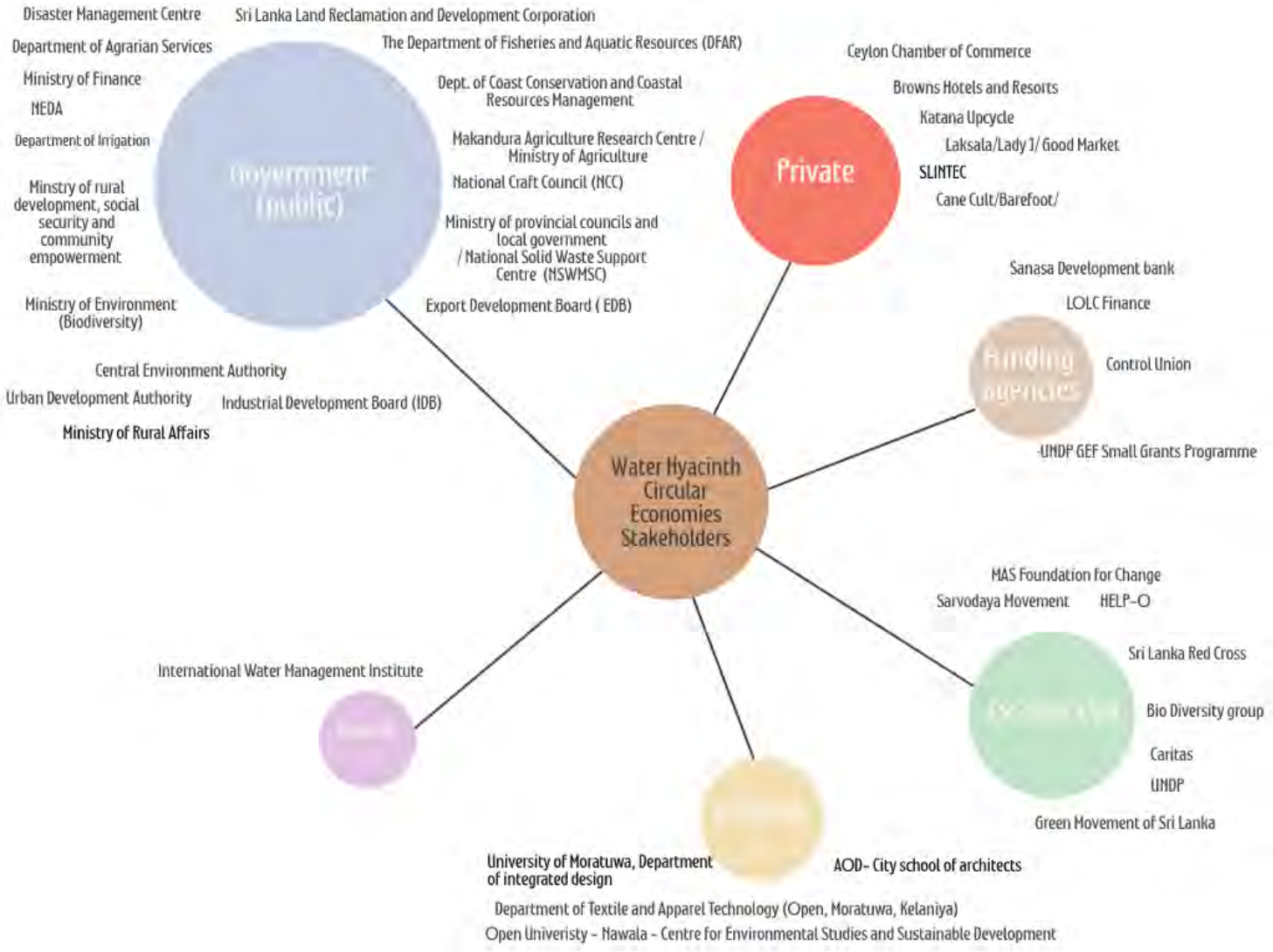
Technically, several pathways depend on machinery or process controls that are scarce at community level, which constrains repeatable quality and throughput in the timeframe of this study. Examples include small-scale fiber preparation and drying for crafts, shredding and moisture control for composting, and precision carbonization/activation and filter housings for point-of-use water treatment; similar gaps appear for paper, bioplastics, pellet fuel, and other medium-tech options where testing rigs, kilns, presses, or pulping lines are not readily accessible. These constraints limit how far the study could validate yield, durability, and quality at scale, and they temper extrapolations from bench-scale or literature to field conditions.

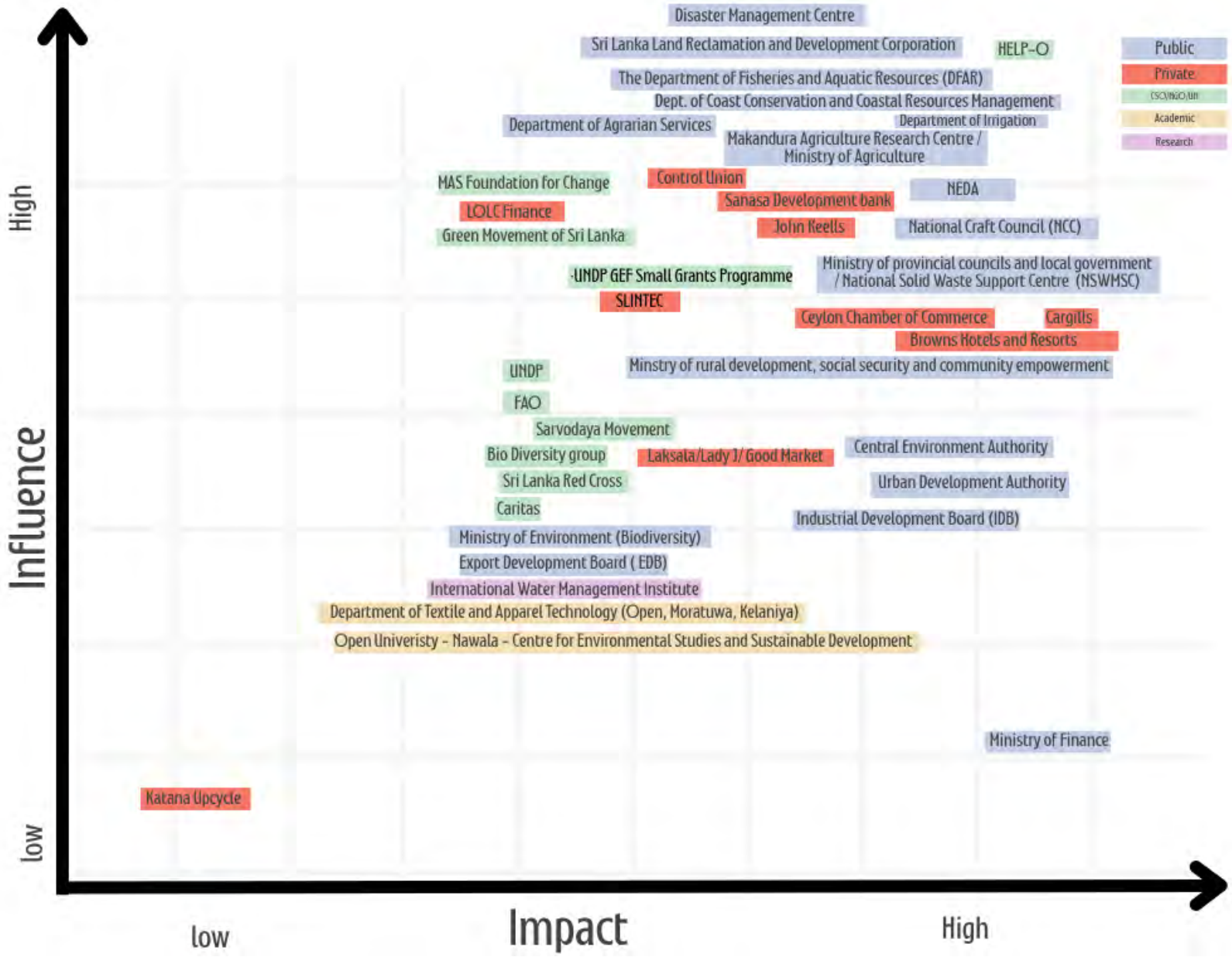
Finally, supply-chain realism is still evolving. Availability is seasonal and spatially fragmented; quality of stems and dried fiber varies by source and handling; storage and aggregation models are nascent; and current human/machine capacity can lag raw biomass peaks, so volumes left unprocessed may distort cost and productivity estimates in the short run. Until standardized

preprocessing, storage, and hub-and-spoke aggregation are proven, any scale assumptions remain provisional.

Together, these limitations do not negate the opportunity but frame it: the study's conclusions should be treated as directional, with phase-II work prioritizing data tightening (costs, seasonality, compliance timelines), field validation under real equipment and QA conditions, and site-specific environmental due diligence to de-risk the most promising community, medium-tech, and market pathways.

6 STAKEHOLDER MAP AND ANALYSIS




Disaster Management Centre
Sri Lanka Land Reclamation and Development Corporation
HELP-O
The Department of Fisheries and Aquatic Resources (DFAR)
Dept. of Coast Conservation and Coastal Resources Management
Department of Agrarian Services
Department of Irrigation
Makandura Agriculture Research Centre / Ministry of Agriculture
MAS Foundation for Change
Control Union
NEDA
Sanasa Development bank
LOLC Finance
John Keells
National Craft Council (NCC)
Green Movement of Sri Lanka
UNDP GEF Small Grants Programme
Ministry of provincial councils and local government / National Solid Waste Support Centre (NSWMSC)
SLINTEC
Ceylon Chamber of Commerce
Cargills
Browns Hotels and Resorts
Minstry of rural development, social security and community empowerment
UNDP
FAO
Sarvodaya Movement
Central Environment Authority
Bio Diversity group
Laksala/Lady J/ Good Market
Sri Lanka Red Cross
Urban Development Authority
Caritas
Industrial Development Board (IDB)
Ministry of Environment (Biodiversity)
Export Development Board (EDB)
International Water Management Institute
Department of Textile and Apparel Technology (Open, Moratuwa, Kelaniya)
Open Univeristy - Nawala - Centre for Environmental Studies and Sustainable Development
Ministry of Finance
Katana Upcycle
Public
Private
(SC)/NGO/Un
Academic
Research
High
Influence
low
low
Impact
High

Stakeholder Landscape

Goverment (public sector)

Government agencies are central to the **regulatory, policy, and enabling environment** for circular solutions. Entities such as the National Enterprise Development Authority (NEDA), National Craft Council (NCC), Ministry of Agriculture, Central Environmental Authority, and the Department of Fisheries and Aquatic Resources possess high levels of both influence and impact. Their mandates cover **policy formulation, regulatory compliance, resource allocation, and the facilitation of market access**. These agencies are also instrumental in access to community, local government and ensuring **alignment with national development priorities**.

Private Sector and Funding Entities

The private sector, represented by organizations such as Ceylon Chamber of Commerce, Sanasa Development Bank, Cargills, John Keells, and others, plays a pivotal role in **market development, financing, and innovation**. These stakeholders are well positioned to **drive commercialization, support value chain development, and provide access to new markets**.

Civil Society, NGOs, and INGOs

Civil society organizations, including Caritas, MAS foundation, Sri Lanka Red Cross, Green Movement of Sri Lanka, and Sarvodaya, contribute significantly **to community mobilization, grassroots implementation, and local level advocacy**. Their **established networks and experience in working with local communities** make them valuable partners for ensuring **inclusive participation and local ownership**. INGOs and NGOs also facilitate access to donor funding and technical expertise.

Academia and Research Institutions

Academic and research institutions, such as the University of Moratuwa, University of Kelaniya, Open University, and the International Water Management Institute (IWMI), provide **critical technical expertise, research, and innovation**. Their ongoing studies on WH properties, applications, and environmental impacts higlight the scientific credibility of the project and support the **development of evidence based solutions**.

Financial Institutions

Financial institutions, including Sanasa Development Bank, LOLC Finance, and other banks, are key enablers for **project expansion** and **financial support** for community led producers. They offer not only funding but also **financial literacy programs**. Their participation is vital for **supporting entrepreneurs, facilitating investments**, and helping to sustain the long-term circular economy initiatives.

International Organizations

UN agencies such as FAO, UNDP and other international partners bring **global knowledge, technical assistance, and opportunities for scaling up**. Their involvement enhances the project's credibility and opens avenues for **international collaboration and funding**.

Impact, Influence and Engagement

Stakeholders have been mapped according to their level of impact and influence on the project. Those with both high impact and high influence such as NEDA, NCC, Ministry of Agriculture, Cargills, John Keells, and Central Environmental Authority are identified as strategic partners for close engagement and co-creation. Medium impact or medium influence stakeholders are engaged for their specialized expertise, market access, or community reach. Low impact and low influence stakeholders could be contacted at later stages.

By leveraging the strengths of each stakeholder group, the project can achieve greater impact, sustainability, validity and scalability, feeding into the accelerator phase.

7 WATER HYACINTH VALUE CHAIN ANALYSIS

Turning water hyacinth from an invasive weed into marketable products involves a multi-step **value chain** with numerous stakeholders (Delina, Dayawansa , & Silva , 2019)

This chapter outlines a concise value chain for water hyacinth valorisation in Sri Lanka tailored to natural fibre business ventures and related product pathways. It aligns with the scoping structure by starting from end-market requirements, mapping actors and functions, and specifying governance, support services, and compliance needs. In addition to woven crafts and homeware, the analysis includes paper and packaging, biochar, and organic fertiliser as promising products with defined quality, safety, and performance parameters. Strategic support is framed across local and national government institutions for access, permitting, quality infrastructure, and market facilitation, paired with private sector interventions in design, processing, aggregation, and export development through structured public–private partnerships. Delivery is calibrated to market quality standards and buyer specifications, with clear actions to stabilise supply, improve preprocessing and QA, standardise product attributes, and secure reliable route-to-market channels.

7.1 VALUE CHAIN STAGES AND PRINCIPAL ACTORS

Stage 1. Harvesting and collection. Community groups remove water hyacinth from tanks and canals under local authority oversight. Evidence from the Galgamuwa tank system shows invasive aquatic plants, including water hyacinth, are a major threat to marshland environments and hydraulic systems, and that removal improves dissolved oxygen and benefits aquatic fauna. Key actors: Women's groups and farmer organisations, Pradeshiya Sabhas, Irrigation and Agrarian agencies, NGOs.

Stage 2. Primary processing. Fresh biomass contains 90 to 95 percent water, which requires prompt sorting, cleaning, and drying to stabilise quality and avoid spoilage. Weather proof drying racks and simple presses reduce variability and losses.

Stage 3. Secondary processing and material preparation. Dried stems are split, braided, or pulped to produce intermediate materials for weaving, paper, boards, briquettes, or compost blends. Operational mapping of activities, inputs, time, outputs, and spatial logistics at this node improves consistency and yield.

Stage 4. Product manufacturing and finishing. MSMEs, cooperatives, and designers convert intermediates into finished goods. An empirical study using SEM PLS shows that product differentiation, creativity, and green entrepreneurial orientation improve performance, and that higher performance strengthens competitiveness.

Stage 5. Marketing and distribution. Domestic channels include craft outlets, institutional buyers, and curated markets. Export entry requires volume, quality, and verified social and environmental responsibility, which are central to the Phase 1 scoping deliverables on market analysis and strategic interventions.

Stage 6. End consumers. Domestic eco conscious buyers and hospitality procurement, and international curated retail and e commerce, reward uniqueness, verified environmental claims, and reliable delivery. This is consistent with the performance to competitiveness pathway evidenced in the competitiveness study

7.2 GOVERNANCE, SUPPORT MARKETS, AND ENABLING ENVIRONMENT

Governance. Lead buyers set specifications and assure compliance. Local authorities govern removal and movement of invasive biomass. Cooperatives can enforce basic quality assurance and aggregation rules. The scoping framework requires explicit stakeholder roles, compliance pathways, and recommendations for Phase 2.

Support markets. Finance, quality testing, design and product development, logistics, and export facilitation are critical meso level services that enable firm upgrading. These are included in the Phase 1 scope and deliverables.

Enabling environment. Streamlined guidance for harvesting permissions, transport, processing, and product claims, combined with rural infrastructure for collection and drying, reduces

coordination costs and investment risk. These matters are explicitly listed under regulatory challenges, infrastructure gaps, and pathways to strengthen implementation

Given the alignment and successes discussed, there is significant **upside potential to scale** water hyacinth circular solutions both within Sri Lanka and beyond its borders.

A similar empirical study of craft-based small and medium enterprises that used structural equation modeling to examine how firm capabilities convert into market competitiveness. The study validated a pathway in which product differentiation, creative capacity, and a green entrepreneurial orientation raise operational performance, and improved performance then strengthens overall competitiveness. The insights translate directly to natural-fiber product lines such as water hyacinth, where disciplined design, verified sustainability, and reliable delivery determine access to premium local and export channels. (Albushairi & Huda, 2021)

Key findings of the study is extracted below as insights relevant to water hyacinth valorisation context in Sri Lanka where learnings and findings of the study to be adopted to implementation of the project.

Figure 10: Findings of the empirical study done on performance and competitiveness on Water Hyacinth crafts on strategic product innovation

(Albushairi & Huda, 2021)

7.3 Risks and Systemic Constraints

Raw material logistics and seasonality. Irregular growth cycles and weather dependent drying create supply volatility and quality drift.

Infrastructure gaps. Lack of drying, storage, and basic quality assurance facilities increases spoilage and rejects. These gaps are within the scoping remit for infrastructure and investment needs.

Market access requirements. International buyers require quality, traceability, and social responsibility, which can exclude small producers without support. The scoping plan anticipates this through strategic intervention design.

Policy and coordination frictions. Fragmented guidance on removal, transport, and claims slows investment and scale. The environmental chapter template lists precise compliance and permitting items to resolve.

7.4 UPGRADING OPTIONS

Process upgrading. Install village level covered or solar racks and simple presses and adopt standard operating procedures for moisture targets to stabilise fibre quality and reduce transport costs.

Product upgrading. Develop coordinated collections for crafts, paper, and boards with buyer validated specifications and durability metrics and use the scoping study's market analysis to confirm trend fit.

Functional upgrading. Enable cooperatives to take on aggregation, grading, quality checks, and packing to capture margin and improve reliability. These steps align with the programme's stakeholder mapping and ecosystem design.

Channel upgrading. Pursue hospitality procurement and curated export wholesalers while building domestic institutional buyers for compost blends and paper goods, with promotion supported by the accelerator plan.

7.5 SELECTION AND PRIORITISATION FOR SRI LANKA

Use the programme's selection logic to score geographic clusters and product pathways by feasibility and impact. Steps include longlisting, participatory shortlisting, targeted data collection, and scoring that feed Phase 2 accelerator design.

Harvesting & Collection: Water hyacinth is manually harvested from infested water bodies (village tanks, lakes, canals) by **local communities**, which often include farmer groups or women's collectives. In some cases, government agencies (e.g. Irrigation Department, local authorities) facilitate removal drives.

Stakeholders: rural villagers (often poor farming families), sometimes supported by NGOs or local government labor schemes to clear weeds. Harvesters benefit by obtaining the raw material at no cost (and sometimes via "harvest incentive" programs for invasive control).

Primary Processing (Drying & Treatment): Fresh water hyacinth is 90-95% water and must be processed promptly. Harvested plants are **sorted and pre-processed** on-site: roots and leaves may be trimmed off, and stems are cleaned of mud and impurities. The stems (and sometimes petioles) are then **sun-dried** for several days to a week until they turn tan and leathery. In village settings, sun drying is traditional, though introducing simple drying racks or solar dryers can speed up the process. Some groups also use mechanical dewatering presses to squeeze out moisture, and occasionally apply natural treatments (saltwater or eco-friendly chemicals) to prevent mold and pest infestation in the dried fiber.

Stakeholders: the **artisans or cooperatives** themselves handle drying; development projects (like CRIWMP) have provided equipment such as presses and shelter for drying to improve efficiency. Ensuring proper drying is critical – insufficient infrastructure here (e.g. lack of drying space in rainy seasons) is a common bottleneck.

Secondary Processing & Material Preparation: Dried water hyacinth stalks are then made ready for crafting or manufacturing. This may involve **splitting or twisting the stems** into rope-like strands, braiding them, or pounding into fiber. For example, craft weavers often halve the dried stems lengthwise and soak them briefly to increase flexibility for weaving. In paper-making

enterprises, the dried hyacinth (along with other fibers) is chopped and pulped in a slurry to produce paper pulp. In bioenergy use-cases, chopped dried biomass might be compacted into briquettes or fed into digesters.

Stakeholders: **artisans and small manufacturers** perform these steps; **technical experts** or NGOs sometimes introduce improved techniques (e.g. demonstration of fiber extraction, or mixing hyacinth fiber with other materials for better strength). Local tool-makers may supply knives, looms, or molds for this stage.

Product Manufacturing / Crafting: This is the **value addition** stage where the prepared hyacinth material is transformed into final products. It includes weaving of baskets, bags, mats, and furniture on one hand, and molding or pressing of paper, boards, or briquettes on the other. Traditional weaving techniques are commonly employed (similar to cane, reed, or rush weaving which many rural artisans are already skilled in). For instance, **women artisans weave water hyacinth baskets and bags** that are remarkably strong yet lightweight – a quality that even impressed international tourists on the Mekong who couldn't tear a woven hyacinth bracelet. In furniture-making, dried hyacinth may be woven around frames to create chairs and sofas, as done by companies like Viveca. Paper-making units convert pulp into sheets of handmade paper and then into stationery, packaging, or craft paper products.

Stakeholders: **micro-entrepreneurs and SMEs** are at the heart of this stage – individual weavers, handicraft cooperatives, small factories. **Designers** and **product developers** also play a role by introducing new product ideas (for example, developing fashionable handbags or blended-fiber paper). This stage often involves a high proportion of **women's labor**, especially in weaving and craft assembly, providing them employment and income.

Marketing & Distribution: Once products are made, they enter distribution channels. Locally, **sales** occur through craft fairs, gift shops, government-run outlets (e.g. Laksala or regional craft centers), and direct orders from institutions. Udeni's group, for example, sells to schools, government offices, and private companies in nearby towns. Some products target the **tourism market** (resorts and souvenir shops sourcing eco-friendly handicrafts).

Increasingly, **export** channels are being explored: Sri Lankan craft exporters and the Export Development Board (EDB) have showcased hyacinth-based products to international buyers, and global retailers like IKEA, Target, and Home Depot already carry water-hyacinth woven homeware sourced from other Asian countries. Thus, there is potential for Sri Lankan producers to tap into these supply chains if they can meet volume and quality requirements.

Stakeholders: **retailers and wholesalers** (local and international), **export facilitators** (EDB, trade intermediaries), **marketing platforms** (e-commerce sites or Good Market-type outlets), and **logistics providers** for transporting bulky goods. Government craft marketing boards and NGOs also help promote these products as ethical and sustainable.

End Consumers: The end-users of water hyacinth products range from **Sri Lankan consumers** (who increasingly seek eco-friendly alternatives) to **international consumers** in the eco-conscious home décor and stationery segments. Modern consumers value that these products are biodegradable, handmade, and tied to a social cause. Customer feedback at home and abroad drives further innovation (e.g. design tweaks) and can create brand stories around invasive weed upcycling.

Stakeholders: **Consumers and communities** ultimately benefit – consumers get green products, and communities get cleaner water bodies and incomes from supplying those products.

Throughout this value chain, several **cross-cutting stakeholders** deserve mention: **government agencies** (e.g. Ministry of Industry, Provincial Industrial Development Authorities, Craft Council) which provide training, equipment or seed funding; **NGOs and donor projects** (like Red Cross, UNDP, JICA) which have catalyzed community enterprises and linked them with resources; and **financial institutions** (rural banks like Samurdhi or microfinance lenders) which sometimes support these small businesses. Conceptually shows how these actors interact – from local harvesters and producers up to policymakers and markets – forming an ecosystem needed to sustain the hyacinth circular economy.

8 MARKET ANALYSIS

The market analysis will quantify demand, price ranges, and buyer specifications across four priority pathways: natural fibre crafts and homeware, paper and packaging, biochar, and organic fertilizer. It will map target segments in Sri Lanka and relevant export markets, identify lead buyers, and benchmark competing suppliers and substitute materials.

The study will test product market fit through samples and structured buyer feedback, document the required standards and certifications, and assess channel options including hospitality procurement, curated retail, and e-commerce. It will estimate attainable volumes by season, set quality and delivery thresholds, and model unit economics from raw material to landed price. The output will be a route to market plan with clear KPIs for conversion, repeat orders, price realization, and on-time delivery, supported by a risk register with mitigation actions.

8.1 CURRENT MARKET DEMAND

Water Hyacinth, a plant once notorious for being an invasive weed that destroys aquatic ecosystems, is currently undergoing a dramatic transformation to become one of the hottest sustainable materials in the home decor and furniture market for the 2025–2026 period. Driven by increasingly eco-conscious consumer demand, this natural material perfectly represents the burgeoning eco-friendly furniture sector, which is projected to surge with a CAGR of 8.6% through 2030. By 2026, water hyacinth is anticipated to move from being a mere trend to becoming a primary eco-choice in the accessories and decor segment, as it provides a strong sustainability narrative: turning an environmental problem (invasive species) into a high-value economic opportunity. Each product, created through traditional local craftsmanship, carries a premium added value and directly supports rural economies, making it a flawless blend of environmental responsibility, product authenticity, and the warm aesthetic appeal highly sought after by the global market. (ASEAN SOURCING, 2025). In the domestic market, schools, government offices, companies, and hospitality operators are adopting eco - friendly substitutes for everyday items and décor. Procurement teams increasingly apply sustainability criteria, which supports steady

orders when suppliers can meet basic standards on consistency, safety, and origin. Tourism retail adds seasonal lift and helps validate designs for higher margin lines.

Export interest is strongest in-home organization and décor, where buyers expect uniform sizing, color fastness, and load bearing performance. Globally, retailers have embraced water hyacinth woven products: major chains like IKEA, Target, and Home Depot sell baskets, bins, and home decor made from water hyacinth, which have become popular for their earthy aesthetic and sustainable image (Chandra, 2025). Retailers seek suppliers who can document inputs, ensure moisture-controlled drying, and pass simple compliance checks. Sri Lanka's advantage lies in a credible conservation narrative, small batch flexibility, and the ability to link production to monitored ecosystem benefits.

Additionally, niche markets such as eco conscious stationery using hyacinth paper, garden supplies based on biofertilizers and compost from hyacinth, and green construction using fiber boards are emerging. Fertilizer and bioenergy from water hyacinth have already been piloted in other countries, which signals potential future demand in these sectors.

Capturing this demand requires dependable biomass supply, standardized preprocessing, and light but consistent quality assurance. Basic branding and traceability support buyer confidence and allow price premiums linked to verified environmental gains. Coordinated offtake, shared designs, and simple vendor onboarding can convert small community production into repeat orders.

The outlook is positive. Near term growth will come from décor and organization categories, corporate and institutional procurement, and tourism retail. Medium term opportunities lie in stationery, soil inputs, and bio-based materials as standards and distribution mature. A focused accelerator and buyer development program can bridge capability gaps and position producers for scale while reinforcing measurable ecological restoration.

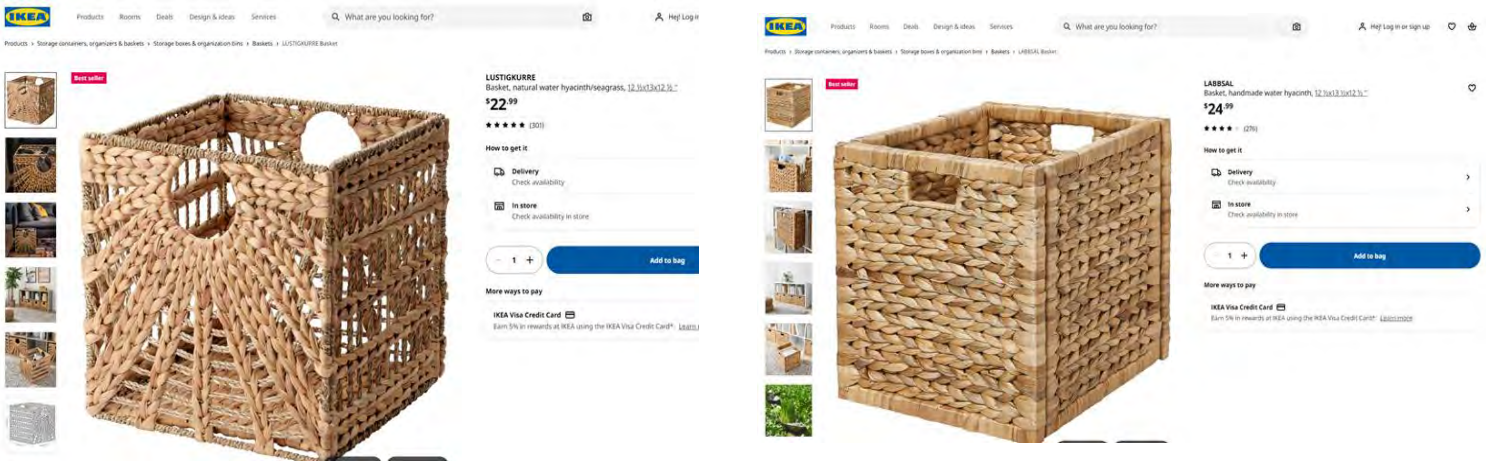


Figure 11: IKEA Lustigkurre and Labbsal basket made of natural Water Hyacinth

(IKEA, 2025)

In summary, market demand is healthy and growing, particularly for handicrafts and décor in the near term, with latent demand for bio-based products (compost, biofuel, fibers) in specialized markets.

8.2 Market Requirements and Buyer Priorities

Buyers across domestic institutions, tourism retail, and export homeware select water hyacinth products that combine credible sustainability, reliable quality, and relevant design. Global research indicates a rising preference for products with verified environmental attributes and low plastic content, which supports demand for bio-based materials such as water hyacinth (Rogers et al., 2023)

Design forecasters for 2025 to 2026 highlight tactile handcrafted textures, circular and renewable inputs, and earthy matte finishes. Water hyacinth aligns with these trends. (ASEAN SOURCING, 2025). Export buyers emphasize responsibly sourced natural fibres and circular design principles, which translate into expectations on quality consistency, durability, and traceability. Leading retailers also signal this direction by expanding ranges made from renewable natural fibres such as water hyacinth (*Sustainable Public Procurement*, 2022). In Sri Lanka, the National Policy on Green Procurement sets specifications that favour renewable or recycled inputs and verifiable

environmental benefits, shaping institutional purchasing. (*National Policy on Green Procurement*, 2023).

Sustainability And Story	Verified renewable inputs Low-plastic content, Clear environmental narrative. Positioning the material as an invasive biomass diverted from waterways strengthens appeal, particularly for export and urban buyers.
Quality and Durability	Odor-free and mould-free finish Consistent weave, and sturdy construction based on correct drying and processing. When these standards are met, satisfaction and repeat orders improve.
Design Relevance	Contemporary forms and practical features that suit home organisation and hospitality use. Textural warmth and natural colorways support biophilic interiors.
Price and Value	Competitive landed prices against benchmark suppliers in Vietnam and Indonesia, with room for boutique premiums where craftsmanship and verified impact are demonstrated

Figure 12: Drivers of trial and repeat orders for the Water Hyacinth product market

8.3 SUPPLY DYNAMICS

Raw material supply of water hyacinth in Sri Lanka is abundant *to the point of oversupply*. Vast mats of hyacinth are available in tanks and wetlands across the dry zone and some wet zone lakes, especially during warm months. Communities often can harvest far more tonnage than they can process. This abundance keeps the raw material *cost at essentially zero* (in fact, removal often yields environmental benefits).

The challenge, however, is in the **logistics of supply**: hyacinth is bulky and heavy when fresh, making transport from waterbody to processing site labor-intensive. Typically, communities gather it manually and need to haul it to the shore – mechanized harvesting or boats could ease this, but are rarely used currently. Once dried, the weight drops significantly, and dried bales can be transported in bulk.

Key supply gaps and constraints are discussed below.

Processing Capacity*:* The ability to convert raw hyacinth into finished goods is limited by human and machine capacity. Often, during peak growth seasons, more hyacinth is available than the

artisans can handle, leading to large volumes being left to rot (missed opportunity). For example, after initial training, Udeni's group struggled to keep up with orders due to lack of equipment and had to turn some raw material into compost or discard it. Increasing processing capacity (through more tools and labor) would allow a greater portion of the supply to be utilized.

Consistency and Quality of Raw Fiber: Hyacinth quality can vary by location and season. Stems from shaded or highly polluted water may be thinner or weaker, and if not harvested at the right maturity, they can be too short for weaving. Ensuring at least 50cm stem length and proper thickness is ideal for handicrafts. Additionally, if dried improperly, fibers can develop fungus or become brittle. Thus, maintaining a consistent stock of high-grade dried hyacinth fiber is a supply-side challenge. This might require establishing central processing centers where raw weed from many collectors is standardized (graded, properly dried, and treated) before distribution to artisans.

Geographical Spread and Coordination: Supply is geographically spread out – many tanks in different villages each have heaps of hyacinth. Coordination is needed to aggregate supply for larger orders. Currently, there's a gap in supply chain coordination: no formal network or aggregator exists to collect dried hyacinth from multiple villages and supply to a big manufacturer. This fragmentation means most enterprises operate with hyper-local supply, limiting their scale. Developing a hub-and-spoke model (with village collection hubs feeding a central production unit or warehouse) could address this.

Seasonality: While water hyacinth is perennial in Sri Lanka's climate, growth accelerates in the rainy season and may die back slightly in extreme drought (though dormant seeds ensure regrowth). There might be seasonal peaks in availability. Enterprises need to plan for raw material storage during glut periods. Dried fiber can be stored for many months if kept dry and pest-free; building storage facilities is thus part of supply chain management.

8.4 MODEL BUSINESS WITH MULTIPLE DEVELOPMENTS COMBINED

There could be possibilities to work with other area-based needs and opportunities such as energy needs, climate smart dairy, agriculture, tourism etc. in the same area. Therefore, there is a site-specific element to our project development.

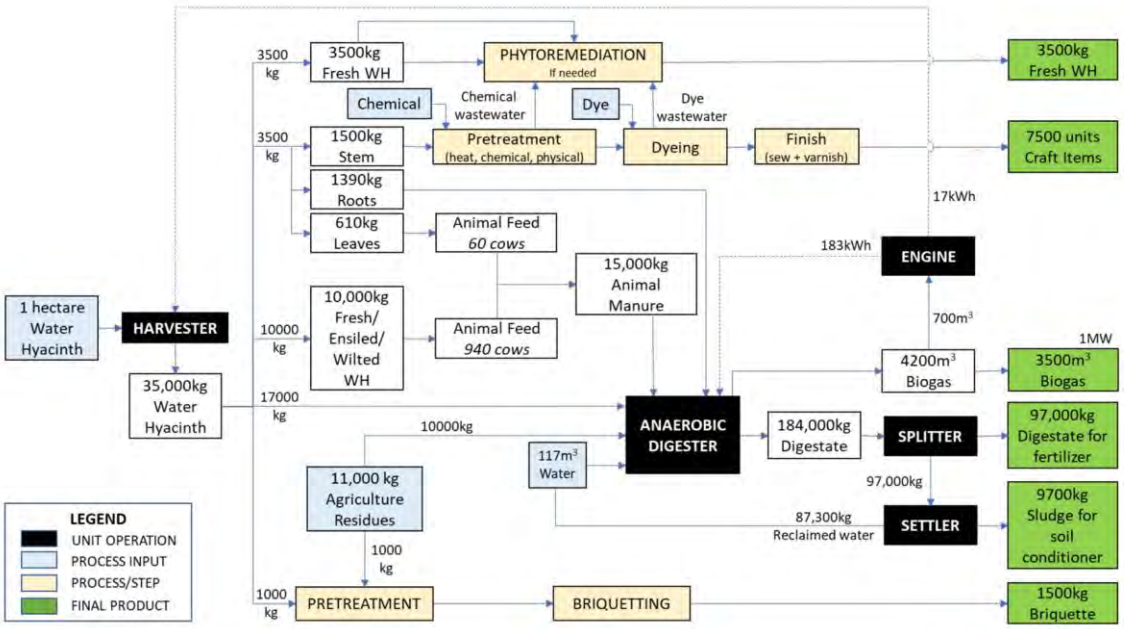


Figure 13: The proposed model for the valorisation of Water Hyacinth into bioproducts, agricultural residues reclaimed water and technologies that can be readily adopted by rural communities

(Harun et al., 2021a)

8.5 Supply Gaps vs. Market Demand

Paradoxically, we see excess raw material supply on one hand, and insufficient finished product supply on the other (relative to potential market demand). This gap arises because the current number of artisans and scale of operations are too small to convert all available hyacinth into products. For instance, even as local markets show interest, groups like those in Kurunegala can only produce a limited quantity per month, constrained by manual production speeds. There is a *latent market* (especially internationally) that remains unfilled by Sri Lanka due to these capacity issues. Bridging this gap will require scaling up production (through training more artisans or mechanization where feasible), improving productivity, and possibly introducing **new enterprises** that utilize hyacinth in novel ways (e.g., a paper factory that could consume large volumes of pulp). Until then, supply of finished goods remains the limiting factor, not the raw hyacinth itself.

Market linkage is another critical gap driving the market growth. Many rural producers lack direct access to lucrative markets. They may rely on a few local buyers or middlemen, meaning their products don't always reach high-paying customers. This suppresses supply incentives (if producers can't sell more, they won't make more). Strengthening links to urban and export markets via e-commerce, trade fairs, or cooperative marketing can unlock increased supply by assuring producers of sales.

In summary, Sri Lanka is in the fortunate position of having *plentiful natural supply* of water hyacinth. The focus now must be on converting that into a steady pipeline of quality products to meet growing demand. By investing in processing and expanding the artisan base, the country can move from sporadic cottage supply to a more reliable production system, seizing both domestic eco-consumer trends and international market opportunities for sustainable goods.

8.6 Business Models and Revenue Streams

Existing and potential **business models** for water hyacinth utilization in Sri Lanka range from grassroots community enterprises to fully commercial ventures.

Below are several models observed or envisaged, along with their revenue streams:

Community-Based Cooperative Model

This is exemplified by village women's groups or farmer cooperatives (like the Ehetuwewa handicraft group). In this model, members collectively harvest hyacinth and produce crafts, sharing resources like drying areas and tools. They often operate informally or as a registered society.

Revenue streams: Sale of finished handicrafts to local markets or via NGOs. For instance, Udeni's co-op fulfills orders for schools and offices and splits the earnings among members. Additional income may come from small grants or microfinance loans (often used to buy equipment, but occasionally grants subsidize initial operations). The value proposition here is the authentic, handmade nature of goods and the social impact story, which can attract NGO support and

eventually ethical consumers. Scaling this model might involve forming networks of cooperatives to bulk-sell to larger buyers.

Social Enterprise Model

A step up in formality, social enterprises like Mana Ceylon operate as businesses with a clear social/environmental mission. They might be registered companies or cooperatives that reinvest profits into community or expansion. Mana Ceylon, for example, is a women-led company turning invasive plant fibers (including water hyacinth) into handmade paper products. *Revenue streams:* Sale of paper goods (notebooks, gift cards, packaging) to corporate clients and retailers; possibly export orders in the future. They may also secure impact investment or prizes from environmental business competitions. Additionally, social enterprises often monetize their story via branding – e.g. premium pricing for being eco-friendly and community-driven. Donor-funded programs might contract them for specific projects (like supplying paper for a green campaign), providing another income source.

Private Commercial Model (SME)

This model treats water hyacinth purely as a **raw material input** to a conventional business. Viveca Rattan Crafts is a prime example – a private company integrating hyacinth fiber into its product line alongside other materials. The business model is to produce high-quality furniture and homeware for sale in domestic showrooms and export. Here, water hyacinth is part of the supply chain, but the company's core competency is design, manufacturing, and marketing. *Revenue streams:* Sales revenue from furniture and décor items (potentially large orders from hotels or foreign buyers). Profit margins depend on efficient production and branding; environmental benefits are a plus but are marketed in service of the product's appeal (e.g. "nature's furniture" tagline. This model can scale significantly if demand grows, by contracting more raw material suppliers (possibly buying dried hyacinth from village groups) and expanding production capacity. It's a profit-driven model, though often with a sustainability ethos.

Micro-Entrepreneur Model

Besides cooperatives, there are individual artisans or family businesses – for instance, a single craftsman making hyacinth-based goods as part of their broader craft portfolio. They might weave baskets at home and sell at local fairs or to intermediaries. *Revenue streams:* Direct sales to customers, sometimes tourism sales (e.g. a craftsman in Polonnaruwa selling hyacinth mats to visiting tourists at a heritage site). Though small in scale, cumulatively these micro-entrepreneurs form a significant part of the craft sector and can be empowered via training to improve their income. They often diversify, so water hyacinth products might be one of several lines (others could be reed mats, cane ware, etc.), giving them multiple income streams.

Waste Management Service + Product Hybrid Model:

An innovative model is where an entity is paid for water hyacinth removal services and then also generates revenue from products made out of the collected biomass. For example, a local company could contract with a municipality or irrigation authority to clear a lagoon of hyacinth (earning a service fee), and then process that biomass into compost, biogas, or crafts for additional revenue. *Revenue streams:* Service fees from government (or CSR funds) for cleanup, plus sales of by-products (e.g. compost fertilizer bags sold to farmers, or electricity if biogas is converted to power and sold to the grid). While this model isn't yet fully realized in Sri Lanka, it aligns with circular economy goals and could be piloted. It essentially monetizes environmental restoration – a compelling proposition if structured well (it might involve public-private partnerships).

Industrial Processing Model (Future)

Looking ahead, there is potential for larger industrial uses – for instance, a plant that converts water hyacinth to ethanol or biogas at scale, or a factory making fiberboards or pellets. These would be capital-intensive and require steady feedstock supply and technology. *Revenue streams:* Sale of energy (biogas or electricity), sale of ethanol (if fuel grade), or sale of fiberboards/pellets as fuel or material. For example, in other countries water hyacinth has been studied for ethanol production and as an additive in animal feed. If economic viability is proven

and policies (like a biofuel mandate) support it, a business could earn through fuel sales or byproducts (like high-protein silage from hyacinth). Such a model might also generate carbon credits (if it demonstrably reduces methane emissions from rot or offsets fossil fuels). However, these models are not yet in commercial operation in Sri Lanka and would likely need government and investor backing to materialize.

Across these models, the revenue streams primarily come from product sales. In crafting models, this means unit sales of baskets, bags, paper, etc. For many small producers, joining the export value chain (even indirectly) can exponentially increase revenue – e.g., supplying a foreign order of thousands of baskets rather than dozens sold locally. The EDB and global fair-trade networks can facilitate such linkages.

Another potential revenue stream is eco-tourism integration: communities making hyacinth products can offer workshops or demonstrations to tourists for a fee, or run community-based tourism where visitors purchase crafts on-site. This adds experiential income (tour fees, donations) alongside product revenue.

Value addition is key to maximizing revenue. Simply selling raw or semi-processed hyacinth yields minimal returns (since the raw weed is free). Each additional stage – whether weaving into a complex product or transforming into energy – multiplies the value. For instance, turning hyacinth into handmade paper and then into a crafted notebook captures far more value (and price) than selling dried stems. Therefore, business models that integrate more of the value chain (from harvesting to final product) or that innovate unique products tend to have better revenue potential.

Finally, many of these models can tap multiple funding sources during growth: traditional sales, grants (from environmental or rural development funds), impact investments (from social venture funds interested in livelihood and environment outcomes), and crowdfunding (if the story resonates globally). A diversified funding approach can help early-stage enterprises become financially sustainable.

In summary, Sri Lanka's water hyacinth entrepreneurs can be positioned along a spectrum from informal cooperative to formal SME. A healthy ecosystem will include all these models, with

smaller players feeding into larger value chains. By strengthening viable business models and ensuring they have access to markets and financing, the sector can move from scattered pilots to a robust industry – one that turns a profit while delivering social and ecological benefits.

8.7 Barriers to Market Entry and Scaling

Despite the promising models and successes to date, there are several **barriers that new entrants face and challenges to scaling up** water hyacinth utilization businesses. Understanding these barriers is crucial to formulate interventions:

Skill and Knowledge Gaps:

Many potential entrepreneurs or communities lack awareness of water hyacinth's economic uses and the know-how to process it. Initial training is needed in harvesting techniques, drying, and crafting. Without organizations like the Divisional Secretariat or NGOs providing training, villagers might simply view hyacinth as garbage rather than a resource. This dependency on external training can be a barrier to spontaneous market entry. Additionally, more advanced knowledge (e.g. how to make paper pulp or operate biogas units) is confined to a few experts or institutions. Scaling will require broader knowledge dissemination and technical training programs to build human capacity across regions.

Initial Capital and Equipment

Starting a water-hyacinth venture, while low-cost relative to many businesses, still requires some equipment and setup. For crafts, items like sewing machines, weaving frames, knives, and most critically dewatering or drying apparatus can be beyond the means of poor communities. Udeni's group, for instance, struggled with manual dewatering and only scaled up after receiving a mechanical press and a new sewing machine through a project. For larger ventures (like paper making), equipment like beaters, molds, or digesters are needed. Access to affordable credit is limited for rural artisans, and microfinance interest rates can be high. Thus, lack of upfront capital is a barrier both to entry (for a new group to start) and to scaling (for a successful group to invest in better tools or a workspace). Potential mitigations include grant support, soft loans, or equipment donation/leasing schemes via government or CSR programs.

Market Access and Marketing Challenges

Reaching profitable markets is not straightforward for village producers. Entrants face the "last mile" problem of connecting to buyers. They often have no brand recognition and limited marketing channels. Participating in trade fairs or maintaining an online presence requires skills and resources that these small businesses might not have. As a result, many are confined to small local markets where demand is thin and prices are low. Scaling up necessitates breaking into urban retail or export markets, which involves meeting quality standards, packaging, consistency, and dealing with regulations (e.g. export documentation, customs). These can be daunting for first-timers. Without intermediaries or platform support, the market access barrier can stymie growth.

Quality Control and Standardization

For scaling, consistency in product quality is key – especially if catering to large orders or exports. New entrepreneurs might face a learning curve to achieve uniform quality. Issues like uneven drying leading to mold, inconsistent weaving tightness, or colour variations can all reduce product acceptability. Larger buyers demand standardized products (or at least reliable quality batches). The artisanal nature of production, while a selling point, also means variability. Implementing quality control processes (inspections, training on best practices, possibly simple mechanization for uniformity) is a challenge that must be overcome. Until then, small producers may find it hard to scale orders because defects or inconsistency undermine buyer confidence.

Scalability of Production

Many current operations are labor-intensive and slow to scale. Hand weaving or handmade paper production doesn't easily double output without doubling labor. Recruiting and training additional skilled labor is itself a challenge – younger generations may be less interested in manual craft work, or may migrate to cities for other jobs. Thus, labor availability and the time-consuming nature of techniques limit scaling. Mechanization could help (e.g. semi-mechanized looms, hydraulic presses for board-making, or mechanized harvesting to gather more raw material quickly), but those require capital (as noted) and can alter the craft-based employment

dynamic. Striking a balance between maintaining livelihoods and improving productivity is a barrier that needs careful navigation.

Logistical and Infrastructure Barriers

Scaling up from village-level to regional industry highlights infrastructure gaps. Transportation is one – moving bulky materials or finished goods from remote villages to cities or ports can be costly and complicated (poor rural roads, lack of vehicles). This adds to costs and reduces competitiveness. Electricity and utilities can be an issue for processing; some remote areas might not have reliable power to run even simple machinery or to light a workspace for longer hours. Storage facilities for dried hyacinth or finished inventory are often lacking, exposing materials to weather or pests. These infrastructure shortcomings disproportionately affect rural enterprises and present barriers to consistent large-scale operations.

Regulatory and Policy Hurdles

While there is generally an enabling stance toward removing invasives, some regulatory aspects can pose barriers. For example, export regulations require phytosanitary clearances for plant-based products – producers must ensure their dried hyacinth goods are pest-free (possibly fumigated or baked) before shipping, which adds complexity and cost. Compliance with international standards (like no chemical residues, specific labeling requirements, or quality certifications) can be daunting without guidance. If someone wants to produce organic fertilizer or animal feed from hyacinth, they'd need to navigate approvals from the Department of Agriculture or Animal Production – there may be no clear precedent or streamlined process for that, given water hyacinth isn't a standard input. Additionally, business registration, tax compliance, and other formalities can be barriers for informal groups transitioning to formal enterprises. In some cases, entrepreneurs might face bureaucratic delays in obtaining approvals or support promised by policies due to local administrative inefficiencies.

Perception and Cultural Barriers

Some consumers – and even craftspeople – initially perceive products made from "weeds" or waste as inferior or dirty. Overcoming the stigma that water hyacinth is just a nuisance plant can

be a subtle barrier. Changing mindsets to see it as a valuable resource is happening, but slowly. Within communities, some might doubt the income potential or be reluctant to participate in what they consider non-traditional work (especially men might be hesitant to engage in craft-making, seeing it as women's work). These cultural perceptions can limit who joins such enterprises and how boldly products are marketed. A concerted effort in branding and success stories is needed to dispel doubts.

Environmental and Health Concerns

One lesser-discussed barrier is that water hyacinth can accumulate heavy metals and pollutants from the water. If harvested from contaminated water (say near industrial effluents), using it for certain products (especially fertilizer or animal feed) could pose health risks or fail safety standards. Entrepreneurs must be aware of the source – this could restrict the use of hyacinth from some locations. For craft products, this is less of an issue (metals remain locked in fibers and the product isn't ingested), but for any food-related or soil-related use, testing may be necessary. This need for lab testing or ensuring clean supply adds another layer for businesses to consider.

Competition and Market Saturation

As the idea catches on, there is a potential future barrier of competition both domestically and from imports. If many groups start making similar hyacinth baskets without differentiation, the local market could saturate and prices could fall, squeezing margins. Internationally, Sri Lankan producers compete with large-scale producers in Southeast Asia who have been exporting hyacinth crafts for years (Vietnam, Indonesia, Philippines). These competitors often benefit from economies of scale and well-oiled export networks. New Sri Lankan entrants must find ways to differentiate – through superior design, quality, or certified fair-trade/ethical branding – otherwise scaling into export markets could be difficult against entrenched players.

In summary, while the raw material is plentiful and the concept proven, a number of hurdles hinder the smooth expansion of water hyacinth enterprises. Overcoming these barriers will require targeted interventions: training and capacity building, credit and equipment provision,

marketing and logistics support, policy tweaks, and a strong network or platform to support new entrants. The recommendations section of this report will address many of these challenges, proposing solutions to convert barriers into opportunities for strengthening the value chain.

8.8 Alignment with Circular Economy and Inclusive Growth Goals

Water hyacinth utilization in Sri Lanka naturally aligns with both circular economy principles and inclusive growth objectives, making it a compelling model for sustainable development:

At its core, the concept epitomizes “waste to wealth” or rather “waste to resource”. Circular economy aims to keep resources in use for as long as possible and to regenerate natural systems. Using water hyacinth checks both boxes. This invasive biomass is essentially an untapped renewable resource that otherwise goes to waste (or worse, harms the ecosystem). By harvesting and repurposing it into products, we apply several of the “10 Rs” of circular economy: Remove (the weed from nature), Repurpose/Recycle (turn it into new goods), and Recover (derive value in place of virgin materials). Instead of burning or landfilling the weeds, which would be linear approaches, we create a closed-loop where the plant matter re-enters the economy. Furthermore, many hyacinth products (like baskets or paper) are biodegradable – after use, they safely decompose, returning nutrients to the environment, thus closing the loop. This stands in contrast to plastic or synthetic alternatives that would persist as waste. In effect, water hyacinth utilization contributes to a regenerative system: waterways are restored (improving water quality and biodiversity), and the output products avoid use of plastics or timber (reducing waste and deforestation). It’s a clear win-win in circular terms.

Resource Efficiency and Substitution

Hyacinth-based production can reduce dependence on other raw materials. For example, every sheet of paper made from hyacinth and agricultural fibers is a sheet not made from wood pulp, thus saving trees and reducing pressure on forests. Each hyacinth basket potentially replaces a plastic basket. By substituting abundant biomass for scarce or polluting inputs, the approach improves overall resource efficiency of the economy. It also turns a costly problem (weed

management) into an input for industries, offsetting the costs that would otherwise be incurred to dispose of the weed.

8.9 INCLUSIVE GROWTH

Inclusive growth means economic progress that creates employment opportunities and helps reduce poverty, bringing marginalized groups into the fold. Water hyacinth enterprises directly target and benefit some of the most marginalized communities in Sri Lanka – rural women, small farmers, unemployed youth in villages, and even conflict-affected or climate-affected populations. These initiatives create jobs at the local level where opportunities are scarce, thereby distributing economic activity away from urban centers. The model inherently requires local labor for harvesting and crafting, which means the community at the site of the environmental problem is the one gaining economically from solving it.This is a textbook case of inclusive green growth: the approach doesn't rely on high technology or big capital that might exclude people; instead, it *elevates traditional skills* (weaving, crafting) and provides additional training to those who need livelihood support, thus empowering disadvantaged groups.

Gender Inclusion

As noted, women play a leading role in water hyacinth enterprises. This aligns with gender-inclusive growth goals. By providing women with income-generating work that can be done close to home (important in cultures where women juggle household duties), these initiatives enhance women's financial independence and decision-making power. In many cases, women artisans become community leaders and savvy businesspersons, challenging gender norms positively. International frameworks like the SDGs emphasize women's economic empowerment, and this model delivers on SDG5 (Gender Equality) alongside SDG8 (Decent Work) and SDG12 (Responsible Consumption and Production). The Colomboscope festival curators highlighted that Sri Lankan designers working with local materials and upcycling are supporting vulnerable groups and linking living traditions for an inclusive future. Water hyacinth projects are a prime example of this ethos – blending ecological practice with social upliftment.

Community and Rural Development

Inclusive growth also means bridging urban-rural divides. By fostering a hyacinth-based industry in rural areas, value addition and income stay in those communities rather than everything being extracted to cities. It encourages community entrepreneurship, such as the cooperative model where profits are shared and invested locally (in family needs, education, etc.). As incomes rise, so does community resilience. There is also a multiplier effect: successful groups may hire others, purchase local services (like transport, tailoring for bag linings, etc.), thereby stimulating the rural economy. Over time, such grassroots industries can slow rural-urban migration by providing viable livelihoods in villages.

Environmental Restoration and Climate Co-Benefits

The alignment with inclusive growth extends to environmental justice. Often it is the poorest communities who suffer most from environmental issues (like tanks choked by hyacinth affecting farmers' water supply). This model engages those very communities in the solution and ensures they *benefit from restoring their environment*. Cleaner waterways mean improved agriculture and fishing for them, and reduced disease risk. In climate terms, removing hyacinth may reduce methane emissions that rotting vegetation would produce in anaerobic water, and using it as biofuel or material can displace fossil fuel use – thus contributing to climate mitigation in a small way. Adaptation-wise, diversified livelihoods and restored water bodies make communities more climate resilient. These are important aspects of *sustainable inclusive growth*, where economic, social, and environmental gains go hand in hand.

Circular Innovation and Entrepreneurship:

By aligning with circular economy, these enterprises encourage a mindset of innovation among local entrepreneurs – seeing every waste or problem as an opportunity. This is a transformative way to achieve long-term inclusive growth: equipping often-excluded groups (like rural women) with the ability to innovate and participate in new green markets ensures they are not left behind as the country and world shift to greener economies. It also fosters pride and ownership –

communities become *custodians of both economy and environment*, an ideal outcome for sustainable development.

In conclusion, water hyacinth utilization initiatives strongly support Sri Lanka's commitments to a circular, inclusive economy. They operationalize high-level concepts (like circularity) on the ground in tangible ways – cleaning a lake, making a basket, earning a living. Few development interventions tick so many boxes simultaneously. This alignment is a key reason why supporting and scaling these businesses is not just an economic endeavor, but also a strategic social and environmental investment for the country. It harmonizes with national and global goals (SDGs, Paris Agreement, etc.) and showcases Sri Lanka as a leader in community-driven circular solutions.

8.10 Opportunities for Scale

Furthermore, the potential strategic interventions can be discussed under the below areas.

8.10.1 Domestic Scaling Opportunities:

Geographic Expansion:

Many regions in Sri Lanka with water hyacinth infestations have not yet been tapped for enterprise development. For example, the North Central and Eastern Provinces have large irrigation tanks (e.g., Polonnaruwa, Batticaloa) with hyacinth issues. These could replicate the Kurunegala model – engaging local farmer societies or women's groups to start craft or compost enterprises. Since the raw material is *island-wide* (water hyacinth is found in most lowland wetland areas the model can be expanded to dozens of communities. **Cluster-based scaling** could be pursued: identify high-infestation clusters and develop multiple enterprises in those areas, possibly linked to a central facility. The government's plan to establish **"1,000 new handicraft villages"** is an opportunity to integrate water hyacinth crafts into those villages, especially in areas where traditional rush/reed crafts exist (they can incorporate hyacinth as a new material).

Product Line Diversification:

Within existing enterprises, there is room to broaden the **range of products**, which opens new markets. For instance, moving beyond bags and baskets to products like **home storage organizers, lampshades, even footwear** (which hyacinth fiber is used for in some countries). Sri Lankan artisans could experiment with **fusion products** – e.g., hyacinth woven with palmyra or cotton fabric to create new textures. **High-value design collaborations** (perhaps involving local designers or design students working with villagers) could produce contemporary items that attract urban boutique buyers. Another avenue is **furniture components** – supplying woven hyacinth panels or sheets to furniture manufacturers domestically (there is a market for eco-friendly furniture as hotels and restaurants look for sustainable sourcing). By diversifying products, enterprises can increase their revenue and reduce risk (if one product's demand dips, another can compensate).

Institutional and Corporate Partnerships

There is an opportunity to scale demand by partnering with institutions that have sustainability goals. For example, Sri Lankan government offices and banks can adopt eco-friendly office items (as some have started) – imagine if all government offices switched to hyacinth-based file folders, pen holders, wastebaskets, etc., it would create substantial local demand. Corporate CSR programs could also support by procuring hyacinth products (e.g. gift baskets, branded stationery) and in turn support the producer groups. Scaling this requires marketing and advocacy, but it could create steady bulk orders.

Local E-commerce and Retail

Domestically, leveraging e-commerce platforms (like Kapruka, or the Good Market online) can allow small producers to reach consumers across the country. A curated line of "invasive plant products" (including water hyacinth, invasive wood crafts, etc.) could be marketed as a unique green category. Physical retail through outlets like Laksala or the new Crafts Marketing Village in Battaramulla can also be expanded – these channels can carry more hyacinth products, giving

them visibility to tourists and locals alike. As more Sri Lankans practice sustainable living (e.g., avoiding plastics), the local retail market for these products can grow significantly.

8.10.2 INTERNATIONAL SCALING OPPORTUNITIES:

Export of Finished Products: Perhaps the most immediate international opportunity is exporting handcrafted products. With the right support, Sri Lankan producers can tap into the established global market for water hyacinth furniture and baskets. Countries like Vietnam have demonstrated the scale – their hyacinth craft villages export containers of goods globally Sri Lanka can find its niche by emphasizing quality and unique design. Fair trade and ethical market channels are particularly promising – organizations in Europe/US that import from community enterprises (with fair prices) would find the social/environmental story compelling. Also, premium markets like boutique hotel chains or eco-resorts worldwide may source decor items. Attending international trade shows (e.g., Ambiente in Germany for decor, or regional craft expos) with a Sri Lankan hyacinth collection could open export deals. The EDB and missions abroad could facilitate these connections.

Regional South Asian Market

Closer to home, there's opportunity to sell in regional markets like the Maldives (resorts could use hyacinth beach furniture, placemats, etc.), India (huge market for handicrafts with growing eco-conscious urban middle class), and other Indian Ocean islands. Trade within the region might have lower barriers and freight costs. Marketing Sri Lankan hyacinth crafts as part of a South Asian sustainable design ethos could attract buyers in these neighboring markets.

Raw Material or Semi-processed Exports

In addition to finished goods, Sri Lanka could potentially export semi-processed hyacinth fibers or pulp to countries where it's needed. For instance, if a paper company abroad wants plant fiber for specialty paper, we could supply dried, shredded hyacinth fiber (assuming it meets phytosanitary requirements). Or an international bio-packaging company might incorporate hyacinth fiber into their products. While exporting raw dried stems is low value (and bulky), exporting processed fiber, yarn, or pulp could add some value domestically while feeding larger

manufacturers abroad who have scale. This could be an avenue if domestic product-making capacity is lagging the raw supply.

Technology and Knowledge Transfer

As Sri Lanka scales its expertise, it could export not just goods but knowledge and technology. For example, if we develop an efficient community biogas system for hyacinth, that model could be exported to other countries with similar issues (e.g., African or Asian nations dealing with the weed). Sri Lankan experts could become consultants in invasive species utilization. Similarly, South-South collaboration could be pursued: perhaps a joint venture with an Indian biofuel company or a Thai craft exporter – where Sri Lanka contributes raw material or craftsmanship and the partner contributes machinery or market access. These creative international partnerships can significantly expand scale and impact.

Leveraging International Support and Climate Finance

There is a global recognition of nature-based solutions and circular economy's role in climate action. Sri Lanka's water hyacinth project can be scaled via tapping into international climate finance or green funds. For example, the Green Climate Fund (GCF) or Global Environment Facility (GEF) could fund a larger rollout in multiple river basins, tying it to ecosystem restoration and livelihood development (the CRIWMP project was GCF-funded and could be a precedent). International NGOs might also fund expansions in exchange for carbon and biodiversity benefits. This kind of infusion can accelerate scaling in terms of geographic coverage and infrastructure.

New Product Opportunities – Bio-based Industries

Internationally, there's growing interest in bio-based materials – e.g., bioplastics, natural fiber composites, and sustainable textiles. Water hyacinth's cellulose-rich fiber can be a feedstock. Sri Lanka could position itself in research or small-scale production of such materials. For instance, producing fiberboards or particle boards from hyacinth (to use in furniture or construction) could open a new export category (especially if formaldehyde-free green boards are in demand). Another example: some innovators are making charcoal briquettes and activated carbon from water hyacinth for use as natural filters. If Sri Lanka developed a high-quality activated carbon

from hyacinth (leveraging its adsorbent properties), it could export that for water purification uses. These are more technologically intensive opportunities but could be pursued with research partnerships (perhaps with local universities and foreign labs). It diversifies the portfolio beyond crafts, tapping into larger industrial supply chains.

In essence, the scaling opportunities are multifaceted – horizontally to more communities and vertically into more products and markets. Sri Lanka has an opportunity to become a regional leader in invasive plant utilization – a niche that can garner international acclaim. By systematically scaling, the country could in future convert thousands of tons of water hyacinth (currently a menace) into a stream of value-added exports and local products, supporting hundreds of rural families. Achieving this will require surmounting the earlier-noted barriers, strategic investment, and likely a coordinating mechanism (no single small enterprise can scale. nationally alone – a consortium or accelerator-driven approach is needed). The next section on policy environment will discuss how conducive the current landscape is for such scaling, and what adjustments might facilitate it.

8.11 POLICY AND REGULATORY LANDSCAPE IN SRI LANKA

A supportive policy environment is crucial to enable market access, reduce regulatory hurdles, and provide infrastructure for water hyacinth enterprises. This section reviews relevant Sri Lankan policies, regulations, and institutional factors:

Market Access and SME Promotion Policies: Sri Lanka's government in recent years has emphasized **inclusive and sustainable businesses** as part of its development agenda. The National Policy Framework and the SME development policies encourage private-sector-led growth, especially in rural industries. Specific to crafts, the government (through the National Craft Council and EDB) runs programs to promote rural artisans, such as establishing craft villages and marketing centers. For example, the **Crafts Marketing Village in Battaramulla** was set up to give artisans from across the country a direct market in the capital. Water hyacinth craft producers can leverage these existing schemes – e.g., by becoming registered craftsmen with the Council to receive training and stall space. Additionally, the government often sponsors

participation of artisans in international expos through EDB; aligning water hyacinth products with these initiatives can ease market entry abroad. The **Sri Lanka Export Development Board** has identified sustainable products and giftware as an area for export growth, and has given guidance and exposure to companies like Viveca Rattan to enter foreign markets. Continued advocacy could see hyacinth products included in national export product catalogs and trade delegations.

8.12 REGULATORY CHALLENGES:

Invasive Species Regulations: As noted earlier, Sri Lanka has very old legislation – **Water Hyacinth Ordinance of 1909** – which technically prohibits cultivation of water hyacinth and calls for its destruction. While largely obsolete (since the plant is widespread and the law is not enforced in any punitive way against those removing it**), this highlights that any *utilization must be coupled with removal*, not propagation**. The 1909 ordinance and subsequent plant protection regulations mean one cannot intentionally grow water hyacinth on new sites (for example, you shouldn't spread it to an unaffected tank just to harvest later). This is sensible from an ecological view. For entrepreneurs, it means raw material should be sourced from existing infested areas and handled carefully to avoid any spread (e.g., ensuring seeds are not transported inadvertently). If any entrepreneur misguidedly thought to "farm" water hyacinth for volume, that would be against policy and counterproductive environmentally. Instead, policy encourages **control and eradication** of invasive species – utilization is welcome as a control method, but not if it incentivizes maintaining the weed in ecosystems. Policymakers will need to ensure utilization efforts don't conflict with eradication programs (for instance, if a lake is slated for complete clearance via herbicide, that could disrupt a craft group's raw material source – coordination is needed so that manual removal for enterprise is prioritized over destructive removal).

Environmental and Harvesting Permits:

Currently, anyone removing water hyacinth (especially from public water bodies) should coordinate with local authorities (e.g., irrigation engineer or agrarian services). There isn't a heavy regulatory burden here – in fact authorities are usually happy for communities to remove

it. However, in protected areas (if any wetlands with hyacinth fall under wildlife sanctuaries), permission from the Department of Wildlife Conservation might be needed to collect biomass. Similarly, the Coast Conservation Department might have a say if it's in a coastal lake. These cases are rare but should be noted. One improvement would be formalizing community user rights to invasive biomass – a policy could explicitly authorize registered local groups to harvest invasives from state waters for economic use, to avoid any ambiguity.

Product Regulations*:*

For handicrafts and furniture, there are no specific regulatory barriers beyond general consumer product safety (e.g., ensuring no sharp edges, etc.) and any fumigation requirement for exports. For consumable products (like compost, biogas, feed), there are some regulatory hoops. A **fertilizer** made from water hyacinth might need approval under the Fertilizer Act – ensuring it meets quality standards and is free of harmful substances. Likewise, if someone develops animal feed, the Department of Animal Production and Health would likely require trials or certification to ensure it's safe (due to fiber content and possible toxins if any). These processes are navigable but can be time-consuming without support. The government could ease this by commissioning research or providing fast-track testing for such new products.

Infrastructure Gaps and Rural Development

One policy challenge is the lack of rural industrial infrastructure – often termed the *"last mile infrastructure"* problem. The government has identified infrastructure gaps (transport, storage, processing centers) as a barrier for rural producers in general. There are ongoing programs: for example, **Provincial Industrial Development Authorities (IDAs)** are meant to support cottage industries. The news about the North Central Province Local Industrial Development Program (with JICA support) equipping Mana Ceylon with machines thecolombopost.org shows that provincial policy instruments can aid these businesses. However, such support is not uniformly accessible. A national program to provide **common facilities centers** for invasive plant processing could be a game-changer – e.g., setting up mini processing parks with drying, baling, and storage facilities in key regions (possibly through public-private or donor funding). This aligns with rural development goals to provide infrastructure and value addition at source.

Inclusive Policy – Livelihood and Environment Nexus

Sri Lanka's climate change and environmental policies increasingly stress nature-based solutions and community adaptation. For instance, the Climate Change Secretariat and related policies encourage utilizing ecosystem approaches for adaptation (removing invasives to restore water flows, etc.). The **CRIWMP (Wew Gam Pubuduwa)** project which backed hyacinth crafts is a result of such policy thinking. It integrated livelihood development into climate adaptation. One can expect future policies or funds (like Climate Adaptation Fund grants) to continue this integrated approach. On the biodiversity front, the National Invasive Species Policy (if finalized by the Ministry of Environment) likely highlights community participation in controlling invasives. That provides a supportive policy backdrop, though it might focus more on control than utilization. We can advocate that it explicitly mentions utilization for livelihoods as a strategy, which would firmly legitimize these enterprises in the policy realm.

Market Development and Standards

One area where policy could help is by developing standards and certifications for these green products. For example, an "Eco Label Sri Lanka" certification is being promoted to authenticate eco-friendly products. Hyacinth crafts could qualify and benefit from that label to build consumer trust. Additionally, if the Bureau of Standards were to issue guidelines on water hyacinth fiber quality or products, it could help streamline quality across producers. Currently, lack of formal standards means each producer operates on their own terms, which can make it hard for big buyers to trust consistency. This is more of a soft policy measure but significant for scaling market access.

Legal Identity and Business Environment

Many rural groups operate informally. To engage in larger contracts or exports, they may need to register as businesses (sole proprietors, cooperatives, etc.). The government's **ease of doing business** initiatives and SME registries should be made accessible to these groups. Simplifying registration or providing special guidance to convert a women's society into a cooperative or company can formalize them, making them eligible for bank loans and government schemes. Also, tax policies like **VAT or other levies** could impact profitability if not managed – small craft

businesses are often below tax thresholds, but if scaling up, they should be prepared. A supportive stance might be to exempt or offer tax holidays to green community enterprises for initial years to help them grow.

Supporting Laws and Rural Finance

Broader policies like financial inclusion, microfinance regulation, and cooperative law all play a role. Ensuring that microfinance institutions offer fair interest rates and that government banks (like Regional Development Bank) have tailored loan products for craft or agro-waste enterprises would address financial barriers. There might also be scope under **enterprise Sri Lanka loan schemes** or similar to prioritize circular economy startups – the policy could explicitly list invasive plant utilization as an eligible sector for concessionary loans.

Labour and Social Security

As these enterprises grow, labour laws may kick in (if they formally employ people). Right now they are typically informal or self-employed arrangements. Over time, policies to bring such workers under social protection (insurance, EPF/ETF if applicable) will be needed to ensure inclusive growth remains equitable and the jobs are decent and secure. The cooperative model often provides self-governed welfare, but with scaling, formal labor considerations come in.

In summary, **Sri Lanka's policy environment is cautiously supportive** of this space – there are certainly no outright prohibitions on making use of water hyacinth (rather, it is encouraged as part of invasive control). The main gaps lie in the absence of explicit mention of these solutions in policy frameworks and the need for coordinated support (infrastructure, finance, marketing) which current policies touch on but in a fragmented way. The regulatory hurdles are surmountable but require some navigation; streamlining those (especially for export and for new product approvals) would accelerate progress.

It would be beneficial for an inter-ministerial effort (involving environment, agriculture, industries, and social services) to craft a targeted program or policy directive for **"Invasive Plants for Circular Economy and Livelihoods"** – essentially legitimizing and promoting what the Hyacinth project aims to do, and allocating resources to scale it up. Aligning this with rural

development and poverty alleviation strategies (such as integrating it into Samurdhi livelihood programs) could also strengthen pathways to scale.

8.13 Financial and Infrastructure Needs

To scale water hyacinth enterprises from isolated successes to a thriving sector, certain financial investments and infrastructure developments are required. The needs identified has been summarized below.

8.14 Capital Requirements

Seed Funding for Start-ups

New community groups or entrepreneurs need initial capital to cover training, basic equipment (Sewing machine -main drying mats, gloves, knives), and perhaps a modest shed or workspace. This can often be a few hundred thousand LKR (~a few thousand USD) per group to get started. There is an opportunity for impact investors or grant programs to provide seed funding in exchange for social impact. A key grant program with a strong private sector engagement and partnership element would be able to facilitate such financial requirements. Comparatively the investment is relatively low and implemented through a community model, considering the impact potential from an environmental and community empowerment angle this has a high potential to have a sound and strategic financing element.

Equipment and Technology Upgrades

For existing enterprises poised to scale, investment in equipment is crucial. This includes: more de-watering presses, mechanical shredders for fiber, improved looms or weaving machines for consistent mats, paper pulping machines, solar dryers, etc.

A cluster of enterprises could share some of these if located near each other. In an instance where capital funding is required government schemes could step in with low-interest loans or leasing options or the private sector banks can be utilized. Perhaps a dedicated “Green enterprise

equipment fund" could be established to subsidize 50% of the cost of needed machinery for qualified water hyacinth businesses, making it easier for them to invest.

Working Capital

One often overlooked need is working capital for operations, especially as businesses take on larger orders or enter export. They may need to buy raw materials in bulk (pay harvesters or other villages), hold inventory, or extend credit to buyers. Working capital loans or revolving funds would help them not stall due to cash flow issues. For example, if an exporter places an order for 1,000 baskets to a cooperative, the coop might need upfront cash to mobilize more harvest and labor to fulfill it well before payment is received. Setting up a revolving credit line for producer groups could possibly be managed by a microfinance partner or a cooperative bank could be a solution.

8.15 INFRASTRUCTURE INVESTMENTS:

Establishing localized processing centers can dramatically increase efficiency and output. A **"Water Hyacinth Resource Center"** at district level, equipped with large drying rooms (with solar or bioenergy heaters for rainy days), chopping machines, storage, and quality testing labs. Such centers could serve multiple villages around. They would take in fresh hyacinth, process it to a stable intermediate (like dried fiber or pulp), and either supply it to local artisans or even process further to final products. The investment could come from public funds or a public-private partnership (e.g., a private investor runs it as a fee-for-service facility, charging producer groups a nominal fee to use equipment). Land and building would be a cost – local authorities might provide land or an unused warehouse for conversion. Since this is capital heavy, it might require donor or government grants to catalyze, but once running, it could even operate commercially (selling processed fiber to companies like Viveca or exporting pulp).

A potential and less capital-intensive pathway is to utilize banana fibre facilities and after evaluation the situation to add water hyacinth processing embedded as they both share very similar machinery and equipment at processing. This could potentially be considered as a threat

to the banana product lines but in terms of machinery and equipment utilization it would be an efficient aspect to consider and explore.

Transportation and Logistics

There is a need for vehicles even as simple as a community tractor with a trailer or a small lorry – to collect and distribute materials and products. Investing in a few shared vehicles in hyacinth-rich areas can reduce the burden on producers. Perhaps a provincial council or cooperative federation could own these and rent them out at low cost. Moreover, improvements to access roads to tank sites (so that harvested hyacinth can be trucked out easily) are an infrastructure aspect local government can handle as part of rural road development.

Energy, Utilities and Digital Infrastructure*:*

Investment in such renewable energy infrastructure would further enhance circularity and cut operating costs (and could attract green energy grants). But at an initial stage bio gas, solar or battery pack installation would require more capital where this could be considered at a phase 2.

A modest investment in digital literacy and an online marketplace platform specifically for these products (could be integrated with existing e-commerce) would boost market access.

8.16INVESTMENT OPPORTUNITIES

Social/Impact Investors

There is a growing pool of impact investment funds looking for triple-bottom-line returns (social, environmental, financial). Water hyacinth enterprises offer exactly that. Impact investors could fund a cohort of businesses (through equity in a social enterprise like Mana or through a debt fund for cooperatives) and expect moderate financial returns alongside measurable impact metrics (tons of hyacinth removed, women employed, etc.).

For example, an impact fund might invest in scaling Mana Ceylon's production capacity in return for a share of its export's profits, or invest in a new venture that will make biofuel from hyacinth.

Given the global interest in circular economy startups, positioning these as green innovation ventures could attract such capital.

Corporate CSR and Foundation Grants

Sri Lanka's larger corporations (and multinational companies present) often have Corporate Social Responsibility programs focusing on environment and livelihoods. They could sponsor elements of this strategy – e.g., a bank could fund a training center for hyacinth craft as CSR, or a manufacturing firm could donate machinery to a community group. Likewise, international foundations that fund women's empowerment or invasive species control might give grants to expand the project. These are usually one-time injections but can cover critical needs like training for hundreds of women or building a community workshop.

Government and Donor Funding

The Sri Lankan government can allocate part of its rural development or environmental management budget to these initiatives. For instance, the Ministry of Industries or Ministry of Rural Development could have a special grant scheme for "circular economy MSMEs" offering matching grants for capital purchases.

Also, multilateral donors (UNDP, FAO, World Bank) could integrate this into broader projects (like a hypothetical "Ecosystem Restoration and Livelihood Project"). There's also potential to tap climate finance as mentioned – preparing a proposal for GCF focusing on ecosystem-based adaptation through hyacinth removal and livelihood generation might secure multi-million-dollar funding that can build infrastructure and subsidize the accelerator program over a few years.

Private Sector Partnerships

Another investment angle is partnering with established private companies in complementary sectors. For example, a paper packaging company might invest in a hyacinth pulp facility to source sustainable fiber for its products (giving them a green USP). A furniture retailer might partner with local producers, investing in design improvements and buying in bulk (like a contract

manufacturing deal). These partnerships often come with technical assistance too (the private partner wants the venture to succeed to secure supply).

Microfinance and Cooperative Finance:

On a smaller scale, encouraging microfinance institutions to create tailored loan products for these enterprises is an opportunity. If the perceived risk is mitigated (perhaps by a partial credit guarantee from a development program), microfinance could scale up lending for working capital or small equipment at reasonable rates. Also, mobilizing savings within communities (a traditional savings group that reinvests in their own business) can be a source of capital – though usually limited, it fosters ownership.

Financial Viability and Returns:

It's worth noting that many hyacinth enterprises have low overhead costs once set up (free raw material, cheap labor inputs), so their profitability can be good if they reach markets. A small investment can yield sustained income.

For example, an investment of LKR 1 million to equip a 10-person cooperative could enable them to produce perhaps LKR 2-3 million worth of products annually within a couple of years. A great return in terms of local income generation.

For larger investments like a centralized facility, revenue streams from selling processed fibers or final products could make it self-sustaining in a few years if volume is achieved. These are the sort of numbers investors will consider; initial research suggests positive unit economics if markets are secured.

Infrastructure Synergies

There's an opportunity to integrate with existing infrastructure programs. The government's rural infrastructure development (roads, warehouses under various programs) could be slightly realigned to support this – e.g., ensure new rural storage buildings consider space for agro-based product storage. Even educational infrastructure: vocational training centers in villages could

include a space and tools for hyacinth craft training. Using existing underutilized public buildings as production or training centers (with minimal refurbishment) is a quick infrastructure win.

In conclusion, the needs are relatively clear: financing for startups and scale-ups, and infrastructure for processing and logistics. These needs present investment opportunities with tangible impact. The financial and infrastructural inputs, if provided in a coordinated way, will significantly de-risk and accelerate the water hyacinth circular industry. The resulting businesses will not only repay economic dividends but also social/environmental dividends, which is why multi-stakeholder investment (public, private, philanthropic) is justified. The next and final section will tie together these findings into concrete recommendations, including how an accelerator program can orchestrate these support elements for high-potential enterprises.

8.17 Establish the Water Hyacinth Accelerator Program

Key recommendation is to **design and implement a structured Accelerator Program** to identify, nurture, and scale high-potential water hyacinth enterprises.

Cohort Selection

Use a competitive process to select perhaps for enterprises or enterprise ideas representing the identified high potential water hyacinth utilizing product categories and potentially new products. Selection criteria should emphasize impact (livelihoods created, environmental benefit) and business viability. Diversity of models should be also suggested to be encouraged – e.g., include some craft coops, one paper company, one bioenergy idea, etc., to explore the spectrum.

Curriculum and Mentorship

The program will provide an intensive curriculum covering business planning, financial management, product design, marketing & branding, operations optimization, and investment readiness.

This should be delivered via workshops and one-on-one mentorship. Each enterprise is paired with mentors: a business mentor (to guide on strategy and financials) and a technical mentor

(experienced in relevant tech like weaving or biofuel). For instance, successful entrepreneurs from related sectors (like the founder of Viveca or Earthbound) can coach participants on pitfalls and scaling tips. The curriculum should also incorporate exposure visits – e.g., visiting a large craft exporter's facility or a similar project in another country virtually – to broaden perspectives.

Market Access Support

During the accelerator, arrange a **demo day or exhibition** where the cohort can pitch or display to potential buyers, investors, and partners. Leading up to that, help them refine their branding and story. Possibly engage a professional marketing consultant to help each enterprise create a slick product catalog or website. The accelerator can also connect them to EDB officers for export guidance, and to local retail chains. Essentially, the program acts as a bridge between these grassroots businesses and the market/investment ecosystem.

Financial Support Linkages

The accelerator could preferably include a finance track that links firms to seed funding for pilots, concessional working-capital loans, and purchase-order or invoice-discounting to bridge buyer payment cycles. Partner banks will align revolving credit limits to offtake schedules and offer partial guarantees and escrow to de-risk first transactions. A matching fund will co-finance essential equipment at producer sites and Common Facility Centres. Participants will receive practical support in bookkeeping, costings, cash-flow planning, and digital payments, with an on-call financial literacy helpline for ongoing guidance.

Peer Learning and Network

The cohort should meet regularly to share experiences – building a **network of hyacinth entrepreneurs** who can continue supporting each other beyond the program. Also integrate them with larger entrepreneur networks like existing alumni group (e.g. Good Life X alumni), so they become part of Sri Lanka's startup ecosystem, not isolated.

Ongoing Support

After formal program period, continue light-touch support for another 6-12 months. This could include quarterly check-ins, troubleshooting assistance (e.g., if a policy issue arises, the program team can liaise with authorities), and helping them hire talent if needed. Perhaps create a digital forum for all cohorts (if running annually, cohorts can cross-pollinate).

Expected outcomes of the accelerator

Enterprises will emerge with concrete growth plans (like scaling production 3x in a year, entering 2 new markets, or launching a new product line), and with the skills and networks to execute those plans. Success will be measured in increased incomes for communities, more hectares of water cleaned, and successful investment deals or market contracts signed. Over time, we can run multiple cohorts, creating a pipeline of capable enterprises such that the overall sector expands dynamically.

Monitoring, Evaluation, and Continuous Improvement

As a wrap-around recommendation, institute strong monitoring and evaluation (M&E) for all interventions. Track metrics such as: number of enterprises created, jobs (with gender breakdown), income levels, quantity of water hyacinth removed/used, number of products sold (local/export), etc. Use these to continuously refine strategies – e.g., if certain products aren't selling, adjust training emphasis; if some barrier persists (like transportation), feed that back into policy advocacy for more resources. Publishing the results and success stories (perhaps an annual report on "Circular Economy Solutions – Water Hyacinth") will also build credibility and momentum, attracting more partners and funding to keep scaling.

These recommendations, when implemented in concert, create an ecosystem that enables water hyacinth enterprises to thrive from grassroots training to global marketing. The accelerator program serves as a nucleus for driving these changes by concentrating resources and expertise on the most promising solutions and then radiating learnings outward.

By following this roadmap, Sri Lanka can transform the challenge of water hyacinth into an engine of environmental restoration, women's empowerment, and sustainable economic growth. It is a

vision where a purple-flowered weed, once a symbol of nuisance, becomes emblematic of Sri Lanka's ability to innovate and foster inclusive prosperity in harmony with nature. The time is ripe to seize this circular opportunity and support these enterprises to scale new heights.

8.18 Recommendations for Business Strategy and Market Access

Drawing on the analysis above, we propose a set of strategic recommendations to support and scale water hyacinth circular enterprises in Sri Lanka. As per the scope of this project the above proposed framework for the accelerator program to incubate high potential ventures. These overall recommendations target key leverage points from capacity building to market linkages which should be implemented in parallel or as complementary to the accelerator program for the long term with the objective of creating a larger sustainable eco system for water hyacinth utilization in Sri Lanka.

1. Develop a National Initiative for Invasive Plant Utilization

Recommendation: Launch a coordinated national initiative (e.g. "Wage to Wealth: Invasive Plants for Circular Economy") under a relevant ministry or multi-stakeholder task force.

This initiative should set clear targets (e.g., number of enterprises to be established, volume of hyacinth removed/used, income generated) and align resources from environment, industry, and rural development agencies. By elevating the profile, it will legitimize these efforts and ensure policy support is streamlined (e.g., ease any regulatory kinks as discussed). The initiative can also oversee the creation of standards and certifications for water hyacinth products – e.g., a "Sri Lanka Green Product" label – enhancing market trust. It would actively coordinate with local government to identify priority sites (infested water bodies with willing communities) for new enterprise development, essentially creating a pipeline of projects to support.

2. Strengthen Community Capacity and Organization

Recommendation: Provide widespread training and extension services to build the human capital needed.

This can be included with conducting training-of-trainers programs for craft instructors, paper-making technicians, and business mentors who can then train village groups (scaling knowledge transfer).

Developing and distributing simple toolkits and guides (in Sinhala/Tamil with illustrations) on water hyacinth processing techniques, safety measures, and sample product designs.

Facilitating the formation of cooperatives or producer companies among artisans for collective strength. Encouraging independent artisans to group together will assist in bulk buying, sharing equipment, and collective marketing. Government should simplify registration for such groups and perhaps incentivize it via small grants for those who formalize a cooperative.

Ensuring GEDSI (Gender Equality, Disability and Social Inclusion) principles are embedded to continue prioritizing women, include youth, and be mindful of including any marginalized ethnic or caste groups in these areas. Possibly set targets like at least 50% women participation (which is already naturally occurring) and encourage leadership roles for them.

By building robust community institutions around these businesses, we ensure longevity and self-reliance beyond project support.

3. Facilitate Access to Finance and Equipment

Recommendation: Establish a "Circular Enterprise Support Fund", perhaps managed by a development bank or public-private entity, to offer blended finance packages.

Such fund would provide:

a) Small grants for nascent groups (to cover training and basic kit)

b) Low-interest loans or lease-to-own schemes for equipment upgrades (e.g., presses, sewing machines, papermaking equipment)

c) Working capital credit lines.

As part of this, coordinate with microfinance institutions to design tailored loan instruments (e.g., loans where repayment schedules match the production cycle of crafts, and interest rebates if

social targets are met). Encourage banks to treat these enterprises as priority sector lending (possibly guaranteed by a portion of the fund to reduce risk). Furthermore, seek ESG/CSR contributions or impact investment to capitalize this fund by pitching it as an innovative financing model for green livelihoods.

Complementing finance, create an Equipment Library or Sharing Scheme in each region: a facility where groups can borrow or use larger tools that they might not afford individually. For example, a mobile dewatering unit or a chipping machine could rotate between villages as needed. This maximizes use and reach of limited machines.

4. Invest in Processing and Logistics Infrastructure

Recommendation: Set up Common Facility Centers (CFCs) in key hyacinth-rich districts.

These centers should be multi-functional and cater to the following functions involved in the business operation.

a) The housing solar/industrial dryers

b) Chopping and pulping machines

c) Secure storage, and perhaps a small design workshop.

They can be managed by a cooperative federation or local authority and used by any producer group in the area for a nominal fee or membership. The government and donors can fund construction and initial operation, with the goal of them becoming self-sustaining via service fees. Additionally, ensure each target region has at least one vehicle (like a tractor-trailer or small truck) dedicated to transporting raw hyacinth and finished products; this can be part of the CFC or owned by a cooperative union.

A private sector engagement or a joint venture model also can be explored as an alternative route for the CFC operation or where such government or local authority owned models do not work efficiently. This would reduce the funding burden for the government and also would enable absorbing the private sector efficiencies and profit-oriented objectives.

However, it is recommended to evaluate the ground level situation as well the local dynamics to before establishing such CFCs.

Furthermore, in such centres can be added or equipped with innovation infrastructure. Would be a progressive step to pilot a bioenergy unit at one of these efficiently functioning centers (e.g., a biogas digester to handle any surplus or waste hyacinth (which can produce gas to run a generator for the center's power or to fuel drying heat). Also, provide small solar-powered fans or dehumidifiers for village drying sheds to cope with monsoon periods. These infrastructural supports will reduce production downtime and improve efficiency, enabling scaling. This action is recommended to consider once the self-sufficient status is acquired and sufficiently established. Key focus should be to get the intended main objectives to be achieved and sustained.

5. Enhance Product Development and Quality

Recommendation: Bring in design and technology expertise to elevate the product offerings.

This can be done by Partnering designers from local design schools/ institutions (Fashion Design, Interior decorator departments, Technical Colleges, Textile Manufactures etc.) or initiatives like Colombo scope to work with producer groups in developing new, trendy product lines that appeal to high-value markets. For example, explore blending materials (fabric + hyacinth), new color schemes, or entirely new product categories (perhaps modular wall panels made of woven hyacinth for interior décor).

Organizing design competitions or hackathons for creating innovative uses of water hyacinth (like university contests to design, say, a hyacinth-based water filter or toy). The best ideas can receive seed funding and mentorship to become enterprises with the partnerships with the private sector and NGO funding.

Implementing a quality assurance program: train a cadre of quality inspectors drawn from the community to monitor product quality before shipping. Develop simple quality checklists (e.g., moisture content must be below X%, weave tightness standard, weight tolerance, etc.). For export-oriented production, engage Sri Lanka Standards Institution (SLSI) or a testing lab to

certify batches if needed (especially for something like paper where pH or strength might matter for certain buyers).

Explore standardizing processed inputs – for instance, if dried hyacinth straw could be baled and given a grade, this could allow mixing and matching supply for larger orders while maintaining uniform quality. This is more technical but worth investigating at the processing centers.

6. Strengthen Market Linkages and Branding

Recommendation: Aggressively pursue market development through a two-pronged approach – domestic market promotion and export market entry.

Domestically, run an awareness and promotion campaign about invasive-based eco-products. This could involve social media marketing that tells the story of how buying a water hyacinth product helps clean lakes and support rural women empowerment with community building. Perhaps engage celebrities or influencers as brand ambassadors to endorse these products or gift them. Encourage government ministries to procure eco-products (set an example by policy – e.g., the Ministry of Environment could mandate using invasive plant paper for all their reports or advocate public policy on Green Procurement as policy published by the cabinet office of Sri Lanka).

Expand shelf space for these products in urban retail and liaise with lifestyle stores or supermarkets to stock a “green living” aisle containing hyacinth baskets and stationery. Possibly create a dedicated brand or label for these community-made products (similar to how “Palmyrah” products are branded by Palmyrah Board). A unifying brand (for example, “Re:Weave Sri Lanka” or “EcoHyacinth”) could be developed, under which various groups sell, giving them a collective identity that is easier to market.

Internationally, leverage EDB and diplomatic channels to find buyers. Organize a showcase (physical or virtual) for international fair-trade importers, sustainable product buyers, etc., featuring samples from our producers. Use Sri Lanka’s embassies to display these items in exhibitions. Also, utilize online marketplaces: empower groups to list products on platforms like Etsy, Alibaba (for bulk), or specialized fair-trade sites.

If individual groups can't handle that, set up a central export unit possibly managed by a resourceful government or private entity in which aggregates products from multiple producers and handles international orders, logistics, and payments, distributing the earnings back to producers. This solves the problem of each small group figuring out export compliance.

Focus on telling the impact story to differentiate from other countries' products: highlight the habitat restoration aspect unique to Sri Lanka's approach and the human stories. This can justify premium pricing and attract impact-oriented buyers. This could very well to be implemented through strategic storytelling, digital resources, social media and other means to penetrate the niche and the potential markets with high level of conversion growing the sector.

7. Policy and Advocacy Measures

Recommendation: Work with policymakers to implement enabling policy actions:

a) Formally incorporate invasive utilization into the National Invasive Species Action Plan with clear roles and budgets.

b) Advocate for tax breaks or incentives: e.g., exempting equipment imports for processing from duty, or providing tax holidays to companies that invest in communities (similar to BOI incentives for big industries but tailored to social enterprises).

c) Encourage the government to include this sector in its reporting for SDGs and climate commitments – this raises its profile and could draw international support.

d) Simplify any regulatory procedures: Perhaps create a "single window" at IDAs or District Secretariats for these enterprises to get all needed approvals and register with ease.

Ensure that any upcoming plastic-ban or sustainability regulations (like banning certain plastic items) promote alternatives that could be made from water hyacinth (for example, ban plastic flower pots and promote coir or hyacinth pots, etc.), indirectly boosting demand.

9 MARKET ACCESS STRATEGIES

The impacts of uncontrolled water hyacinth erode livelihoods, strain local economies, and degrade aquatic ecosystems. This fast growing, nutrient – rich invasive aquatic macrophyte, offers both opportunities and challenges. (Canning, 2025) With coordinated control and responsible management, the biomass can be systematically harvested, preprocessed, and channeled into value-creating uses that generate local jobs and revenues. This circular approach finances ongoing removal, strengthens community participation, restores water flow and habitat health, and converts a persistent environmental burden into a sustained economic benefit in Sri Lanka.

This introduction positions water hyacinth as a circular business opportunity anchored in environmental restoration and community benefit. The study maps existing enterprises, value chains, and stakeholders, and evaluates demand, pricing, and unit economics to locate viable entry points. Governance, compliance, and partnership structures with communities, buyers, and public agencies are defined alongside risk, mitigation, and financing options. A phased pathway moves from pilots to scale through targeted technical assistance, secure offtake, and an accelerator that reduces production and market-access risk. Execution is guided by clear milestones and KPIs, linking financial returns to measurable gains in waterway health and community livelihoods.

9.1 EXISTING WATER HYACINTH ENTERPRISES

This section documents Sri Lankan ventures using water hyacinth as a raw material. Evidence was compiled through a desk review of public sources during August to September 2025, supplemented by prior professional contacts.

The Ehetuwewa case was identified through the Subhagya Gammana 500 programme and accessed via National Enterprise Development Authority (NEDA) referrals, with telephone confirmation of basic details. As no national registry exists in Sri Lanka for Water Hyacinth products, the dataset is an indicative snapshot under validation through interviews, document checks, and targeted site visits.

From the research and work done in this study, it was identified that water hyacinth utilisation for handicrafts, weaving, and paper production in Sri Lanka can be grouped under four main modalities as below.

1. Government-attached and cooperative women's groups
2. Private women's groups and collectives
3. Private and individual micro-operators
4. Multi-fibre craft and furniture manufacturers and multi-supplier retailers that carry water hyacinth products in their product range

Based on this approach, Table 3 presents the identified cases and their locations. Similar operations are likely active but not yet documented. A fuller inventory will require additional fieldwork and coordination with strategic government and private institutions.

A total of 13 businesses were identified through this method. The portfolio comprises one government-affiliated operation, two private women's collectives, three individual operators, and seven multi fibre craft sellers and retailers. Most serve domestic demand, with a smaller share fulfilling occasional export orders.

Table 3: Key existing businesses and community ventures utilizing Water Hyacinth in Sri Lanka

Business name and location	Type of products	Comments
Saubhagya Group, Ehetuwewa	Handicrafts (Ladies bags, Hand bags, Slippers, Mats, Purses, Pencil cases, Hats, Custom products, etc)	The group is attached to the Ehetuwewa Divisional Secretariat.
JJ Products, Ehetuwewa	Handicrafts (Ladies bags, Hand bags, Slippers, Mats, Purses, Pencil cases,	This is a private operation working with community

	Hats,Cusion covers, Custom products, etc)	member groups and a product trainer.
IMA Water Hyacinth Products, Tangalle	Handicrafts (Ladies bags, Hand bags, School bags, Slippers, Mats, Purses, Pencil cases, Custom products, Hats., Coasters, Table mats, Pens, Pet Boxes, Baskets, Ornamental items, Packaging materials, etc)	This is a private operation – youth and female owned.
Madhu Eco Products, Hikkaduwa	Paper (Paper, Packaging, etc)	This is a private operation.
Mana Ceylon (Pvt) Ltd, Rajanganaya	Paper	This is a private operation led by Mr. Ranil Wasantha.
Earth Ambassador, Mahara	Paper and packaging	This is a private operation led by Mr. Gamini Alexander, an Eth Pawura award winner, with access to multiple women's groups nationwide.
Viveca Rattan Crafts Colombo	Furniture, Decorative items and basketry	An established manufacturer using natural fibers including water hyacinth and exporting to hotels and overseas buyers.

Agasthya Crafts & Weaves, Kandy	Handicrafts	An artisan enterprise weaving plant fibers including water hyacinth and training rural craftspeople.
Community Co-ops (CRIWMP Project), Anguruwewa Cascade and Dry Zone villages	Handicrafts	Farmer and women cooperatives that harvest water hyacinth and produce crafts with basic equipment support.
Paper Link, Colombo	Handmade paper and stationery	Produces paper goods using water hyacinth blended with other natural fibers.
Nature's Paper, Karuwalagaswewa, Puttalam	Gift boxes and paper goods	Uses water hyacinth and other plant fibers for value-added paper products.
Eco.lk, Sri Lanka	Bags and soft goods	Incorporates water hyacinth fiber alongside cane, reed, and jute.
Art Outdoor Furniture Kegalle	Indoor and outdoor furniture	Manufactures woven furniture that includes water hyacinth material.
Cane Cult (Pvt) Ltd,	Furniture	Supplies rattan and wood furniture with

Colombo		selected water hyacinth lines.
Saru Organic, Ilippugamuwa	Bio-inputs	Converts harvested water hyacinth into natural fertilizer and compost.

Few examples of the Water Hyacinth based handicraft products are given below.

Figure 14: Water Hyacinth based handicrafts and related products produced by local operators.

Despite the high concentration of water bodies, and the implied availability of substantial water hyacinth biomass, mature handicraft activity has not penetrated several regions. Where operations exist, they remain dispersed and weakly networked, which constrains aggregation, quality consistency, and market access, and ultimately limits scale. This is clearly visible in the

mainly identified businesses in table 3 where actual producers are scattered geographically and remain as smaller scale operations.

Current water hyacinth landscape comprises community groups, private small scale business operations, retailers, established firms near urban centers such as Colombo, and craft initiatives in Central Province that supply domestic and export markets. Enterprises range from those working exclusively with water hyacinth to multi-fiber producers that use hyacinth as a complementary material. This variety indicates that water hyacinth can serve as a free or low-cost input for village-level crafts and as a credible sustainable material in higher-end furniture and packaging.

However, Ehetuwewa stands out relatively as a specialized hub for water hyacinth craft. Under the Saubhagya 500 Gammana program, local groups were mobilized and trained on the material preparation and product manufacturing from water hyacinth, creating a pocket of skills, simple processing capacity, and supply linkages. That specialization provides a strong anchor for buyer engagement and for piloting standards and quality systems that can be replicated elsewhere.

Refer to the author founded information from Ehetuwewa

Table 4: Information related to the Water Hyacinth eco system in Ehetuwewa

Category	Item	Unit	Min_LKR	Max_LKR	Notes
Equipment	Sewing machine	each	120000	150000	Current market price range
Equipment	Hand press (2-roll) - current	each	50000	50000	Current price
Materials	WH dried fiber	kg	400	650	Buy price
Inputs	Handles - wooden (pair)	pair	480	500	
Inputs	Handles - plastic (pair)	pair	550	620	
Logistics	Transport per delivery	delivery	100	100	Typical bus courier sack (4 kg to 5 kg)
Labour	Daily wage	day	400	700	Piece-rate/daily model

Labour	On-call manpower	day	900	1000	
Labour	Monthly retainer	month	9000	11000	
Labour	Manpower - fixed	month	5000	5000	

** WH products (handicrafts mainly) seem to be priced around in the 20% to 40 % profit margins.

Apart from the handicrafts, artisan products and paper/packaging products, and out of the products and technologies which were identified as well, organic fertiliser, biochar and animal feed production is note mentioning as observed and identified water hyacinth utilisation. All these products outcomes are not 100% using water hyacinth only but it is among the other feed stocks which is being utilised for production.

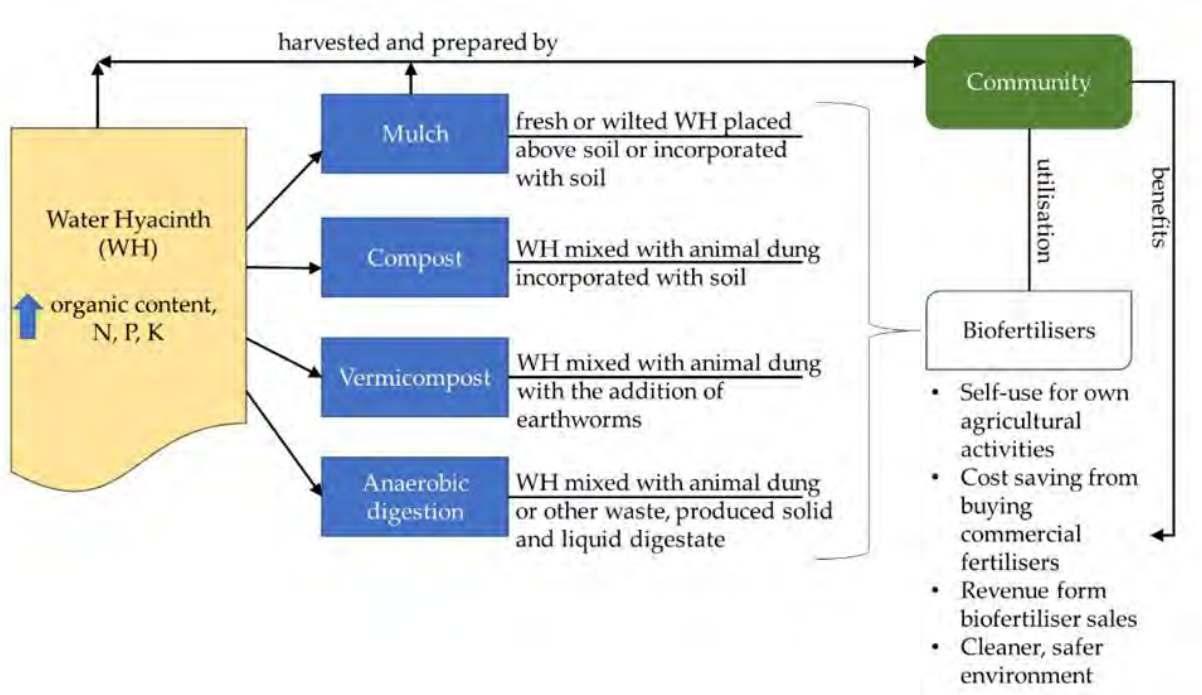


Figure 15: Water Hyacinth valorisation as a bio fertilizer with its community gains

(Harun et al., 2021b)

In Sri Lanka, water hyacinth is a common pathway into organic amendments through co-composting with cattle manure, paddy straw, or sawdust, rather than as a sole input, and trials

report agronomic benefits when appropriately blended. Recent studies indicate that finished composts made with water hyacinth can meet Sri Lanka Standards for heavy metals, though site selection and feedstock ratios must be managed carefully (Amarasinghe, 2021). Key limitations include high moisture and an imbalanced C:N ratio in fresh biomass that require carbon-rich bulking agents and good process control to minimise nutrient losses. Redirecting cleared biomass from canals and tanks into composting supports irrigation access and ecosystem function while returning stabilised nutrients to agricultural soils, creating a practical circular solution for infested water bodies. (Ranawake et al., 2025)

Livestock plays significant role in Sri Lanka. Due to its nutritional value of the water hyacinth, it carries a considerable potential to be used as an animal feed in Sri Lanka. Several studies have been conducted where water hyacinth can be a feed addition or a main feed stock as poultry and animal feed which could be potentially used in Sri Lanka. This could lead to a significant reduction of the production cost in livestock management. However, it is not recommended to use water hyacinth grown in heavily polluted areas due to its high absorption of toxic materials. (Wimalarathne & Perera, 2019)

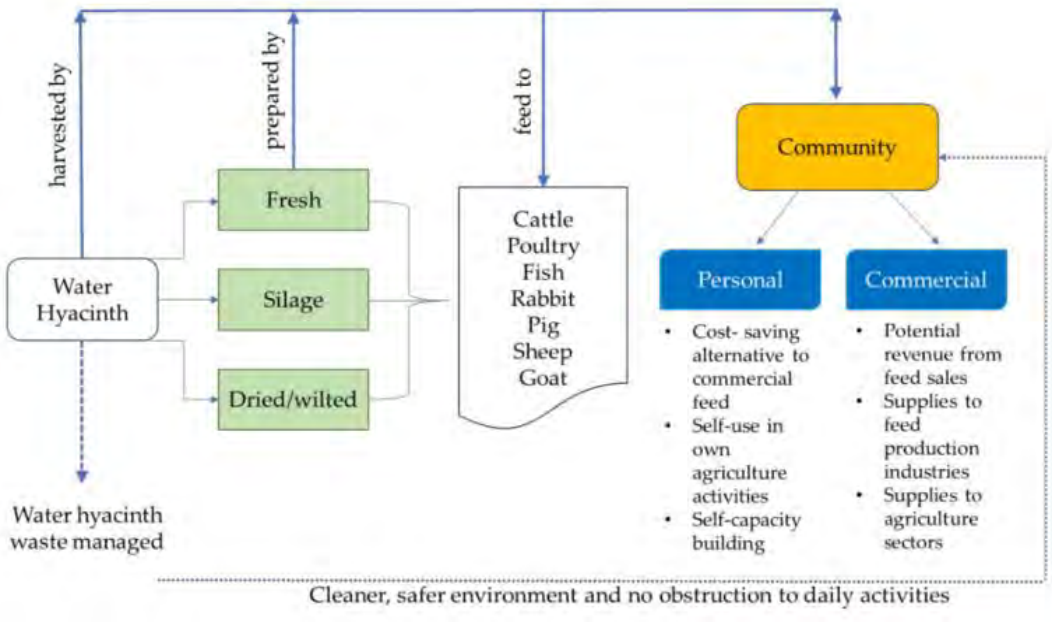


Figure 16: Water Hyacinth animal feed potential and community benefits (Harun et al., 2021b)

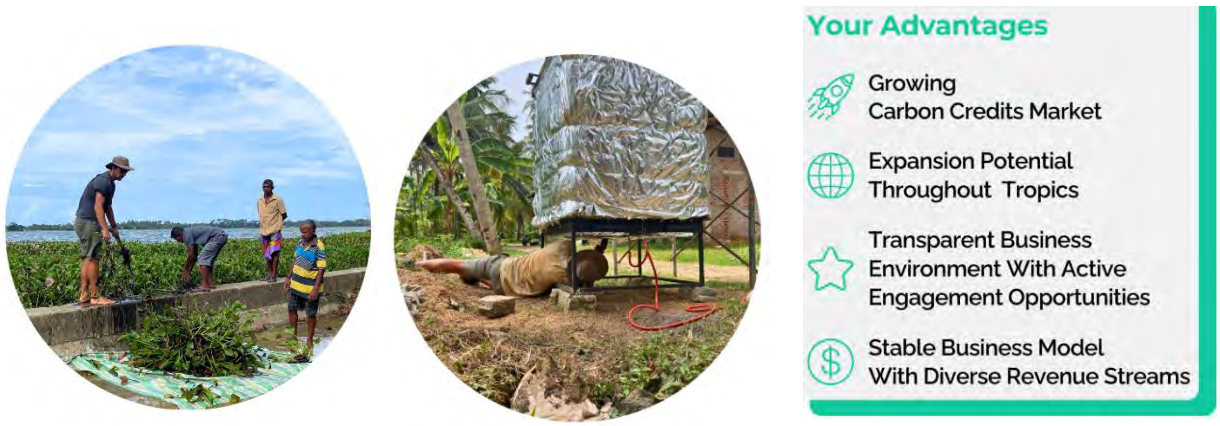


Figure 17: FUSCUM soil enhancer venture with domestic level pyrolysis unit

(Betzold, 2020)

Also, through this scoping study, we came across a currently functional business entity FUSCUM Soil Enhancer in Sri Lanka where they are using specifically water hyacinth to produce biochar/soil conditioner through a community decentralised model with a domestic scale pyrolysis unit which would be further explored for its feasibility as a scalable avenue. Furthermore, the model has incorporated carbon credit generation which is an attractive element of the model which would then provide the opportunity to extract further economic value for the community or the members of the water hyacinth utilization process. (Betzold, 2020)

The current water hyacinth utilisation foot print is fragmented geographically as well as an eco-system. There is clear need to connect producers, codify best practices, and coordinate offtake with markets to extract greater economic value out of water hyacinth. These steps will enable community groups, individual artisans, single-material specialists, and multi-fiber manufacturers to grow as a part of a larger eco system of water hyacinth utilisation. A structured collaboration platform, shared quality and compliance guidance, and targeted market development can convert scattered activity into a resilient, scalable value chain.

9.2 Demographics and Social Profile of Water Hyacinth Enterprises

This section profiles the participants in water hyacinth enterprises and explains how their organisations function across the value chain. Coverage includes workforce composition by

gender, age, and role, together with ownership and organisational structures, income contributions and seasonality, and access to skills, finance, and markets. The analysis distinguishes community groups and cooperatives from established firms and single-artisan units, noting the presence of social objectives, the participation of women and youth, and the position of actors along the informal to formal spectrum. Vulnerabilities such as irregular order cycles and occupational safety risks are identified alongside documented social benefits, including livelihood diversification and local stewardship of waterways. The purpose is to support sound business decisions with an accurate and comprehensive view of capacities and constraints.

Key demographic and social characteristics in the water hyacinth value chain are discussed below.

9.2.1 GENDER

Based on the field visit to Ehetuwewa and the contacted through the primary connections, a major portion of the water hyacinth based weaving and craft production was mainly done by the women members in the community. Both the Saubhagya community and the JJ products in Ehetuwewa were women led. Most of them were working either from home or from one main location from 8 am to 1 pm while fulfilling their other commitment like taking care of their children after the schools, other house chores, side businesses etc. This allows them to have more flexibility in their lives

Field observations during the Ehetuwewa visit indicate that the majority of participants engaged in water hyacinth harvesting, preprocessing, and weaving were women, including housewives and female heads of household. Production was organized either from home or at a central location in morning hours, with piece-rate arrangements that enabled participants to align paid work with caregiving and household responsibilities while generating a reliable secondary income stream. This gendered division of labour and home-based organization is consistent with documented experiences in South and Southeast Asia, where water hyacinth craft enterprises are predominantly women-led and structured around existing skills and domestic routines.

Across Sri Lanka's handicraft sector, women make up a substantial proportion of producers, and hyacinth-based livelihoods follow the same pattern. The broader handicraft sector in Sri Lanka, where **54% of the ~150,000 craft producers are women**. (Lype, 2020) Participation has been shown to increase women's control over earnings and strengthen their voice in household and community decisions. As producer groups formalize, women often move from production into roles in quality control, purchasing, bookkeeping, and group leadership.

Targeted support can accelerate these gains. Practical design and quality training, simple tools, and safe workspaces raise productivity. Group orders and fair contracts stabilize incomes. Access to savings groups or microfinance enables small equipment purchases and working capital. Childcare during training sessions and safe transport from harvesting sites reduce participation barriers. When these elements are in place, women's enterprises become reliable suppliers, local stewardship of waterways improves, and inclusive growth follows (Kariyawasam et al., 2021)

9.2.2 AGE AND YOUTH INVOLVEMENT

Many current artisans are middle-aged adults with traditional skills, but there is growing effort to involve **youth** in these green enterprises. Young people, including rural youth and recent graduates, are being drawn in as designers, entrepreneurs, or technical innovators. An infusion of youth brings digital savvy and innovation – some young entrepreneurs promote hyacinth products via social media and explore e-commerce, expanding the market beyond local towns. In an accelerator scenario, nurturing young innovators to start businesses could be key to diversification.

9.2.3 COMMUNITIES AND LIVELIHOODS

Thousands of major and minor tanks (man-made reservoirs) located particularly in the dry zone of the country are infested with world's worst AIAPs, such as S. molesta and E. crassipes. (Kariyawasam et al., 2021) Due to this fact there is an apparent correlation of WH Most hyacinth initiatives are rooted in farming and fishing communities in the dry zone and wetlands. These communities suffer the direct ill effects of invasive overgrowth. By intervening to clear out the block irrigation canals and water ways, gaining access to fishing and also clearing out the stagnant

water mosquito breeding sites due to water hyacinth , these communities gain strong incentives Furthermore by turning to craft production, they diversify their livelihoods beyond seasonal agriculture, building resilience to climate and economic shocks.(Lype, 2020)For example, the dry-zone farmer groups involved via CRIWMP earned extra income in the off-season by crafting hyacinth products, supplementing their farming earnings (Kariyawasam et al., 2021). Many of these communities are low-income and some are recipients of government poverty alleviation programs (Samurdhi), indicating that hyacinth enterprises are reaching the bottom of the pyramid population. Additionally, in certain cases, war-affected or displaced populations have been engaged (analogous to how Earthbound Creations employs war-affected women for paper-making, demonstrating how such eco-businesses can be vehicles for post-conflict livelihood support. (Earth Bound Creations, 2025)

9.2.4 EDUCATION AND SKILL LEVELS

The artisans typically have basic education. Specialized knowledge (weaving, crafting) is often inherited or learned through government/NGO training workshops or inherited by their earlier generations. For instance, the Divisional Secretariat in Ehetuwewa **trained local villagers in hyacinth craft** in 2018, teaching them how to process the plant and weave products. (Wew Gam Pubuduwa, 2025) This indicates that with even short-term training, individuals can acquire the necessary skills, meaning the barrier to entry skill-wise is moderate. Continued mentorship in design and business, however, is needed to refine their products for sophisticated markets.

9.2.5 CULTURAL ACCEPTANCE

Using water hyacinth for products is relatively new in Sri Lanka (compared to traditional cane or reed craft). Yet, there is an encouraging openness among communities to adopt this *"waste-to-wealth"* practice, especially as they see tangible benefits like cleaner water and income. The pride in creating something beautiful from a nuisance weed is palpable – local artisans gain social recognition as *environmental stewards*. Moreover, these enterprises often form tight-knit **cooperative groups**, enhancing social cohesion and collective action in the village (for example, coordinated harvesting efforts to clear a whole tank). Women artisans also report greater confidence and leadership.

In summary, water hyacinth enterprises in Sri Lanka are characterized by **women-led, community-based participation**, engaging vulnerable rural populations and equipping them with new skills. This demographic profile underscores the inclusive nature of the initiative – creating jobs for those who need them most, and doing so in a way that values traditional knowledge (weaving) while addressing a local ecological problem. Going forward, continuing to prioritize gender inclusion, youth engagement, and community ownership in these enterprises will be critical for scaling impact.

10 TECHNICAL CHAPTER

10.1 APPLICATIONS OF WATER HYACINTH CONVERSION TECHNOLOGIES: A CATEGORIZED REVIEW

10.1.1 TECHNOLOGY CATEGORIZATION

Technological applications in this field span a diverse range of scales and complexities. Based on current literature and ongoing research, they can be broadly categorized into High-Scale Industrial or Large-Scale Technologies, Medium-Scale Technologies, and Community-Level Applications. This classification not only reflects the varying operational scales but also highlights differences in feasibility, resource requirements, and potential impact, providing a clear framework to assess and compare these approaches. The review considers 30 technology applications.

Table 5: Identified Water Hyacinth applications

Production	Study Summary	Novelty
High-Scale Industrial / Large-Scale Technologies		
Bioethanol Production from WH Using Different Microbial Inoculants	Fermentation-based conversion of WH biomass into bioethanol using different microbial inoculants Process: pretreatment, enzymatic hydrolysis, fermentation, distillation. Co-culture microbes improved ethanol yield.	Comparative evaluation of multiple microbial inoculants and demonstration of co-culture fermentation to enhance ethanol yields from low-lignin aquatic biomass; offers a low-cost route for decentralized biofuel production. (Rani & Kumar, 2022)
Extraction of Cellulose Nanofibers (CNFs) from WH	Extraction of cellulose nanofibers from WH leveraging low lignin content (4.1%). Methods tested: chemical-free,	Single-step alkaline extraction reduces chemical use and energy; Produces high-quality CNFs from invasive biomass for sustainable nanomaterial production.

	alkaline, combined sodium chlorite + alkaline. Alkaline treatment alone effectively removed lignin producing CNFs (10–30 nm).	(Ramesh & Kumar, 2023)
WH as a biomass	Review of WH as a biomass feedstock for biochar, biomethane, biohydrogen, biogas and wastewater treatment. Covers thermochemical and biological conversion pathways.	Integrates multiple valorization pathways showing dual benefits (pollution control + energy) and regional opportunities in tropical countries. (Kaur et al., 2020)
Water Hyacinth Biochar and Pyrolysis Temperature	Pyrolysis at 350°C, 550°C, 750°C produced biochar with temperature-dependent properties: higher T decreased yield and some elements but increased pH, ash, surface area, nutrient content, liming capacity; lower CEC at high T.	Temperature–property relationships enable tailored biochar for soil fertility (350–550°C) or liming & carbon sequestration (550–750°C). (Gezahegn et al., 2024)
Water Hyacinth for Heavy Metal Removal	Field demonstration showing water hyacinth effectively absorbs heavy metals and nutrients from wastewater; composted contaminated biomass retained heavy metals and was unsuitable as compost under health regulations.	Real-world pilot highlighting biosorption potential and post-use safety constraints; informs policy on biomass reuse. (Chunkao et al., 2012)
Water Hyacinth in Fired Brick Production	Blending dried water hyacinth (5–20%) with clay and firing at 900°C. Up to 10% WH produced lightweight, thermally efficient bricks with acceptable mechanical properties.	Converts invasive plant into sustainable building material improving insulation and reducing brick mass. (Goel & Kalamdhad, 2018)
Water Hyacinth-Derived Carbon for Supercapacitors / Activated Carbon	Carbonization and activation of water hyacinth to produce high-surface-area carbons tested for adsorption and electrochemical energy storage; methods include chemical activation and gamma pretreatment.	Produces competitive activated carbons and electrode materials from low-cost biomass for water treatment and energy storage. (Materials Study, 2023)
Biohydrogen Production (Dark Fermentation)	Dark fermentation of hydrolyzed water hyacinth	Demonstrates biohydrogen production from invasive aquatic

	stems using anaerobic mixed cultures; optimization of substrate and pH via response-surface methods led to defined hydrogen yields and rates.	biomass and practical optimization for fermentation conditions. (Pattra & Sittijunda, 2017)
Biogas Generation (Anaerobic Digestion)	Anaerobic digestion studies assessing water hyacinth as a feedstock; co-digestion and pretreatments improve methane yields; energy balance examined for electricity generation.	Valorizes abundant invasive biomass into renewable energy at municipal/farm scale and shows co-digestion benefits. (Owuor, 2018)
Medium Scale Technologies		
Floating Wetlands / Constructed Wetlands for Wastewater Treatment	Floating wetland systems using water hyacinth for polishing municipal/industrial wastewater; achieve reductions in BOD, nutrients and suspended solids.	Low-cost, nature-based treatment scalable to municipalities with biomass management considerations. (Wang & Li, 2019)
Nutrient Removal in Eutrophic Water Bodies	Use of water hyacinth to absorb excess N and P in eutrophic lakes and ponds to mitigate algal blooms.	Demonstrates effectiveness in nutrient uptake and bloom control; useful for regional water quality management. (Reddy & DeBusk, 2005)
Pesticide Degradation in Agricultural Runoff	Application of water hyacinth to degrade pesticides (e.g., ethion) and reduce agricultural runoff impacts; plant–microbe interactions aid degradation.	Plant–microbe synergy in degrading recalcitrant pesticides in agricultural runoff. (Nidheesh & Gandhimathi, 2020)
Arsenic Removal from Contaminated Water	Bench and pilot studies using water hyacinth roots and biomass to reduce arsenic concentrations prior to filtration.	Low-tech pretreatment option for arsenic-affected regions that can be implemented in resource-limited settings. (Singh & Tripathi, 2013)
Water Purification Filters (Point-of-Use)	Development of household/institutional filters using processed water-hyacinth-derived sorbent media (raw, carbonized, activated) to remove turbidity, metals and organics.	Affordable point-of-use water treatment option from locally available biomass. (Guna, 2017)

Biofertilizer Production (Composting)	Composting of water hyacinth (alone or co-composted) and assessment of nutrient profile, maturity and safety for agricultural application.	Offers nutrient recycling and soil amendment potential when heavy metals are managed. (Kaur et al., 2020)
Biodegradable Films & Bioplastics (Medium Scale)	Extraction of cellulose/hemicellulose to formulate biodegradable films and polymer blends; mechanical and biodegradation tests for packaging applications.	Local feedstock for biodegradable polymers reducing fossil plastic dependence. (Sangkhom & Chaiwut, 2018)
Activated Carbon for Water/Air Purification (Medium Scale)	Production of activated carbon via carbonization and chemical activation for adsorption of contaminants in water and air purification systems.	Creates high-value adsorbents from waste biomass for environmental technologies. (Nidheesh & Gandhimathi, 2020)
Community-Level Applications		
Handicrafts & Handloom Products (Baskets, Mats, Rugs)	Community-level fiber extraction and hand-weaving into baskets, mats, rugs, placemats and decorative items. Evaluates processing, durability and market acceptance.	Converts invasive weed into livelihoods; low-tech, culturally appropriate income source. (Guna, 2017)
Community Biofertilizer (Local Composting)	Small-scale composting initiatives producing biofertilizer for local farms; assessments consider maturity, nutrient content and safety.	Enables circular agriculture at community level; requires monitoring for heavy metal contamination. (Kaur et al., 2020)
Small-Scale Biogas / Household Digesters	Household-scale anaerobic digesters using water hyacinth to produce cooking gas and bio-slurry for fertilizer.	Decentralized energy solution turning a nuisance into household cooking fuel and soil amendment. (Owuor, 2018)
Floating Gardens / Urban Agriculture	Small floating gardens on water hyacinth platforms for vegetable cultivation in flood-prone or urban areas; links food security with phytoremediation.	Combines urban food production with biomass control and nutrient recycling. (Datta & Islam, 2015)
Aquarium & Decorative Uses	Use of water hyacinth in aquariums and decorative installations for small-scale	Adds economic value through tourism and decoration while aiding small-system water quality. (Guna, 2017)

	aesthetic and water quality benefits.	
Animal Bedding & Mulch (Community Farms)	Chopped/dried hyacinth used as animal bedding and garden mulch; studies assess moisture, decomposition and microbial safety.	Provides farm-level circular reuse; alternative to straw in some regions. (Kaur et al., 2020)
Educational & Community Awareness Projects	School and community projects using water hyacinth for environmental education and small-scale product development.	Builds local capacity for waste-to-resource initiatives and raises awareness on invasive species management. (Guna, 2017)

10.2 SUMMARY OF WATER HYACINTH TECHNOLOGY APPLICATIONS

Table 6: Water Hyacinth application summary based on scale, methodology and novelty

Study No.	Study Title / Application	Scale	Methodology Summary	Novelty
1	Bioethanol Production from Water Hyacinth Using Microbial Inoculants	High	Pretreatment, enzymatic hydrolysis, fermentation with microbes, ethanol quantified.	Co-culture microbial evaluation improves yield.
2	Extraction of Cellulose Nanofibers from Water Hyacinth	High	Alkaline/sodium chlorite treatments, mechanical disintegration, characterization via TEM/XRD/TGA.	Single-step alkaline reduces chemical use and energy.
3	Water Hyacinth as a Biomass: A Review	High	Systematic literature review on energy and wastewater valorization.	Integrates multiple valorization pathways.
4	Water Hyacinth Biochar and Pyrolysis Temperature	High	Pyrolysis at 350–750°C, physicochemical analysis.	Tailored biochar for soil fertility or liming.
5	Heavy Metal Removal – Bueng Makkasan, Thailand	High	Field pilot for wastewater biosorption; composting analyzed for metal retention.	Real-world pilot with biosorption and safety insights.

6	Water Hyacinth in Fired Brick Production	High	Blended 5–20% WH with clay, fired at 900°C, mechanical testing.	Eco-friendly lightweight bricks with insulation.
7	Water Hyacinth-Derived Carbon for Supercapacitors	High	Carbonization and activation; electrochemical testing.	High-surface-area carbons from biomass.
8	Biohydrogen Production (Dark Fermentation)	High	Anaerobic fermentation of hydrolysate; pH/substrate optimization.	Biohydrogen from invasive aquatic biomass.
9	Biogas Generation (Anaerobic Digestion)	High	Anaerobic digestion, co-digestion, methane yield analysis.	Renewable energy from aquatic biomass.
10	Floating Wetlands / Constructed Wetlands for Wastewater Treatment	Medium	WH planted in floating wetlands; BOD, nutrients measured.	Low-cost nature-based municipal treatment.
11	Nutrient Removal in Eutrophic Water Bodies	Medium	Water hyacinth growth monitored in ponds/lakes; N and P uptake measured.	Demonstrates bloom control and nutrient management.
12	Pesticide Degradation in	Medium	Plant–microbe treatment of ethion and other pesticides.	Plant–microbe synergy in pesticide degradation.

	Agricultural Runoff			
13	Arsenic Removal from Contaminated Water	Medium	Bench/pilot study with roots and biomass; arsenic quantified.	Low-tech pretreatment for arsenic-affected regions.
14	Water Purification Filters (Point-of-Use)	Medium	Processed WH as sorbent; household-scale filtration; turbidity/metals removed.	Affordable point-of-use water treatment.
15	Biofertilizer Production (Composting)	Medium	Composting WH alone or co-composted; nutrient content and maturity assessed.	Nutrient recycling and soil amendment.
16	Biodegradable Films & Bioplastics	Medium	Cellulose/hemicellulose extraction; film preparation; mechanical/biodegradation tests.	Local feedstock for biodegradable polymers.
17	Activated Carbon for Water/Air Purification	Medium	Carbonization and chemical activation; adsorption tests.	High-value adsorbents from biomass.
18	Handicrafts & Handloom Products	Community	Fiber extraction, hand-weaving into mats, baskets, rugs.	Converts invasive weed into livelihood.

19	Community Biofertilizer (Local Composting)	Community	Small-scale composting; nutrient and safety assessment.	Circular agriculture at community level.
20	Small-Scale Biogas / Household Digesters	Community	Household-scale anaerobic digesters; cooking gas and bio-slurry production.	Decentralized energy and soil amendment.
21	Floating Gardens / Urban Agriculture	Community	Floating platforms using WH for vegetable cultivation; monitoring yield.	Combines food production with biomass control.
22	Aquarium & Decorative Uses	Community	WH used in aquariums/decorative installations; water quality monitored.	Adds economic value via aesthetics and water quality.
23	Animal Bedding & Mulch (Community Farms)	Community	Chopped/dried WH used as bedding/mulch; decomposition and microbial safety analyzed.	Farm-level circular reuse.
24	Educational & Community Awareness Projects	Community	School/community projects using WH for education and small products.	Builds local capacity and awareness.
25	Bioethanol Production Using	High	Dark fermentation of hydrolysate; hydrogen quantified.	Valorization of invasive aquatic biomass.

	Dark Fermentation			
26	Water Hyacinth-Derived Composite Materials	Medium	Cellulose fibers integrated into polymer composites; mechanical testing.	Adds value to biomass as reinforcement material.
27	Biochar for Carbon Sequestration	High	Pyrolysis at 550–750°C; carbon content and surface area analyzed.	Mitigation of greenhouse gases via biochar.
28	Paper Production from Water Hyacinth Fibers	Medium	Fiber pulping, sheet formation, and mechanical testing.	Local biomass utilization for paper products.
29	Pellet Fuel Production	Medium	Dried WH compressed into pellets; calorific value measured.	Renewable solid fuel from aquatic biomass.
30	Activated Carbon for Dye Removal	Medium	Chemical activation of WH; adsorption of dyes in wastewater.	Wastewater remediation using biomass-derived adsorbent.

10.3 Analysis for Community-Level Resource Recovery and Livelihoods Feasibility

Community-level resource recovery and livelihood approaches focus on low-tech, scalable solutions that deliver tangible socio-economic benefits while addressing environmental challenges. Practices such as handicrafts and handloom products, local composting for biofertilizer, small-scale biogas digesters, floating gardens, animal bedding, and community education initiatives not only manage water hyacinth effectively but also support local

entrepreneurship, enhance food security, promote energy self-sufficiency, and build environmental awareness. These hands-on, visible interventions empower communities by integrating ecological management with practical livelihood opportunities.

Table 7: Community level gains and merits on Water Hyacinth utilisation different applications

Study No.	Application	Practicality & Community Benefit
18	Handicrafts & Handloom Products	Converts an invasive weed into mats, baskets, and rugs. Encourages local entrepreneurship, traditional skills, and income generation.
19	Community Biofertilizer (Local Composting)	Promotes circular agriculture. Residents gain organic fertilizer for home gardens; easy to replicate at village level.
20	Small-Scale Biogas / Household Digesters	Produces cooking gas and bio-slurry. Energy self-sufficiency plus fertilizer benefits. Simple technology for rural/urban households.
21	Floating Gardens / Urban Agriculture	Combines water hyacinth control with vegetable production. Enhances food security, urban greening, and income.
23	Animal Bedding & Mulch	Supports smallholder farmers; reduces waste disposal issues; improves farm sustainability.
24	Educational & Community Awareness Projects	Increases knowledge, enhance local stewardship, and engages schools and youth.

10.4 COMMUNITY-FRIENDLY ENVIRONMENTAL SOLUTIONS

Community-friendly environmental solutions focus on low-tech, accessible interventions that directly improve local ecosystems and water quality. Approaches such as floating or constructed wetlands, nutrient removal in eutrophic water bodies, point-of-use water purification filters, and localized arsenic removal combine environmental management with practical community engagement. These initiatives not only enhance water quality and public health but also enable communities to take an active role in maintaining their local environment.

Table 8: Community friendly environmentally friendly Water Hyacinth solutions and its merits

Study No.	Application	Practicality & Community Benefit
10	Floating Wetlands / Constructed Wetlands	Low-cost municipal-scale wastewater treatment; communities can maintain small wetland units for pond/lake water quality improvement.
11	Nutrient Removal in Eutrophic Water Bodies	Simple pond/river monitoring and manual harvest; helps control blooms and supports fisheries.
14	Water Purification Filters (Point-of-Use)	Household-scale water filters using WH biochar or fibers. Affordable and health-promoting.
13	Arsenic Removal from Contaminated Water	Low-tech filtration can be localized in arsenic-affected villages.

10.5 MEDIUM-TECH APPROACHES – POTENTIAL FOR COMMUNITY INTEGRATION

Medium-tech approaches involve solutions that require some training or infrastructure but can still be adapted for community use. Applications such as larger-scale biofertilizer production, aquarium and decorative uses, paper production from water hyacinth fibers, and pellet fuel

manufacturing offer opportunities for cooperatives, microenterprises, and small-scale energy production. While these interventions need additional effort or equipment, they provide practical pathways for communities to generate income, utilize resources sustainably, and engage in value-added activities.

Table 9: Potential community integrated Water Hyacinth products

Study No.	Application	Feasibility at Community Level
15	Biofertilizer Production (Composting at larger scale)	Could be scaled up for cooperatives or farmer groups.
22	Aquarium & Decorative Uses	Niche, small-scale business opportunity; limited sustainability impact.
28	Paper Production from WH Fibers	Requires some pulping equipment but can support microenterprises.
29	Pellet Fuel Production	Low-tech pelletizing possible at village-scale; energy product is valuable but requires effort and initial investment.

10.6 High-Tech / Industrial Applications

High-tech and industrial applications encompass advanced technologies such as bioethanol production, supercapacitors, biohydrogen, and specialty carbon products. While these approaches are not practical for direct community engagement due to their complexity, high costs, and infrastructure requirements, they offer significant industrial value. Communities can still contribute indirectly by supplying harvested water hyacinth to industrial facilities, creating a link between local resource management and high-tech value chains

10.7 TECHNOLOGY PRIORITIZATION MATRIX IN 3 DIMENSIONS

Table 10: Community engagement feasibility + environmental impact + economic potential of Water Hyacinth applications

Study No.	Application	Community-Engagement Feasibility	Environmental Impact	Economic Potential
1	Bioethanol Production	Low	High	Low
2	Extraction of Cellulose Nanofibers	Low	Medium	Medium
3	Water Hyacinth as a Biomass:	Low	High	Low
4	A Review	Low	Medium	Medium
5	Water Hyacinth Biochar and Pyrolysis Temperature	Low	High	Low
6	Heavy Metal Removal – Bueng Maxkasan. Thalland	Low	Medium	Medium
7	Water Hyacinth in Fired Brick	Medium	Medium	Low
8	Supercapactiors	Low	High	Medium
9	Biohydrogen Production (Dark Fermentation)	Low	Medium	Low
10	Sesentic Removatal	High	High	Medium
11	Floating Wetlands /	Medium	Medium	Low
12	Constructed Wetlands for Wastewater Treatment	Medium	Medium	Medium
13	Nutrient Removal in Eutrophic Water Bodies	Medium	High	Medium
14	Pasticide Degradation in Agricultural Runoff	Low	High	Medium
15	Arsenic Removal froms	Medium	High	Medium
16	Community Biofertilizer (Local Composting)	High	Medium	Medium
18	Small-Scale Biogas /	High	High	Medium
19	Household Digestors	High	High	Medium
20	Floating Gardens / Urban	Medium	Medium	Low
21	Aquarium & Decorative	High	Medium	Medium
22	Animal Bedding & Mulch (Community Farms)	High	Medium	Low
23	Educational & Community Awareness Projects	Low	Medium	Medium

10.8 Developing Circularity Scenarios Through Technology applications

10.8.1 Scenario 1: Community-Centric Circular Model

(Basic Technology Level- Like current Ehetuwewa)

Low-tech, community-driven resource recovery.

- Water hyacinth harvested by local communities from lakes, rivers, or ponds.
- **Processes:** Conversion into handicrafts, compost, biogas, animal bedding, and small-scale urban agriculture (floating gardens).
- **Output/Value:** Income generation, organic fertilizers, clean energy for households, improved local food security.
- **Circularity Aspect:** Waste is transformed into livelihood resources; harvested hyacinth returns nutrients to the soil or energy cycle, creating a closed-loop at the community level.

10.8.2 Scenario 2: Medium-Tech Cooperative Model

(Example for next development)

Cooperative or small-enterprise scale with moderate technology adoption.

- Aggregated water hyacinth collected from multiple communities or municipalities.
- **Processes:** Production of biofertilizer at cooperative scale, paper/fiber products, pellet fuel, or niche decorative products.
- **Output/Value:** Marketable products for local or regional sale; enhanced energy and material utilization.
- **Circularity Aspect:** Resource flows from multiple sources into value-added products; nutrient and energy recovery is embedded, supporting economic sustainability while reducing environmental burden.

10.8.3SCENARIO 3: INDUSTRIAL / HIGH-TECH INTEGRATED MODEL

(Example for Industrial scale- long term approach, provided supply and demand feasible)

High-tech industrial valorization integrated with community harvesting.

- Bulk water hyacinth collected from community programs or municipal bodies.
- **Processes:** Bioethanol, biohydrogen, advanced carbon products (biochar, supercapacitor-grade carbon), heavy metal removal, or industrial composting.
- **Output/Value:** High-value industrial products; energy, chemicals, or materials for broader markets.
- **Circularity Aspect:** Communities provide raw biomass, creating upstream resource loops; industrial outputs can support carbon sequestration, energy, or soil enrichment initiatives downstream.

11 ENVIRONMENTAL CHAPTER

Water Hyacinth (*Eichhornia crassipes*) is a perennial monocotyledonous crop that belongs to the *Pontederiaceae* family. In freshwater environments, hyacinth reduces water quality, increases habitat complexity (Journal of Experimental Marine Biology and Ecology 2021, Volume 544).

Yiling Chen and Zhaoyang Xu (2024) confirmed that water hyacinth invasions significantly reduce biodiversity (by about 30%) and cause a notable decrease in dissolved oxygen levels impacting aquatic ecosystem health. Jennifer H. et. al., 2021 highlighted potential disturbance to estuaries, especially after tropical storms or other high water run off events, where water hyacinth enters estuarine habitats and colonizes, altering the distribution of estuarine species.

11.1 ENVIRONMENTAL IMPACT

In Sri Lanka, the main environmental challenges observed due to water hyacinth are:

- Blocking of waterways obstructing water flow and restrict transportation
- Reduces dissolved oxygen and kills fish stocks
- Blocks irrigation & hydro infrastructure and increases flood risk
- Breeding ground for disease vectors (mosquitoes, snails)
- Economic loss to agriculture, fisheries & tourism

Doubles biomass in 5–15 days, forming dense mats that:

- Block sunlight → suppress submerged vegetation
- Reduce dissolved oxygen → fish kills, biodiversity loss
- Alter nutrient cycles → accelerate eutrophication
- Biodiversity loss → Displaces native aquatic plants, alters habitat for fish, birds, and invertebrates' Hydrological Impacts: Increases evapotranspiration, reduces water availability for irrigation
- Climate link → Anaerobic decay emits methane (CH_4) - a Green House Gas (GHG) with 28 times more potent than Carbon Dioxide (CO_2).

This fast-growing plant is effective at nutrient uptake and is also used in the removal of organic compounds, nutrients and heavy metals capitalizing in its phytoremediation capabilities.

Based on the literature following points can be summarized, that are related/relevant to Sri Lanka conditions.

1. When the WH plants are removed, any leftover buds and stolons can generate new plants through asexual reproduction. Further, WH produces a large number of seeds, enabling a significant number of offspring. WH seeds can survive in water and sediments for several years and give rise to new plants whenever conditions are favorable.
2. The resilience of water hyacinths is particularly pronounced in nutrient-rich freshwaters found in tropical regions where water hyacinth thrives and reproduces year-round.
3. Biological and chemical control methods can have positive impacts in opening water bodies and promoting ecosystem health and economic activities, but both approaches contribute to the accumulation of dead biomass in the water, that could lead to anoxic conditions, which are harmful to biodiversity.
4. Removing water hyacinth biomass should be institutionalized and integrated into a supply chain that offers economic benefits. Continuous removal and utilization Continuous removal of water hyacinth offers numerous advantages such as opening of water surface, enhancing ecosystem functions and promoting ecosystem health and primary productivity.
5. Cleaning creates reproduction grounds for fish, leading to improved fishing opportunities and navigation over water bodies.
6. Water hyacinth serves as a phytoremediation agent, aiding in removing environmental pollutants, especially effective when combined with catchment area management strategies. Catchment management approach involves implementing various practices such as appropriate tillage, terraces, stone/soil bunds, filter strips, grassed waterways, and agro-forestry combined with governance (regulations and enforcement to avoid discharging untreated sewage and other pollutant effluents from factories and towns.
7. The biomass of water hyacinth can be converted into various eco-friendly products, such as biogas (a climate-friendly fuel), compost/green manure, animal feed supplements

(using wilted water hyacinth), fish meal for aqua farming (via vermiculture), fuelwood (by burning the biomass to produce biochar), and a wide range of household handcrafts.

8. Given the infeasibility of complete eradication and permanent cessation of propagule input, improving water quality emerges as the only sustainable solution. This can be achieved by co-managing continuous removal of water hyacinth to facilitate nutrient removal through phytoremediation alongside catchment and waste management practices to reduce nutrient load.

11.2 Key Agencies Important for Water Hyacinth Management

There are several entities relevant to the environment governance aspects related to the WH value chain. Each agency in (Table 11) has different responsibilities, however it is important they all draw information from a pooled data system and use a multi-sector, multi-stakeholder approach in environment governance.

Table 11: Relevant government agencies for the environmental aspects of Water Hyacinth

Stakeholder/Agency	Role	Gaps or SWOT Notes
Ministry of Environment / Biodiversity Secretariat	Lead agency for invasive alien species policy, permitting, and monitoring	Limited budget for IAS control; fragmented enforcement across agencies
Central Environment Authority (CEA)	Permitting and enforcement under the National Environment Act, including Environment Protection Licence; oversight with delegated functions to local authorities	Limited focus on SME compliance; delegation without robust quality control; weak data and monitoring systems
Department of Wildlife Conservation	Protect aquatic biodiversity; enforce the Fauna and Flora Protection Ordinance	Jurisdiction overlaps with fisheries in some areas; limited inter-agency coordination
Department of Fisheries & Aquatic Resources	Manage aquatic resources; issue harvesting permits	Weak integration with IAS eradication plans; insufficient coordination with other authorities
Local Authorities / Pradeshiya Sabhas	Coordinate removal, disposal, and community engagement; issue	Limited technical capacity; significant gaps in

	environmental licences under CEA delegation	monitoring and water-quality data collection
Community-based Organisations / Women's Groups	Manual harvesting, basic processing, and product innovation at community level	Need training on safe harvesting, environmental safeguards, and basic business skills
Private Sector / SMEs	Invest in WH-based products and services (bioenergy, handicrafts, compost, inputs)	Require clear compliance pathways, predictable permitting, and incentives to invest and scale
Academia / R&D Institutes	Research on WH impacts, utilisation technologies, and methodologies	Research-to-policy gap; limited and episodic funding; weak pathways to scale applied solutions

11.3 Availability and Access to Water Hyacinth Materials

The most relevant and aligned government agencies relevant to the water bodies which have WH are discussed 15.14 Annexure 14

In summary the access and key roles that can be expected from key agencies can be summarized **Table 12** below.

Table 12: Key government agencies and their roles in Water Hyacinth management

Agency	Water Bodies Controlled	Role in WH Monitoring	Current/Relevant Programmes
Irrigation Dept.	Major/medium reservoirs, canals, rivers	GIS, real-time water monitoring; can integrate weed mapping	Water quality & pollution prevention programmes
Mahaweli Authority	Mahaweli Basin reservoirs, canals, settlements	Watershed & canal rehabilitation projects; potential for community monitoring	IWWRMP, Mahaweli Water Security Program

Agrarian Development Dept.	Minor tanks & village irrigation systems	Farmer-based monitoring & manual removal	Smart farming systems, ASC-level tank management
Sri Lanka Land Development Corp.	Urban wetlands, lakes, canals (esp. Colombo)	Direct weed removal, wetland restoration	Beira Lake & Colombo wetland management,

Therefore, **Irrigation Dept. and Mahaweli Authority** is best positioned for large-scale monitoring and integration into basin management while **Agrarian Development Dept**. could be effective for community-driven removal in village tanks**. SLLDC** could be the main partner for urban wetlands.

11.4 Key Legislations and Policies on IAS in Sri Lanka

There are a number of legislations and policies related to the WH handling (value chain) in Sri Lanka. The most relevant aspect is the National Environment Act managed by the Central Environment Authority (CEA) in coordination with the Biodiversity Secretariat of the Ministry of Environment as described in the **National Environmental Act (NEA), No. 47 of 1980 (as amended by Acts No. 56 of 1988 and No. 53 of 2000)**

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018357/

The NEA is the **umbrella environmental legislation** in Sri Lanka. It established the **Central Environmental Authority (CEA)** as the lead agency for environmental management. http://www.cea.lk/web/en/acts-regulations/national-environment-act. It provides the legal basis for **environmental protection, pollution control, environmental impact assessment (EIA), and natural resource management**. Although NEA is not a species-specific law, it creates the **regulatory framework** under which invasive alien species can be controlled, especially when they threaten ecosystems, water bodies, or protected areas.

NEA uses several tools and key areas that are relevant to WH management. **IAS and Environmental Impact Assessments (EIA/IEE) -**Any project that may introduce or spread invasive

species (e.g., aquaculture, agriculture, infrastructure near wetlands) must undergo EIA under the NEA. **Environmental Protection Licensing (EPL) -** Activities that discharge effluents or alter ecosystems (which may facilitate IAS spread) require EPL, giving CEA leverage to impose conditions. Further, in terms of **Habitat Protection -**The NEA empowers the Minister to declare **Environmental Protection Areas (EPAs)**, where introduction or spread of IAS can be restricted. As such the CEA works with the **Biodiversity Secretariat (Ministry of Environment)** to implement the **National IAS Policy (2016)**, using NEA provisions to regulate pathways of introduction.

CEA Role in IAS Control

- Provides the **legal umbrella** for cross-sectoral coordination on IAS.
- Ensures that **development projects** do not exacerbate IAS spread.
- Supports **monitoring, enforcement, and compliance** through the CEA.
- Acts as the **legal bridge** between sectoral laws (e.g., Plant Protection Act, Fauna & Flora Protection Ordinance) and the **National IAS Policy**.

11.5 Environmental and Social Safeguards

Environmental safeguards related to the WH control and management need to cover the entire value chain in Water Hyacinth biomass management. This aspect is critical for global trade as well as to protect the local ecosystems.

A detailed environmental safeguard across the entire value chain of WH is demonstrated in 15.17 Annexure 17

A broader WH business design could include extensive monitoring using indicators / KPIs Table 13 below This approach is a key to access climate finance and to work with global brands on WH products (For example EU Green Deal dis-incentivize products from polluted or poorly managed ecosystems).

Table 13: Illustrative Safeguards Matrix – Water Hyacinth Value Chain

Value Chain Stage	Key Risks	Safeguards & Mitigation	Monitoring / KPIs
Harvesting & Transport	Spread of invasive seeds; habitat disturbance; turbidity spikes of water leading to less sunlight penetration and oxygen generation in water bodies	Enclosed collection & dewatering at site; thermophilic drying to neutralize seeds; staged removal to protect DO levels; silt curtains in sensitive zones	% biomass neutralized before transport; water quality (DO, turbidity) pre/post harvest conditions in water bodies.
Pre-processing & Storage	Leachate contamination; pest attraction; fire hazard	Covered drying floors with leachate capture; pest control; fire safety protocols	Monitoring of Leachate COD/BOD; pest incidence; fire drills conducted
Fiber Extraction & Compounding	High water use; dust inhalation; chemical binder hazards	Closed-loop water systems; local exhaust ventilation; use of PPE by workers; bio-based binders; monitoring of water quality and air quality of facilities	Water reuse rate; airborne dust levels; % low-toxicity binder use; energy use and energy efficiency measures
Coloring & Finishing	Toxic dyes; effluent pollution; high water use	Use of natural dyes; counter-current rinsing; effluent treatment to standards; awareness and education on potential hazards	Effluent related water quality monitoring COD/BOD/metals; dye bath reuse cycles; energy and water use efficiency
Thermal Conversion (Biochar/Briquettes)	Air emissions; hazardous condensates	High-efficiency pyrolysis with afterburners; condensate	PM/CO/NOx levels; condensate volume & disposal records; energy efficiency

		capture & safe disposal	
Facility Waste Management	Hazardous sludge; organic waste	Stabilize hazardous sludge; compost/digest clean organics; integrated waste, energy and water management; awareness and education	% waste diverted to municipal stream or landfill; compost pathogen kill verification, circular systems related measurements
Occupational Health & Safety	Heat stress; ergonomic strain; injury risk	Job hazard analysis; use of PPE; rest breaks; ergonomic tools; training, awareness and incentives	Lost-time injury rate; PPE compliance rate
Community & Biodiversity	Unequal benefit sharing; biodiversity loss	Fair wage policy; grievance redress; removal plans avoiding nesting seasons; payment for ecosystem services, carbon trading for benefit sharing	% women/youth employed; grievance resolution time; extent of cash through payment for ecosystem services or other sustainable financing (carbon).

Aligning the Safeguards with co-benefits will help the projects to attract donors as well as blended financing with carbon trading potential. The safeguards associated with Water Hyacinth process can be aligned with SDGs: 5, 6, 7, 8, 12, 13, 15

- Jobs for women & youth in processing and crafts
- Restored biodiversity in tanks and wetlands
- Improved water access for agriculture & communities
- Reduced respiratory risk via cleaner cooking fuels
- Transparent and participatory benefit-sharing models in the form of social impact assessments to ensure equitable benefit-sharing among all stakeholders

11.6HARVESTING, IMMEDIATE PROCESSING AND PRECAUTIONS

Water hyacinth harvesting is typically done manually using hooks on long rods from the water's edge, unless mechanical harvesters are available. The quantity harvested depends on the intended use. **Further explanations on harvesting will be provided in the technical chapter.**

However, in summary:

Post-harvest, the key step is **dewatering** to reduce bulk and ease transport and processing. A staged approach is recommended:

- **Initial drainage**: gravity or pressing
- **Drying**: sun or thermal methods depending on scale and purpose

Small-scale/community methods include:

- Sun/air drying on racks, mats, or open ground
- Gravity drainage using sloped racks or perforated platforms

Commercial-scale methods include:

- Mechanical pressing (screw, hydraulic, roller)
- Centrifugation or vibrating belts
- Thermal drying (kilns, solar dryers, low-temp ovens)

Precautions to Take

Several safeguards could be adopted to prevent Regrowth / Spread of WH immediately after harvesting.

- Ensure seeds and viable plant fragments are destroyed (e.g., through composting, anaerobic digestion, or steam sterilization).
- Avoid dumping partially dried biomass back into waterways.
- Manage Odor & Leachate as dewatering piles can release foul odors and nutrient-rich leachate.
- Use lined pits, drainage channels, or collection systems to prevent contamination of soil and groundwater, however, this is not a problem in Sri Lanka at the current scale of operations.

Health & Safety

- Workers should use gloves and protective gear to avoid skin irritation and exposure to pathogens/mosquito breeding in wet biomass.
- Ensure safe handling to prevent accidents with heavy, water-laden material.
- Take precautions from drawing in water bodies and also being alert to crocodiles and other risks

Fire Risk in Drying Stages

- Once dried, biomass can become flammable. Store away from open flames and ensure ventilation.

Environmental Safeguards

- Select drying sites away from wetlands or canals to prevent accidental re-infestation.
- Monitor for invasive seed dispersal during handling and transport.

11.7 Implementation, Financing and Investor Attraction

The following is an attempt to use the Environment Safeguards and Monitoring into a sequence that can be used during the accelerator phase.

Implementation checklist tailored for Sri Lanka

Safeguards - Environment, Social Management Protocol - ESMP

- Scope: Harvesting, transport, processing, dyehouse, thermal units, waste, OHS, community.
- Tools: Risk register, mitigation matrix, monitoring plan, incident/grievance logs, and compliance calendar.

Waterbody MRV:

- Baseline: DO, COD/BOD, nutrient load, biomass density, seasonal dynamics.
- Ongoing: Post-harvest water quality and habitat indicators; fisheries/community feedback.

Process design for circularity:

- Energy: Use pyrolysis heat to dry feedstock; recover and treat condensates.

- Water: Closed-loop dyeing and process-water reuse; rainwater harvesting.
- Materials: Prefer bio-based binders and certified low-impact chemicals; design for disassembly and repair.

Carbon readiness:

- Data spine: Scales, moisture meters, lab carbon analyses, batch IDs, end-use declarations.
- Pilots: 3–6-month biochar field trial with soil tests and durability assumptions; parallel avoided-methane baseline on one high-priority lake.

Product-market fit:

- Quick wins: Woven goods and acoustic panels for hotels/homestays; geotextiles for slope and canal banks.
- Scale bets: Biochar for tea/rubber estates; K-activated carbons for local dyehouse/wastewater treatment.

Partnerships:

- Academic/tech: Universities for activation and adsorption testing; labs for carbon content.
- Finance: Blend climate grants with revenue-sharing from craft and biochar; explore voluntary carbon buyers interested in nature-positive removal.

11.8 CARBON FINANCE POTENTIAL

Water Hyacinth associated processes can be identified with potential **Carbon finance and trading potentials, in addition to the ecosystem and livelihood benefits. As such** the carbon and other sustainable financing mechanisms could help to improve the cashflow of the WH related business and to finance community benefits.

However, not every hyacinth use case is creditable, therefore, we need to focus on routes/value chains with measurable, durable climate benefits and robust Monitoring Reporting and Verification (MRV) possibilities.

11.8.1 Carbon Trading Potential

Water hyacinth interventions can generate carbon credits by both sequestering CO_2 in biomass-derived products and offsetting fossil fuels:

1. **CO_2 Uptake in Wetlands**

Water hyacinth beds can absorb on average 5.3 g $CO_2 \cdot m^{-2} \cdot day^{-1}$, often turning infested water bodies into net GHG sinks, especially where deep enough to prevent rapid CH_4 ebullition.

2. **Biochar-Based Sequestration**

Pyrolysis of harvested hyacinth yields stable biochar; when applied to soil, carbon remains locked for decades. Methodologies such as VCS's "Methodology for Biochar Soil Application" can quantify and certify these sequestration credits.

3. **Biogas-Driven Offsets**

Anaerobic digestion of hyacinth biomass produces biogas that displaces fossil-fuel cooking or grid electricity. Emission reductions can be validated under voluntary schemes like Gold Standard or the Plan Vivo framework.

11.8.2 Key MRV Considerations

Robust measurement of biomass harvested, biochar yields, and displaced fossil-fuel use is essential. Integration with Article 6 carbon market rules may open access to compliance markets, boosting revenue potential for communities.

Several illustrative examples may include:

- **Biochar carbon removal:**
    - **Mechanism:** Stabilizes a portion of plant carbon for 100–1000+ years when applied to soils or used in long-lived materials.
    - **MRV essentials:** Mass balance (wet→dry→biochar), carbon content (elemental analysis), permanence/durability, end-use traceability, leakage safeguards, and conservative decay factors.
    - **Co-benefits:** Soil health, nutrient retention; quantify but separate from core carbon accounting.

- **Avoided methane from decay in water:**
    - Mechanism: Harvesting dense mats prevents anaerobic decay and CH4 emissions in eutrophic waters.
    - MRV essentials: Site-specific baselines (water quality, biomass density), conservative emission factors, harvest logs, and temporal boundaries; discount for uncertainty.
- **Displacement credits (energy/materials):**
    - **Mechanism:** Briquettes, biogas, or process heat **displace fossil fuels**; hyacinth fibers/composites displace higher-emission materials.
    - **MRV essentials:** Credible counterfactuals, measured energy outputs, grid or fuel emission factors, **product substitution evidence**, and leakage checks.
- **Wastewater treatment credits (adsorbents):**
    - **Mechanism:** Hyacinth-based activated carbon replacing virgin coal-based AC may claim embodied emission reductions if cradle-to-gate LCA shows clear advantage.
    - **MRV essentials:** Third-party LCA, supplier attestations, facility energy data.

For our purposes, it may be good to start with biochar carbon removal (well-accepted MRV), add an avoided-methane module for priority lakes after baseline monitoring, and layer displacement benefits for any energy produced onsite or use of biogas transported (Tractor Tubes? as the Navy in Trinco does). We may demonstrate hyacinth's suitability for biochar/activated carbon and energy co-products within circular process designs.

11.9 MONITORING ARCHITECTURE

It is possible to develop a monitoring architecture for Water Hyacinth related project activities and follow ups using selected KPIs/Indicators. These indicators can be selected based on value chain steps.

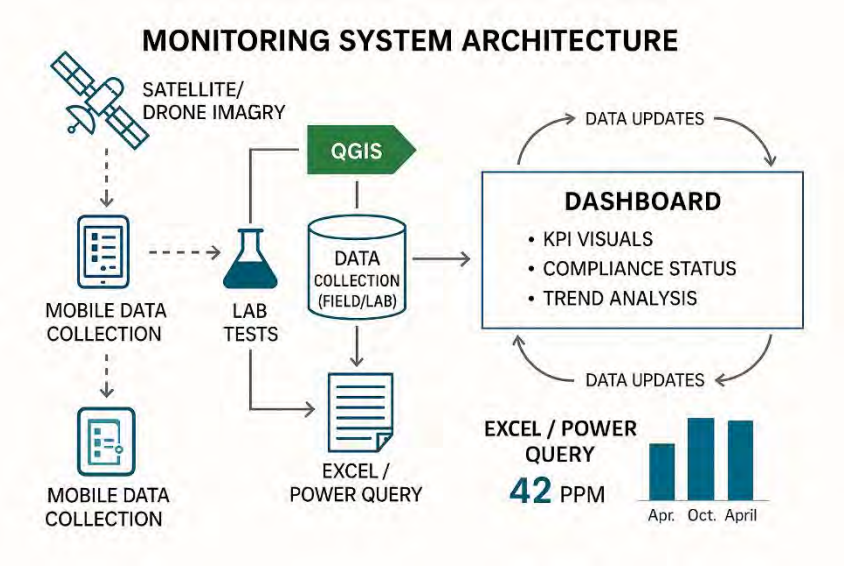


Figure 18: Proposed monitoring architecture for Water Hyacinth related project activities

Monitoring could be designed to include both remote operations supported by Internet of Things (IoT) and ground level monitoring that can be augmented with community inputs or citizen science.

The data collection needs to start from the baseline once the water body to bring into the project is decided. There are several aspects to consider in the monitoring or "Management Effectiveness Tracking (MET)" scheme.

- Are we using the water body to regrow water hyacinth for continuous community led livelihoods and business development?
- How best to balance the community income generation and business interests to ensure long-term sustainability and off-site impacts by hyacinth moving out of site?
- Capacity of the community and the civil society to understand and carryout the business.
- What are the other uses of the water body and how those activities will impact the hyacinth based industrial operation (ex: Fisheries, Tourism, Floating Solar etc.)
- How can we do community or rural development alongside the hyacinth related enterprise development?

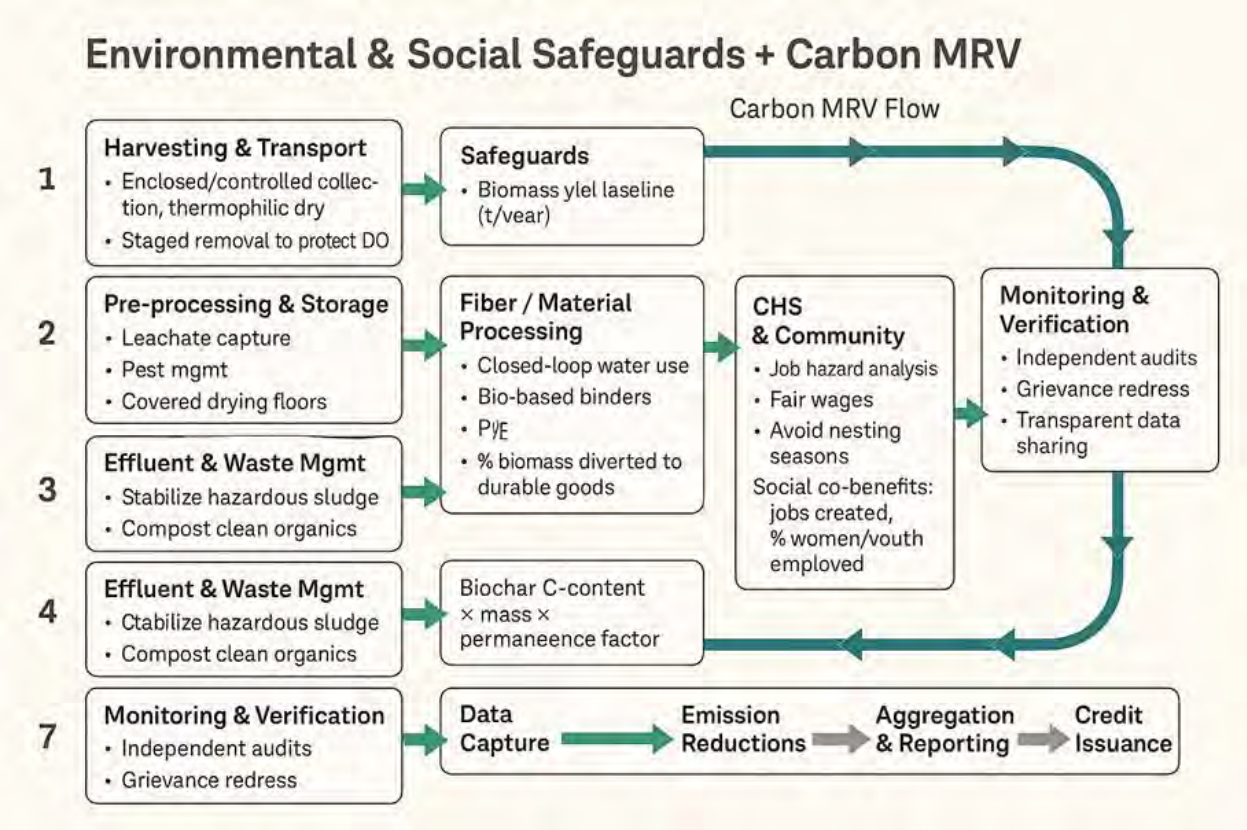


Figure 19: Proposed environmental and social safeguards and carbon MRV

11.10 KPIs Guide – Water Hyacinth Value Chain with Carbon MRV

1. Harvesting & Transport KPIs:

- Total biomass harvested (tonnes/year) – Verified by GPS-tagged harvest logs and weighbridge tickets.
- Percentage of biomass neutralized before transport – Thermophilic drying to kill seeds.
- Water quality - Dissolved Oxygen (DO) (Primary measure of water quality)

2. Pre-processing & Storage KPIs:

- Average biomass moisture content (%) – Critical for accurate carbon content calculation.
- Leachate water quality – COD and BOD tests

3. Fiber / Material Processing KPIs:

- Water reuse rate (% of process water recycled in closed-loop systems)

- Percentage of low-toxicity or bio-based binder use
- Emission factor substitution – Life-Cycle Assessment (LCA) calculation of avoided high-emission materials.

4. Thermal Conversion (Biochar/Briquettes) KPIs:

- Biochar carbon content (%) – Laboratory-verified for permanence in carbon storage.
- Fossil fuel displacement rate – Energy content of briquettes replacing coal or wood.
- Stack emission levels – Particulate Matter (PM), Carbon Monoxide (CO), Nitrogen Oxides (NO_x) within limits.

5. Effluent & Waste Management KPIs:

- Percentage of waste diverted from landfill
- Compost pathogen kill verification – Documented through pile temperature logs.
- CH_4 – Methane (avoided emissions when biomass is composted instead of decaying anaerobically)

6. Occupational Health & Safety / Community Engagement KPIs:

- Lost-time injury rate – Workdays lost due to accidents.
- PPE compliance rate – Percentage of workers wearing required Personal Protective Equipment (PPE).
- Percentage of women/youth employed

7. Monitoring, Reporting & Verification (MRV) KPIs:

- Audit completion rate – Percentage of planned E&S (Environmental & Social) and carbon audits completed.
- Time to grievance resolution – Days from complaint to settlement.

We could combine the Environment and Social Safeguard monitoring with Carbon Trading related monitoring.

Table 14: Environment and social safeguard monitoring with carbon financing

Stage	Safeguards & Mitigation	Carbon MRV Link	KPIs & Verification
1. Harvesting & Transport	Enclosed/controlled collection, thermophilic drying to kill seeds, staged removal to protect DO	Biomass yield baseline (t/year)	GPS-tagged harvest logs, biomass weight receipts
2. Pre-processing & Storage	Leachate capture, pest mgt. covered drying floors	Moisture content pre-conversion for accurate tCO_2eq calc	Lab moisture tests, leachate water-quality tests
3. Fiber / Material Processing	Closed-loop water use, bio-based binders, PPE	% biomass diverted to durable goods (substituting higher-emission materials)	Production logs, life-cycle emission factors applied
4. Thermal Conversion (Biochar/Briquettes)	High-efficiency pyrolysis, condensate capture	Biochar C-content × mass × permanence factor; briquette fossil-fuel displacement	Lab C-analysis, fuel displacement surveys
5. Effluent & Waste Management	Stabilize hazardous sludge, compost clean organics	Compost CH_4 avoidance, sludge treatment emissions factor	Compost pile temp logs, pathogen kill certs
6. OHS & Community	Job hazard analysis, fair wages, avoid nesting seasons	Social co-benefits: jobs created, % women/youth employed	HR records, beneficiary surveys
7. Monitoring & Verification	Independent audits, grievance redress, transparent data sharing	MRV package ready for 3rd-party validation (Verra/Gold Standard methodology alignment)	Full MRV dossier, audit trail

11.11 OPTIONS UNDER THE PARIS AGREEMENT ARTICLE 6

In the event we are developing the projects for Paris Agreement Article 6 related carbon trading (linked to NDCs) or aiming at Voluntary Carbon Markets (VCMs), it may be necessary to consider

the methodologies developed by the two leading carbon trading entities, namely, VERA and GOLD STANDARD (GS).

Summary of the methodologies that can be accessed via internet is provided in **Table** 13, based on the Water Hyacinth Value Chain steps/stages. Three Verified Revenue Streams are known and accepted by VERA and GS.

- **Avoided Methane (CH_4)** from anaerobic decay in waterways
- **Fossil Fuel Displacement** from renewable biomass briquettes
- **Long-Term Sequestration** in biochar/durable goods

11.12 CONCLUSION AND WAY FORWARD

Environment governance related to WH management could be tied to the value chain steps and supported with Science Based Targets and extensive multi-stakeholder monitoring. There are several important key points.

1. At the initial stage of the process or acceleration, the IAS principles may not be that critical as WH is already spreaded around the country. However, as the management and control is going well, the IAS management principles can be applied, gradually.
2. Along with IAS management applied there needs to be a management board to oversee the policy and implementation of the ecosystem and environment governance and the benefit sharing of WH operations. To be effective, the Payment for Ecosystem Services (PES) and carbon and biodiversity related financing could play a key role to empower communities, beyond the livelihood benefits.
3. Technologies required for environment governance from harvesting stage to air pollution, land management (minimize pollution coming from landscape to water bodies), waste and wastewater management, water and energy use efficiency, use of renewable energy etc. can be enhanced from the current level.
4. WH also has a “climate prosperity” element where some of the products can effectively use carbon finance to ease the working capital pressure and to enhance community benefits. For example, the biochar example is already been used in carbon trading in the

voluntary market and this can be upscaled to be in the compliance market under the Paris Agreement Article 6.

5. Investor and donor (including Brands and Philanthropic entities) interests could be enhanced by combining the accelerator with Kungming- Montreal Global Biodiversity Framework, Sendai Framework for Disaster Risk Reduction and Nature based Solutions (ex; PES), aspects.

12 NEEDS ASSESSMENT OVERVIEW

12.1 INTRODUCTION

The Needs Assessment was undertaken to identify practical gaps, readiness levels, and strategic opportunities for the sustainable utilisation of water hyacinth in Sri Lanka. It builds directly on the fieldwork, expert consultations, and stakeholder meetings conducted during August and September 2025 under the scoping phase of the Water Hyacinth Circularity project. The assessment's purpose was to guide the prioritisation of interventions for the accelerator design and provide evidence for Phase II planning.

12.2 APPROACH AND METHOD

The assessment covered the period from 1 August to 25 September 2025 and combined information from stakeholder interviews, field observations, and expert evaluations. A total of **26 records** were reviewed, including inputs from national agencies, community cooperatives, private-sector actors, and technical experts. Stakeholders represented the full value chain: harvesting, processing, product design, marketing, and environmental regulation.

Data were compiled in a shared Needs Assessment matrix, where each criterion was scored on a scale of one to five to indicate the degree of feasibility or readiness. Columns in the matrix correspond to the key dimensions evaluated: technical, environmental, business/financial, and institutional. Each expert completed the section relevant to their domain, and the program team consolidated the results. The "ranking" column represents a composite prioritization agreed upon during the final consolidation meeting on September 30, 2025.

While the assessment offers a strong overview of opportunities and constraints, it remains qualitative and exploratory in nature. Quantitative validation will be required in later phases through targeted business modelling, environmental baselining, and market research. Limitations include a short data collection window, restricted access to some sites due to local administrative barriers, and reliance on self-reported stakeholder information.

12.3 Needs Assessment Summary and Analysis

12.3.1 Feasibility Summary and Priority Scoring

Table 15: Feasibility summary and priority scoring on the Ehetuwewa

Dimension	Score (1–5)	Key Insights & Readiness Indicators
Technical Feasibility	4	Local expertise, basic machinery, and product knowledge already exist. Community-scale operations are viable. Scaling nationally will require improved process management, health & safety systems, and medium-scale technology integration.
Financial Viability	4–5	Current cluster models are profitable and replicable. Integration of Payment for Ecosystem Services, carbon finance, and ESG-linked investment can amplify financial sustainability. Access to blended finance and EU Green Deal mechanisms offers major growth potential.
Market Demand Potential	5	Domestic and export demand for WH-based crafts and fibers is growing. With better tools (e.g., sewing machines), production could double. Strong innovation potential for packaging, leather substitutes, and climate-friendly materials.
Environmental Safety	4	Present operations pose minimal risk if best practices (drying, containment) are followed. Industrial-scale expansion must integrate wastewater treatment, gender & social safeguards, and biodiversity protection.
Community Interest	3–5	Communities are motivated by added income, but long-term participation hinges on fair benefit sharing, transparent governance, and safe working conditions.

Institutional Support	3	Facilities such as the Ehetuwewa DS processing centre remain underused due to access and coordination issues. Strengthened inter-agency cooperation and policy backing are essential.

Overall Feasibility: **High readiness** (average ≈ 4 / 5). The opportunity is proven, but scaling demands institutional clarity, sustainable finance, and inclusive benefit systems.

"Knowledge and technology are not the barrier, coordination, governance, and vision are."

12.4 STRATEGIC RECOMMENDATIONS

12.4.1 IMMEDIATE PRIORITIES (0 – 12 MONTHS)

1. Optimise Existing Operations – Upgrade productivity and product quality within existing clusters. Introduce new designs, branding, and order management systems to enhance reliability and increase profit margins.

2. Maximise Existing Hub Operation Infrastructure Utilisation – Negotiate effective access to the Ehetuwewa DS facility and functionalise NEDA – DS roles to optimise intended outputs.

3. Improve Harvesting & Processing – Adopt whole-plant harvesting, develop SOPs for drying/composting, and introduce low-cost mechanisation for safety and efficiency.

4. Integrate Environmental Safeguards – Create wastewater and solid-waste management protocols linked to circular pathways.

5. Strengthen Market Access & Quality – Conduct quality audits, map export requirements, and prioritise value chains such as handicrafts, biochar, and biodegradable fibre products.

12.4.2 MEDIUM-TERM ACTIONS (1 – 3 YEARS)

1. Establish a Hub-and-Spoke Model – Centralise coordination at the DS facility while supporting decentralised clusters for harvesting, preprocessing, manufacturing, and marketing.

2. Create Financing & Ecosystem Incentives – Launch PES schemes, register carbon projects, and align with EU Green Deal and Science-Based Targets frameworks.

3. Build a National Market Narrative – Position Sri Lanka's WH industry under the theme 'From Waste to Worth' and focus on high-value eco-conscious markets.

4. Advance Data & Monitoring Systems – Conduct biomass mapping, yield surveys, and digital monitoring for transparency.

5. Strengthen Institutional & Policy Anchoring – Integrate WH under IAS policy, engage relevant departments, and seek Cabinet-level endorsement.

12.4.3 Long-Term Vision (3 – 5 Years)

A regenerative, circular economy rooted in community enterprise: restoring waterways and biodiversity, generating inclusive livelihoods, and positioning Sri Lanka as a regional leader in nature-based materials innovation.

"Every harvest of water hyacinth can become a harvest of resilience, transforming invasive abundance into community prosperity."

13 CONCLUSION

In conclusion, this study on water hyacinth (WH) as a circular solution in Sri Lanka presents a strategic foundation by analysing key areas; material innovation, market access, business strategies while also exploring environmental safeguard, impact and sustainable strategies. It furthermore analysis policy landscape, and the relevant government, private and non-government stakeholders needed for scalability and sustainability. The findings and recommendations are designed to inform a forthcoming accelerator programme, which will address the identified gaps and deliver appropriate technical models and support mechanisms for identified water hyacinth producers.

Various technological and material innovation utilisation of water hyacinth were explored using secondary data and a mapping of existing localised research in the country, which could be applicable to the identified candidates in the accelerator programme. In addition, these technologies will serve vital whilst exploring new pathways and approaches for different application models, and could serve as an opportunity for global recognition.

A market access solution roadmap has been developed, emphasizing alignment with government policies, private sector engagement, and advocacy efforts. Addressing gaps in market linkages is essential to creating ecosystems where WH-based products can thrive both locally and internationally, contributing to a robust circular economy. The study supports the entire WH value chain, with initial focus on four key valorisation pathways such as handicrafts. However, with long-term strategic interventions, there is potential to expand into other product categories, enhancing value addition and driving material innovation.

Introducing carbon financing as an additional revenue stream offers financial resilience for community groups, with regulatory support from the government strongly recommended. Environemntal safeguards have been recommended and criteria for monitoring – to ensure robust mechanisms are in place for system strengthening efforts. Furthermore, engaging financial institutions will provide a much-needed buffer between producers and buyers, strengthening the economic viability of WH-based enterprises.

Among the key methodologies, the needs assessment has highlighted critical areas for intervention, which will be directly integrated into this accelerator's design. Medium- and long-term implementation models have been proposed to ensure scalability and sustainability across the WH value chain. These models are underpinned by an enabling environment fostered through strategic partnerships between government entities and the private sector.

In addition, these recommendations have provided important pathways will complement existing government capacity-building initiatives (e.g. the programmes conducted by NEDA) – strengthening systems further. Community-based interventions are central to this strategy, with models tailored to local contexts and key demographics in the targeted locations.

This initiative has the potential to strengthen national policies, position Sri Lanka as a global innovator in climate resilience, and unlock new avenues for tourism and economic development. It also holds promise for improving the livelihoods of communities engaged in the programme. By creating a mid-range scale industry that currently does not exist, this programme serves as a vital pilot, demonstrating how circular solutions can be locally rooted, globally relevant, and deeply transformative.

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15 ANNEXURES

15.1 ANNEXURE 1: DETAILS OF TYPICAL ENVIRONMENTAL SAFEGUARDS

15.1.1 HARVESTING AND TRANSPORT

- **Biosecurity protocol:** Prevent re-seeding and spread. Require enclosed collection, dewatering at site, and thermophilic treatment (e.g., hot-air drying) to neutralize seeds before offsite movement. Document chain of custody for invasive biomass.
- **Water quality protection:** Stage removal to avoid sudden habitat shocks (oxygen crashes, turbidity). Maintain riparian buffers; deploy silt curtains where needed.
- **Vector control:** Remove mats in patterns that don't leave stagnant pockets that foster mosquitoes; coordinate with public health teams.
- **Permits and reporting:** Align with national invasive species and CEA requirements; log volumes, locations, and disposal/use routes.

15.1.2 PREPROCESSING, STORAGE, AND MATERIAL QUALITY

- **Contaminant screening:** Test representative batches for heavy metals and organics if sourced from polluted waters; segregate "clean" vs. "restricted-use" biomass.
- **Leachate management:** Collect and treat pressate from dewatering (screening + aerobic/anaerobic treatment) before discharge or reuse.
- **Safe storage:** Covered, ventilated drying with leachate capture; fire safety for dried biomass.

15.1.3 FIBER EXTRACTION, COMPOUNDING, AND FORMING

- **Low-impact extraction:** Favor mechanical decortication and water-efficient retting; recirculate process water.
- **Binder and additive choices:** Prioritize bio-based or low-toxicity binders (natural latex, PLA, PHA, water-borne PU). Avoid formaldehyde-based resins and halogenated flame retardants; require SDS reviews.

- **Dust and ergonomics:** Local exhaust ventilation, dust collection (HEPA), and ergonomic workstations; provide PPE and training.

15.1.4 Coloring, Finishing, and Coatings

- **Dye selection hierarchy:** Prefer natural dyes or OEKO-TEX/Bluesign-approved low-impact synthetics; avoid azo dyes that can release amines and heavy-metal mordants.
- **Closed-loop baths:** Metering, bath reuse, and counter-current rinsing; capture and treat dyehouse effluents (coagulation–flocculation + biological treatment + tertiary polishing).
- **Coatings control:** Use water-borne systems; prohibit PFAS and high-VOC solvents; monitor VOCs and install carbon capture where needed.

15.1.5 Thermal Conversion (Briquettes, Biochar, Activated Carbon, Energy)

- **Kiln and furnace controls:** High-efficiency pyrolysis with secondary combustion/afterburners; continuous monitoring for PM, CO, NOx; install cyclones/filters/scrubbers as needed.
- **By-product treatment:** Condensates (tars) collected and treated as hazardous; ash characterization and safe disposal or beneficial use per standards.
- **Feedstock compatibility:** Manage high ash/alkali content of hyacinth to limit slagging/fouling in combustion systems.

15.1.6 Wastewater, Sludge, and Solid Waste

- **Effluent standards:** Treat all process wastewater to meet discharge norms; consider constructed wetlands only in contained systems that prevent re-introduction of hyacinth.
- **Sludge management:** Classify dye/metal-bearing sludges as hazardous; stabilize and dispose per regulations or co-process in cement kilns.
- **Organic residues:** Compost or anaerobically digest fines and offcuts; return digestate/compost to safe land applications after pathogen kill.

15.1.7 Occupational Health, Community, and Biodiversity

- **OHS framework:** Job hazard analyses, PPE, first-aid, heat stress and ergonomic plans; inclusive training for community harvesters and artisans.
- **Community safeguards:** Fair wages, grievance redress, gender equity, and benefit-sharing with riparian communities.
- **Biodiversity safeguards:** No cultivation/propagation; removal plans co-designed with fisheries and wetland managers to avoid nesting seasons and sensitive habitats.

15.2 Annexure 2: Monitoring Checklist for Water Hyacinth Value Chain Related Tracking

15.2.1 Harvesting and Transport

- **KPIs**:
  - *Total biomass harvested* (tonnes/year) – Verified by GPS-tagged harvest logs and weighbridge tickets.
  - *Percentage of biomass neutralized* before transport – Thermophilic drying to kill seeds.

15.2.2 Pre-Processing and Storage

- **KPIs**:
  - *Average biomass moisture content* (%) – Critical for accurate carbon content calculation.
  - *Leachate water quality* – Chemical Oxygen Demand (**COD**) and Biochemical Oxygen Demand (**BOD**) tests.

15.2.3 Fiber / Material Processing

- **KPIs**:
  - *Water reuse rate* (% of process water recycled in closed-loop systems)
  - *Percentage of low-toxicity or bio-based binder use*
  - *Emission factor substitution* – Life-Cycle Assessment (**LCA**) calculation of avoided high-emission materials.

15.2.4 Thermal Conversion (Biochar/Briquettes)

- **KPIs**:
  - *Biochar carbon content* (%) – Laboratory-verified for permanence in carbon storage.
  - *Fossil fuel displacement rate* – Energy content of briquettes replacing coal or wood.
  - *Stack emission levels* – Particulate Matter (**PM**), Carbon Monoxide (**CO**), Nitrogen Oxides (**NO_x**) within limits.

15.2.5Effluent & Waste Management

- **KPIs**:
    - *Percentage of waste diverted from landfill*
    - *Compost pathogen kill verification* – Documented through pile temperature logs.

15.2.6Occupational Health & Safety / Community Engagement

- **KPIs**:
    - *Lost-time injury rate* – Workdays lost due to accidents.
    - *PPE compliance rate* – Percentage of workers wearing required Personal Protective Equipment (**PPE**).
    - *Percentage of women/youth employed*

15.2.7Monitoring, Reporting & Verification (MRV)

- **KPIs**:
    - *Audit completion rate* – Percentage of planned E&S (Environmental & Social) and carbon audits completed.
    - *Time to grievance resolution* – Days from complaint to settlement.

15.3 ANNEXURE 3: INTERVIEW QUESTIONNAIRES

15.3.1 COMMUNITY QUESTIONNAIRE

Community Questionnaire

Date:
Location:
Interviewer:
Respondent Name:
Organization/Community:
Designation/Role:
Contact (Optional):

1. Assuming the party is involved with WH - What role does WH play in your daily income? Like is it 100% or half or some or little of your income,
   අදාළ පාර්ශවය ජපන් ජබර කළමනාකරණය සමඟ සම්බන්ධ වී ඇතැයි උපකල්පනය කළහොත් - ජපන් ජබර වලින් ලැබෙන්නේ දෛනික ආදායමෙන් කොපමණ කොටසක්ද? එය ආදායමෙන් 100% ක්, 50% හෝ යම්කිසි කොටසක් හෝ ඉතා ස්වල්ප ප්‍රමාණයක් වශයෙන්

2. Who in your family/business does harvesting, weaving, selling?
   ඔබේ පවුලේ/ව්‍යාපාරයේ අස්වැන්න නෙළීම, විවීම, විකිණීම සිදු කරන්නේ කවුද?

3. What process do you use for WH production at present?
   ජපන් ජබර ආශ්‍රිත නිෂ්පාදන සඳහා ඔබ වර්තමානයේ භාවිතා කරන ක්‍රියාවලිය කුමක්ද?

4. What challenges do you face (childcare, stigma, lack of tools)?
   ඔබ මුහුණ දෙන අභියෝග මොනවාද (දරුවන් රැකබලා ගැනීම, සමාජයේ මුල්බැස ගත් අපහාසාත්මක ආකල්ප, අවශ්‍ය කරන මෙවලම් නොමැතිකම)?

5. Are WH products accepted by your community/customers?
   ඔබේ ප්‍රජාව/පාරිභෝගිකයින් විසින් ජබන් ජබර ආශ්‍රිත නිෂ්පාදන පිළිගනු ලබනවාද?

6. What future do you see for this business?
   මෙම ව්‍යාපාරයේ අනාගතය ඔබ දකින්නේ කෙසේද?

7. What type of support do you need to scale?
   ව්‍යාපාරය පුළුල් කිරීම සඳහා ඔබට අවශ්‍ය වන්නේ කුමන ආකාරයේ සහයෝගයක්ද?

8. Which parts of the water hyacinth plant are mostly used in the production of water hyacinth-based goods?
   ජපන් ජබර ආශ්‍රිත භාණ්ඩ නිෂ්පාදනයේදී වැඩිපුරම භාවිතා කරනු ලබන්නේ එම ශාකයේ කුමන කොටස්ද?

9. How many kilograms (kgs) of water hyacinth are used for making 1 unit of product?
   එක් ඒකකයක් නිෂ්පාදනය සඳහා ජපන් ජබර කිලෝග්‍රෑම් කීයක් භාවිතා කරන්නේද?

15.3.2GOVERNMENT QUESTIONNAIRE

Government Questionnaire

Date:
Location:
Interviewer:
Respondent Name:
Organization/Community:
Designation/Role:
Contact (Optional):

1. Assuming that WH is relevant to your work, How does your institution currently address WH management?
   ජපන් ජබර ඖකය ඔබේ කාර්යයට අදාළ වන්නේ නම්, ජපන් ජබර කළමනාකරණය කිරීම සඳහා මේ වන විට ඔබේ ආයතනය ගෙන ඇති ක්‍රියාමාර්ග මොනවද?

2. What is your annual budget allocation for WH management/IAS? Is it sufficient?
   ජපන් ජබර කළමනාකරණය/ ආක්‍රමණශීලී ආගන්තුක ශාක විශේෂ සඳහා ඔබේ වාර්ෂික අයවැයෙන් කොපමණ මුදලක් වෙන් කර තිබේද? එය ප්‍රමාණවත්ද?

3. What permits/licensing systems are in place for WH harvesting/utilisation?
   අස්වැන්න නෙළීම/භාවිතා කිරීම සඳහා ලබාගෙන ඇති බලපත්‍ර/අනුමත කිරීම් මොනවාද?

4. What barriers exist in enforcing regulations?
   රෙගුලාසි ක්‍රියාත්මක කිරීමේදී පවතින බාධක මොනවාද?

5. How open is your institution to public-private - community collaboration on WH circular solutions
   ජපන් ජබර චක්‍රීය විසඳුම් සඳහා අවශ්‍ය වන රාජ්‍ය-පෞද්ගලික - ප්‍රජා සහයෝගිතාවයකට ඔබ ආයතනය කෙතරම් සූදානම්ද?

6. When considering scalability, how is your board / management willingness - are there any resources that can be accessed within the budgets or cost-sharing in staff time
   ව්‍යාපෘතිය පුළුල් කිරීමට අවශ්‍ය නම්, ඔබේ අධ්‍යක්ෂ මණ්ඩලය/කළමනාකාරිත්වය එයට සහාය වීමට කෙතරම් කැමැත්තෙන් සිටිනවාද? ඔබගේ අයවැය තුළ හෝ පිරිවැය බෙදා ගැනීම හරහා වෙන් කළ හැකි අරමුදල් හෝ කාර්ය මණ්ඩලයේ කාලය වැනි සම්පත් තිබේද?

7. What are the current assets, ecosystem elements, programs, or resources allocated for WH management? What is the current status? Would they be available for this project to consider?
   ජපන් ජබර කළමනාකරණය සඳහා දැනට වෙන් කර ඇති වත්කම්, පරිසර පද්ධති අංග, වැඩසටහන් හෝ සම්පත් මොනවාද? වත්මන් තත්ත්වය කුමක්ද? මෙම ව්‍යාපෘතියට එම සම්පත් භාවිතා කළ හැකිද?

15.3.3SME QUESTIONNAIRE

SME Questionnaire

Date:
Location:
Interviewer:
Respondent Name:
Organization/Community:
Designation/Role:
Contact (Optional):

1. How did you start your WH business?
   ඔබ ඔබේ ජපන් ජබර ව්‍යාපාරය ආරම්භ කළේ කෙසේද?

2. What is the current process you undertake for your business?
   ඔබේ ව්‍යාපාරය සඳහා ඔබ දැනට අනුගමනය කරන ක්‍රියාවලිය කුමක්ද?

3. What products do you make? What are the best-sellers? What is the total annual revenue?
   ඔබගේ නිෂ්පාදන මොනවාද? වැඩියෙන්ම අලෙවි වන නිෂ්පාදන මොනවාද? මුළු වාර්ෂික ආදායම් කොපමණද?

4. Where do you currently sell? (Local, tourist, export, online)
   ඔබගේ නිෂ්පාදන දැනට අලෙවි කරන්නේ කොහේද? (දේශීය වෙළඳපොළ, සංචාරකයින්ට, අපනයන කිරීම්, ඔන්ලයින් ක්‍රමයව)

5. Do you see WH products as scalable? What support would help?
   ඔබේ නිෂ්පාදනය වෙළඳපොලේ සාර්ථකව අලෙවි කළ හැකිද? ඔව් නම්, එයට හේතු පැහැදිලි කරන්න. එසේ නොවේ නම් ඊට හේතු පැහැදිලි කරන්න.

6. What are your biggest challenges in production (tools, drying, storage, capital)?
   නිෂ්පාදන ක්‍රියාවලිය තුළ ඔබ මුහුණපාන විශාලතම අභියෝග මොනවාද (මෙවලම්, වියළීම්, ගබඩා කිරීම්, ප්‍රාග්ධනය)?

7. Do you see WH products as scalable? What support would help?

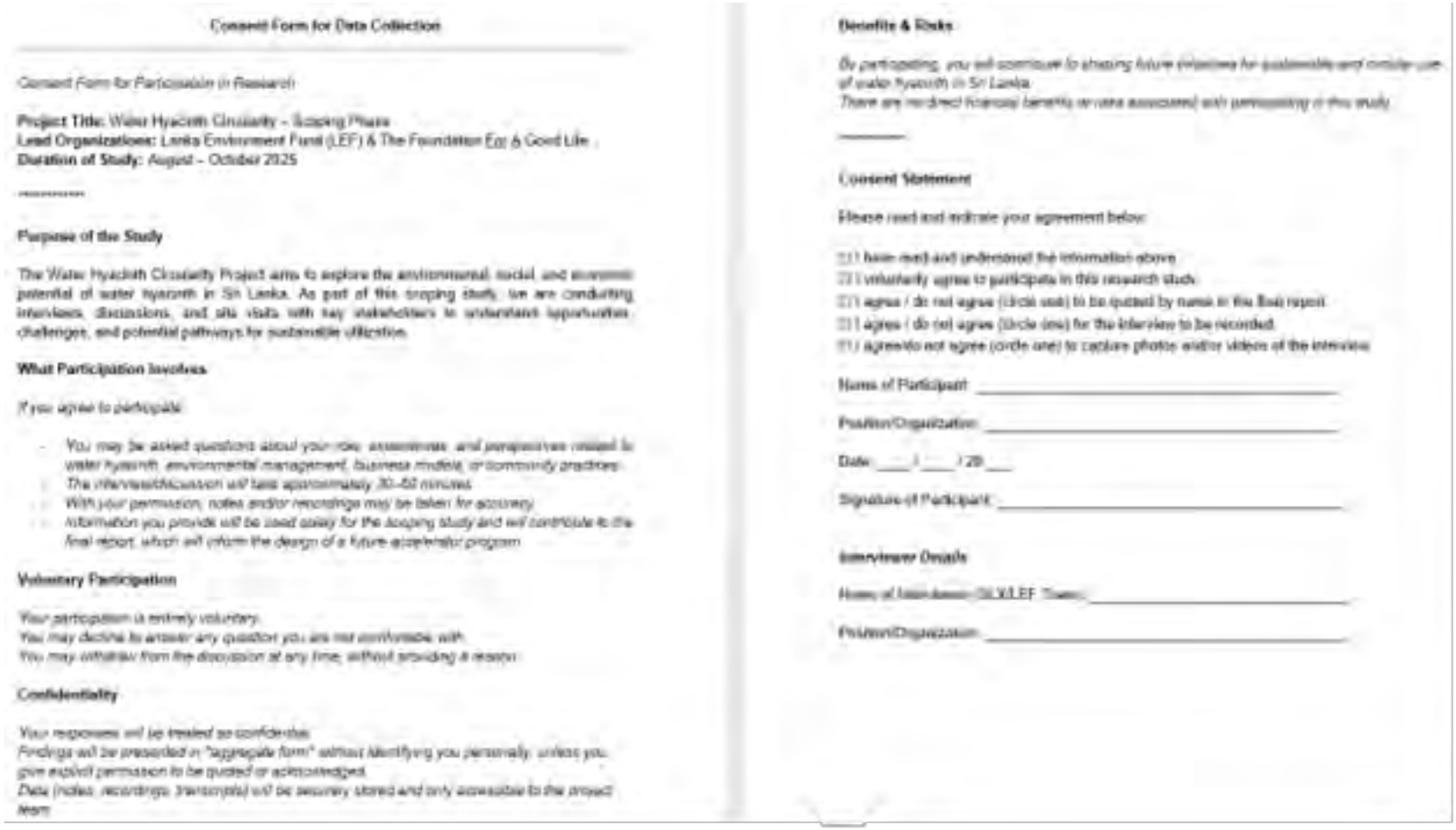
   ජපන් ජබර නිෂ්පාදනය තවදුරටත් සුළුල් කළ හැකි යැයි ඔබ සිතනවාද? මේය සාක්ෂාත් කර ගැනීමට කුමන ආකාරයේ සහයෝගයක් අවශ්‍ය වේද?

8. Would you join a program/accelerator to improve skills, finance, or markets?

   කුසලතා, අරමුදල් හෝ වෙළඳපල අවස්ථා වැඩිදියුණු කරගැනීම් සඳහා ඔබ වැඩසටහනකට/ත්වරක වැඩසටහනකට සම්බන්ධ වීමට අදහස් කරනවාද ?

15.4ANNEXURE 4 : CONSENT FORMS

15.4.1CONSENT FORM IN ENGLISH



Consent Form for Data Collection

Consent Form for Participation in Research

Project Title: Water Hyacinth Circularity – Scoping Phase
Lead Organizations: Lanka Environment Fund (LEF) & The Foundation For A Good Life
Duration of Study: August – October 2025

Purpose of the Study

The Water Hyacinth Circularity Project aims to explore the environmental, social, and economic potential of water hyacinth in Sri Lanka. As part of this scoping study, we are conducting interviews, discussions, and site visits with key stakeholders to understand opportunities, challenges, and potential pathways for sustainable utilization.

What Participation Involves

If you agree to participate:

- You may be asked questions about your role, experiences, and perspectives related to water hyacinth, environmental management, business models, or community practices.
- The interview/discussion will take approximately 30–60 minutes.
- With your permission, notes and/or recordings may be taken for accuracy.
- Information you provide will be used solely for the scoping study and will contribute to the final report, which will inform the design of a future accelerator program.

Voluntary Participation

Your participation is entirely voluntary.
You may decline to answer any question you are not comfortable with.
You may withdraw from the discussion at any time, without providing a reason.

Confidentiality

Your responses will be treated as confidential.
Findings will be presented in "aggregate form" without identifying you personally, unless you give explicit permission to be quoted or acknowledged.
Data (notes, recordings, transcripts) will be securely stored and only accessible to the project team.

Benefits & Risks

By participating, you will contribute to shaping future initiatives for sustainable and circular use of water hyacinth in Sri Lanka.
There are no direct financial benefits or risks associated with participating in this study.

Consent Statement

Please read and indicate your agreement below:

☐ I have read and understood the information above.
☐ I voluntarily agree to participate in this research study.
☐ I agree / do not agree (circle one) to be quoted by name in the final report.
☐ I agree / do not agree (circle one) for the interview to be recorded.
☐ I agree/do not agree (circle one) to capture photos and/or videos of the interview.

Name of Participant: _____

Position/Organization: _____

Date: ___ / ___ / 20___

Signature of Participant: _____

Interviewer Details

Name of Interviewer (SLWLEF Team): _____

Position/Organization: _____

15.4.2 CONSENT FORM IN SINHALA

[illegible]

[illegible]

[illegible]
[illegible]: Lanka Environment Fund (LEF) [illegible] The Foundation For A Good Life
[illegible] 2025 [illegible]

....

[illegible]

[illegible]

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]

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☐ [illegible]

[illegible]: ________________________

[illegible]: ________________________

[illegible]: ____ / ____ / 20__

[illegible]: ________________________

[illegible]

[illegible] (GLX/LEF [illegible]): ________________________

[illegible]: ________________________

15.5ANNEXURE 5 : CASE STUDY FROM THAILAND

WHA Eastern Seaboard Industrial Estate has turned water hyacinth management into an inspirational success story that shows how creative partnerships can transform environmental problems into thriving community businesses. In Thailand's Rayong province, WHA expanded their collaboration with Baan Kai District residents in 2021, who now craft laptop bags and attractive hampers from free water hyacinth collected monthly from the company's wastewater ponds.

This novel arrangement saves communities around 150 Baht per basket in material costs while providing a reliable income stream, with residents earning approximately 10,000 Baht per person each month and the community generating an impressive 1 million Baht annually through WHA's purchase of 300 baskets combined with local products from their Pan Gan Project.

Figure 20: Water Hyacinth circular solution from Baan Kai district Thailand

Furthermore, WHA partnered with PTTGC to develop an innovative textile that combines water hyacinth fibers with recycled plastic bottles from GC's YOUTURN platform and cotton materials, creating a sustainable fabric with remarkable commercial potential.

This collaboration generated multiple revenue streams:

communities earned over 36,000 Baht preparing water hyacinth fibers, while WHA made approximately 40,000 Baht selling processed fibers to manufacturers for further development. The partnership's crown achievement was producing 200 laptop bags and 300 hampers from this cutting-edge eco-fabric as premium corporate gifts that delighted WHA's most valued customers.

Figure 21: Women's group in Baan Kai Thailand with their Water Hyacinth products

What makes this model particularly interesting is how it demonstrates the evolution from simple handicraft production to sophisticated textile innovation, creating a knowledge base that empowers communities to generate future income while establishing sustainable supply chains that turn invasive plant management into profitable industrial applications. WHA's approach proves that with creativity and strategic partnerships, environmental challenges can become the foundation for thriving circular economy solutions that benefit everyone involved.

**

Source:

https://www.wha-group.com/en/sustainability/our-campaigns/social/1172/water-hyacinth-project#:~:text=As%20a%20result%20of%20this,satisfaction%20with%20the%20gifts%20received.&text=Your%20browser%20can't%20play%20this%20video.&text=An%20error%20occurred.,is%20disabled%20in%20your%20browser.

15.6 ANNEXURE 6 : CASE STUDY FROM SRI LANKA

Imalka is a young woman from Beliatta area in Tangalle who creates handicrafts using water hyacinth. She first discovered this craft through YouTube videos, which sparked her interest in the potential of water hyacinth as a raw material. Motivated by what she learned, Imalka decided to take action.

Her mother plays a key role in the process. Riding a small motorbike, she travels to the nearest water body and manually collects water hyacinth. She then straps the harvested plants to the back of the bike and returns home, where Imalka awaits.

Together, they wash the plants and lay them out to dry outside their home. This drying process takes about 10 days to two weeks, depending on the weather - highlighting the seasonal nature of harvesting water hyacinth.

Once dried, Imalka processes the plants using a manual machine that flattens them, making the material easier to weave. She has created Rigi foam molds to shape products in various sizes. In her modest two-bedroom home, Imalka has dedicated one room to crafting and processing, while her mother, younger brother, and grandmother share the other room.

Imalka notes that there is demand for her products, but she struggles to keep up. She believes she is the only person in Sri Lanka who weaves water hyacinth by hand, whereas others use sewing machines to stitch the material together.

For over five years, Imalka has been producing these items on a small scale. After officially registering her business, “IMA Water Hyacinth Products,” she gained access to markets through the Ceylon Chamber of Commerce. This exposure enabled her to receive small grants from The Asia Foundation, which she used to purchase digital devices like laptops and printers to support her home-based business.

She has also had opportunities to showcase and sell her products at various NGO-run market spaces. Imalka’s journey is a powerful example of grassroots entrepreneurship that, with the right support, has the potential to scale and transform into a sustainable enterprise that her family can depend on. However, more focussed interviews must be conducted.

Interview conducted by: Chrruti Pieres, Project Lead – Water Hyacinthesis, Lanka Environment Fund (LEF).

** No written consent forms were collected for this case study; however, verbal approval was obtained from Imalka. Chrruti discovered Imalka’s operation through Google Maps, where it is marked as being located in Tangalle. However, the listed address is inaccurate. Imalka’s home is actually located two lanes away from the marked location.*

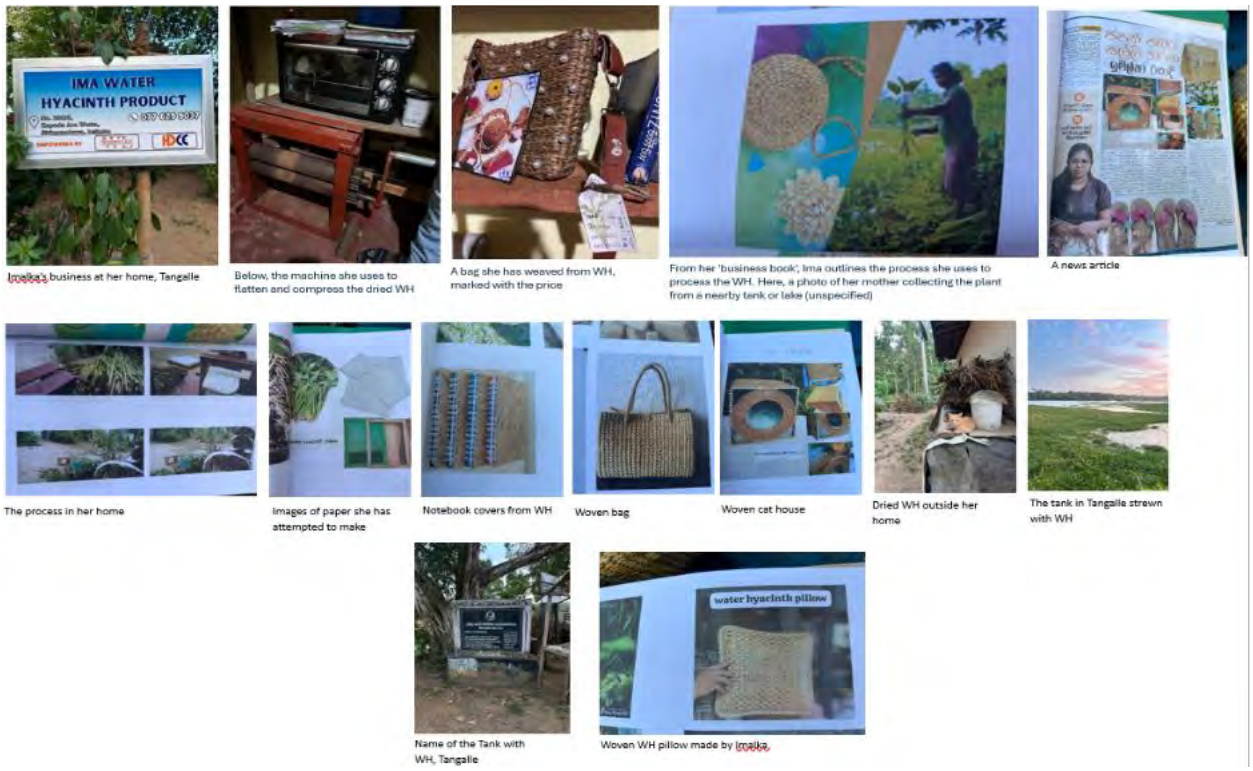


Figure 22: Imalka's business in Tangalle, her machinery, and products made using Water Hyacinth

15.7 ANNEXURE 7 : TECHNOLOGICAL TOOLS FOR MAPPING AND IDENTIFYING WATER HYACINTH IN SRI LANKA

1. Earth Observation (EO) Satellite Data: The primary tool is **Norway's International Climate and Forests Initiative (NICFI) data products**, which are monthly mosaics derived from **Planet imagery**. These provide very high-resolution data at a **4.77m spatial resolution**, offering almost cloud-free coverage essential for accurately monitoring water bodies in Sri Lanka.

2. Google Earth Engine (GEE) Platform: This cloud-based platform is crucial for processing the large volumes of high-resolution NICFI imagery, enabling scalable mapping and analysis of water hyacinth spread across Sri Lankan water bodies.

3. OpenStreetMap (OSM) Data and QGIS: Water body boundaries for 28 selected water bodies in Sri Lanka are obtained from **OpenStreetMap (OSM) data**. The **OSM Downloader Plugin within QGIS** (a free and open-source Geographic Information System software) is used to extract these geographical boundaries, providing the foundational dataset for analysis.

4. Machine Learning Techniques for Delineation: Several algorithms are integrated for precise identification.

5. Principal Component Analysis (PCA): Used to transform and construct images, retaining most of the variability for subsequent analysis.

6. K-means clustering: An unsupervised machine-learning algorithm that partitions processed data into distinct clusters, allowing for the identification and extraction of the cluster corresponding to water hyacinth.

7. Otsu thresholding: Applied simultaneously to determine the current water extent by automatically selecting an optimal threshold value.

8. Spectral Signature Analysis: A core method for distinguishing water hyacinth from other aquatic vegetation and water is based on its **unique spectral signature** [Conversation History]. Healthy water hyacinth exhibits the **highest reflectance in the Near-Infrared (NIR) band (780-860 nm)** and high absorption in the Red band (590-670 nm), making it clearly distinguishable from other plants and water

9. GPS Camera for Ground-Truthing: To validate the remote sensing results, limited ground-truthing is conducted using field photographs acquired with a **GPS camera** at specific water bodies in Sri Lanka, including Talangama, Diyawanna, and Werahara.

**

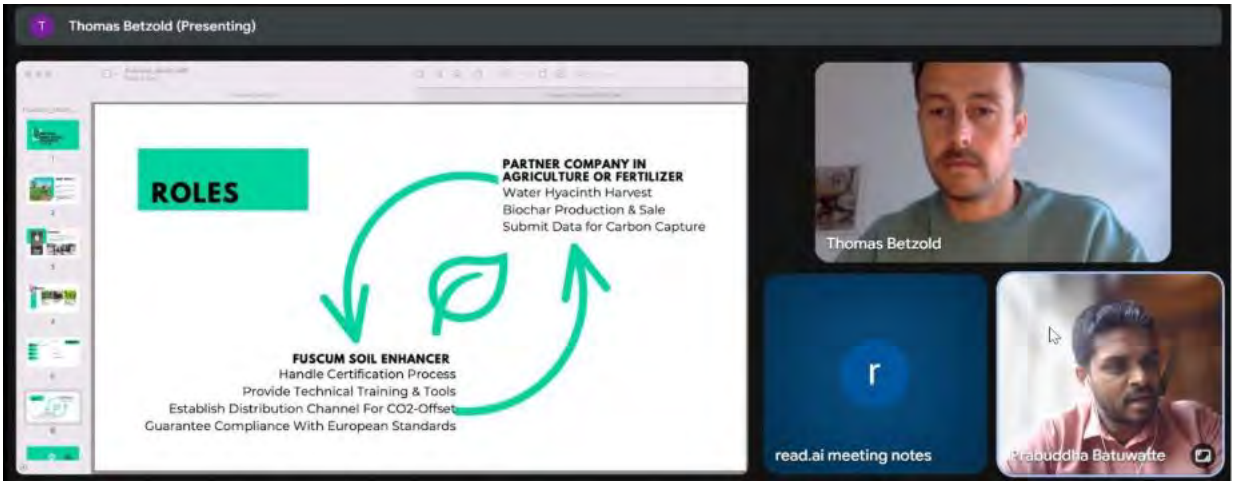
Source:

Ghosh, S., Jaykody, C. M., Taron, A., & Drechsel, P. (2024). A rapid assessment of Water Hyacinth (aquatic vegetation) mapping using machine learning for Circular Economic Opportunity in Sri Lanka. IEEE India Geoscience and Remote Sensing Symposium, 1–4. https://doi.org/10.1109/ingarss61818.2024.10983971

15.8 Annexure 8: Photos Captured of Water Hyacinth Products and During Stakeholder Meetings, and Field Visits

15.8.1 Products


15.8.2 Stakeholder Meetings



Thomas Betzold (Presenting)
ROLES
PARTNER COMPANY IN AGRICULTURE OR FERTILIZER
Water Hyacinth Harvest
Biochar Production & Sale
Submit Data for Carbon Capture
FUSCUM SOIL ENHANCER
Handle Certification Process
Provide Technical Training & Tools
Establish Distribution Channel For CO2-Offset
Guarantee Compliance With European Standards
Thomas Betzold
r
read.ai meeting notes
Prabuddha Batuwatte

15.8.3FIELD VISITS

15.9ANNEXURE 9 : STAKEHOLDER DATABASE

STAKEHOLDER DATABASE							
Entered by: *(Name of data entry individual)*	**Stakeholder Category** *(Private / Public / INGO)*	**Stakeholder Entity** *(Name of Entity i.e NEDA, For individuals, we can set the Stakeholder entity to "SME")*	**Impact** *How much does the project impact them?* *(Low, Medium, High)*	**Influence (Scoping /Accelarator)*** *How much influence do they haver the project?* *(Low, Medium, High)*	**Stakeholder contribution to the project (Scoping / Accelerator)*** *Type of support the stakeholder can provide – Scoping = knowledge, compliance, access; Accelerator = finance, markets, scaling*	**Additional Remarks**	**Value chain relationship** *(Ex: Land/Tank Ownership related to the Harvesting and Preprocessing; Processing Support (drying and forming), Technology (all steps); Financing (green finance, soft loans, microfinance etc.), Incentives/Subsidies (Govt. budget such as Aswesuma, Punarudaya); Environment Sustainability (Circularity, waste mangement, health concerns); Business Continuiety and Disaster Resilience (Bouncing back effect)/ability); Marketing and Networking Support (market information, new product development designs etc.); International Relations (market information, trends and new buyers); Quality, Standards and Packaging (value added packaging, humidity controls, preservations during transit, storage etc.); Research and Development / Innovation; Policy Alignment (Government support, how to deal with IAS legislations etc.))*
Prabuddha	Public	National Enterprise Development Authority (NEDA)	High	High	Knowledge & Access Scaling	Strategic entity who developed initial WH ecosystem in Ehetuwewa area. Island wide HR network to SME support	
Prabuddha	Public	Export Development Board (EDB)	Medium	Medium	Marketing (Export Markets)	They currently have one WH products exporter. Ultimately export market would allow to generate more revenue.	
Prabuddha	Private	MAS Foundation for Change	Medium	High	Knowledge Scaling	Through their ocean strainers , they closely work with SLRDC and local communities	
Prabuddha	Public	National Craft Council (NCC)	High	High	Knowledge , Markets	Mainly would be able to support us with accessing markets and linking up with the potential customers through strategic partnerships	
Prabuddha	Public	Makandura Agriculture Research Centre / Ministry of Agriculture	High	Medium	Knowledge Access	As a knowledge partner, resrouce entity and scalable solutions in composting.	
Prabuddha	Public	Ministry of provincial councils and local government/ National Solid Waste Support Centre (NSWMSC)	High	High	Knowledge Access Scoping	As a knowledge partner, resrouce entity and scalable solutions in composting.	
Prabuddha/Ananda	Public	National Aquatic Resources Research and Development Agency (NARA)	Medium	High	Knowldge on aquatic species	NARA has the best research information on coastal water bodies	
Prabuddha/Ananda	Private	Ceylon Chamber of Commerce	Medium to High	High	Leveraging private sector interests	He is also the Head of Sustainability of Union Bank and a key player in Bankers Association	
Prabuddha	Private	Sanasa Development bank	High	Hight	Acclerator - Finance, Markets, Scaling	SDB can play key role when scaling, training financial literacy. Also Sanasa roots and access to community clusters would be a credible asset.	
Prabuddha	Private	Cargills	High	High	Accelerator - Markets , Scaling	Plastic alternatives (bags, packaging solutions for egg cartons etc,)	
Prabuddha	Private	John Keells	High	High	Accelerator - Markets , Scaling	Plastic alternatives (bags, packaging solutions for egg cartons etc,)	
Prabuddha	Private	Katana Upcycle	Low	Low	Markets	Make stationary. Pages can be made by JJ paper	
Prabuddha	Private	Control Union	High	High	Markets and Scaling	Certifcations and industry standards .	
Prabuddha	Private	LOLC Finance	Medium	High	Finance, Markets, Training	LOLC finance can play an important financial service provider and training role in this project	
Prabuddha	Private	Browns Hotels and Resorts	HIgh	High	Market and Scaling	Browns is very much interested to consider how WH products can cater to their requirments in their hotel and restuarant industry	
Prabuddha	INGO	Caritas	Medium	Medium	Community cluster access and implementation	Caritas a very high network of community clusters around the country which can be utilised for cluster development with ground level presence	

STAKEHOLDER DATABASE							
Entered by: *(Name of data entry individual)*	**Stakeholder Category** *(Private / Public / INGO)*	**Stakeholder Entity** *(Name of Entity i.e NEDA, For individuals, we can set the Stakeholder entity to "SME")*	**Impact** *How much does the project impact them?* *(Low, Medium, High)*	**Influence (Scoping/Accelarator)*** *How much influence do they haver the project?* *(Low, Medium, High)*	**Stakeholder contribution to the project (Scoping / Accelerator)*** *Type of support the stakeholder can provide – Scoping = knowledge, compliance, access; Accelerator = finance, markets, scaling*	**Additional Remarks**	**Value chain relationship** *(Ex: Land/Tank Ownership related to the Harvesting and Preprocessing; Processing Support (drying and forming), Technology (all steps); Financing (green finance, soft loans, microfinance etc.), Incentives/Subsidies (Govt. budget such as Aswesuma, Punarudaya); Environment Sustainability (Circularity, waste mangement, health concerns); Business Continuiety and Disaster Resilience (Bouncing back effect)/ability); Marketing and Networking Support (market information, new product development designs etc.); International Relations (market information, trends and new buyers); Quality, Standards and Packaging (value added packaging, humidity controls, preservations during transit, storage etc.); Research and Development / Innovation; Policy Alignment (Government support, how to deal with IAS legislations etc.))*
Prabuddha	Public	Industrial Development Board (IDB)	High	Medium	Training, Manufacturing capacity	IDB can be a knowledge partner as well its capacity to develop small scale to mid scale machinery and equipment can be an asset for the program	
Prabuddha	Public	Open Univeristy - Nawala - Centre for Environmental Studies and Sustainable Development	Medium	Low	Access Scaling		
Prabuddha	Public	Minstry of rural development, social security and community empowerment	Open Univeristy - Nawala - Centre for Environmental Studies and Sustainable Development	High	Access Scaling	Accessing and empowering community They propably have financial instruments and support programs in place	
Prabuddha	Public	The Department of Fisheries and Aquatic Resources (DFAR)	High	High	Policy, access		
Prabuddha	INGO	Sri Lanka Red Cross	medium	medium	Funding, Quality, Access		
Prabuddha	Private	Bio Diversity group	medium	high	Funding, Quality, Access		
Prabuddha	Semi Gov	Technical Colleges and Educational Institutes	high	high	Training		
Prabuddha	Public	SLSI	medium	high	Access		
Prabuddha	Private	Lady J/Manjari/Odel	medium	high	Market Access		
Prabuddha	Private	Laksala/Lakpahana / Barefoot	medium	high	Market Access		
Prabuddha	Private	Other Banks/Financial Institutions	Low	high	Financing		
Ananda M	Public	Sri Lanka Land Reclamation and Development Corporation	High	High	Access, Partnerhip Potential, Cost Sharing	Spoke - willing to talk more - Already MAS holdings is approaching them	
Ananda M	Public	Ministry of Environment (Biodiversity)	Medium	Medium	Policy environment	Was instrumental in Invasive Alien Species policy	
Ananda M	Public	Dept. of Coast Conservation and Coastal Resources Management	High	High	Partnership, Policy environmnet and knowledge	Coastal wetlands has mulitiple opportunities and a accademic with high energy. This depatment has the legal jurisdiction on coastal water bodies to a great extent	
Ananda M	Public	Department of Agrarian Services	High	High	Partnerhip potential, access to minor waterbodies, tanks etc.	Department is incharge of all minor tanks and when I spoke they recognized it as a problem but not done much	
Ananda M	Public	Central Environment Authority	Medium	Medium	Regulatory complience on water quality etc.		
Ananda M	NGO	Green Movement of Sri Lanka	Medium	High	Community level project experience, umbrella organization for over 100 CBO/NGOs	Useful if we were to expand as a national initiative. Good with donors and Government	
Ananda M	NGO	HELP-O	High	High	Knowledge	Use of WH in Compositing and Biogas	
Ananda M.	UN	FAO	Medium	Medium	Upscaling potential, knowledge, food security aspect	Excellent partnership as FAO work intenvely with food security and developing a Climate Smart Investment Plan for Agriculture	
Ananda M.	Private	Aitken Spence PLC	High	High	Knowledge, Networking	Experience in Paper Making with Elephant Dung and connected with companies	
Ananda M.	Public	Disaster Management Centre	High	High	Access, Scaling	Disaster / flooding aspects of WH	

STAKEHOLDER DATABASE							
Entered by: *(Name of data entry individual)*	**Stakeholder Category** *(Private / Public / INGO)*	**Stakeholder Entity** *(Name of Entity i.e NEDA, For individuals, we can set the Stakeholder entity to "SME")*	**Impact** *How much does the project impact them?* *(Low, Medium, High)*	**Influence (Scoping /Accelarator)*** *How much influence do they haver the project?* *(Low, Medium, High)*	**Stakeholder contribution to the project (Scoping / Accelerator)*** *Type of support the stakeholder can provide – Scoping = knowledge, compliance, access; Accelerator = finance, markets, scaling*	**Additional Remarks**	**Value chain relationship** *(Ex: Land/Tank Ownership related to the Harvesting and Preprocessing; Processing Support (drying and forming), Technology (all steps); Financing (green finance, soft loans, microfinance etc.), Incentives/Subsidies (Govt. budget such as Aswesuma, Punarudaya); Environment Sustainability (Circularity, waste mangement, health concerns); Business Continuiety and Disaster Resilience (Bouncing back effect)/ability); Marketing and Networking Support (market information, new product development designs etc.); International Relations (market information, trends and new buyers); Quality, Standards and Packaging (value added packaging, humidity controls, preservations during transit, storage etc.); Research and Development / Innovation; Policy Alignment (Government support, how to deal with IAS legislations etc.))*
Ananda M.	Public	Urban Development Authority	High	Medium	Access, Complience and Finance as a partner	Urban wetlands angle (Colombo Wetlands)	
Ananda M.	Public	Irrigation Ministry / Mahaweli Authority	High	High	Access, knowledge and potential partnerhips	Mahaweli and many other water bodies including hydro dams	
Ananda M	Public	Ministry of Finance	High	Low	Knowledge, Policy, Incentives	If we were to go for green financing	
Ananda M	Public/Private	Indpendent Consultant/ Former Director of Agriculture	High	High	Knowldege, Policy, Investment	Gaps and Impacts of WH on agriculture and community actions	
Arosha H	Semi Gov	Sri Lanka Water Partnership , International Water Management Institute, No. 127, Sunil Mawatha, Pelawatta, Battaramulla,	Medium	Medium	Knowledge/ scaling	Looking for research collaborations. Experice in their researches on this area	Research and Development/ Innovation
Arosha H	Semi Gov	International Water Management Institute	Medium	Medium	Knowledge/ scaling	Looking for reserch colloaboration	Research and Development/ Innovation
Arosha H	Public	Department of Textile and Apparel Technology, University of Moratuwa	High (Technical)	Medium	Knowledge/ scaling	They have done the researches on extraction and characterization of water hyacinth fibers	Research and Development/ Innovation
Arosha H	Public	Department of Textile and Apparel Technology, Open University	High (Technical)	Medium	Knowledge/ scaling	They have done the special researches on water absorption and flammability properties of water hyacinth fibers.	Research and Development/ Innovation
Arosha H	Public	Faculty of Science, University of Kelaniya	High (Technical)	Medium	Knowledge/ scaling	Currently run a research on convering leaf of WH to paper. At the end of the study	Research and Development/ Innovation
Arosha H	Public	Waste Management Authority	Medium	Medium	Market/Scaling		Processing support as SLRDC
Arosha H	Public	Central Environmental Authority	High	High	Complience	They do the legislations on WH-based products; linking to national circular economy & sustainability goals	Policy Alignment
Thushan Wickramasinghe	NGO	Sarvodaya Movement	High	Medium	Access, Scaling	They do the legislations on WH-based products; linking to national circular economy & sustainability goals	
Arosha H	Public	Faculty of Technology, University of Sri Jayawardenapura	High	Medium	Knowledge/ scaling	Currently run a research on convering leaf and flower of WH to colour pigments. at the begining of the study	Research and Development/ Innovation
Thushan Wickramasinghe	Public	University of Moratuwa Integrated Design	High	Medium	Knowledge/ scaling		
Arosha H	Private	SLINTEC	Medium	Medium	Knowledge/ scaling	Looking for research collaborations	Research and Development/ Innovation
Count							
Public:	31						
NGO and INGO:	8						
Semi Gov:	3						
UN:	2						

15.10 ANNEXURE 10 : STAKEHOLDER MEETING MEMO

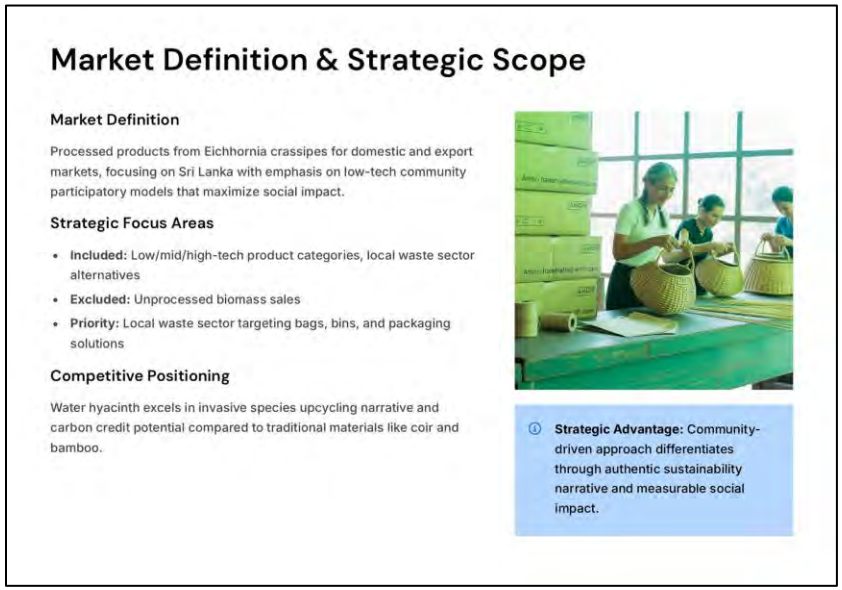
Project Hyacinthesis - Stakholder Meeting Memo

Meeting Date	Mode	Stakeholder Name	Designation	Institute/Organization/Business	GLX Staff	LEF Staff	Experts	Other	Meeting Objective	Expected Outcome
2 September 2025	In-person	Mr. Dhanuka Liyanagamage	Director	National Enterprise Development Agency (NEDA)	Thushan Wickremesinghe and Harisma Visvanathan	Chrruti Pieres	Prabuddha Batuwatte (Business), Dr. Ananda Mallawatantri (Environment)	N/A	- To understand NEDA's involvement in supporting water hyacinth management	- Learn NEDA's involvement in commercializing WH. - Understand the type of support given by NEDA.
4 September 2025	In-person	Dr. N.S. Wijayaratna	Deputy General Manager	Sri Lanka Land Developement Corporation (SLLDC)	Thushan Wickremesinghe	Hafsa Jamel and Chrruti Pieres	Dr. Ananda Mallawatantri (Environment) and Dr. Arosha Hemali (Technical)	N/A	- To understand SLLDC's involvement in WH management in SL and challenges encountered	- Identify the water bodies in which WH are mostly present. - Know the variety of other stakeholders involved in WH management.
10 September 2025	In-person	Dammika Priyadarshini	Entrepreneur	Small and Medium Enterprise producing Water Hyacinth based products located in Galkatiyagama, Ambogama	Thushan Wickremesinghe and Harisma Visvanathan	Chrruti Pieres	Prabuddha Batuwatte (Business), Dr. Ananda Mallawatantri (Environment)	Mr. Dhanuka Liyanagamage (Director, NEDA), Ms. Oshani Bodhiwansa (Assistant Director, NEDA), Mrs. Ayesha Liyanaarachchi (Enterprise Promotion Officer, NEDA), Mr. L.H.S.K Sudath Lamahewa (Enterprise Development Officer, NEDA Regional Office) and Mrs. W. Peshala Subhashini Wanninayake (Entrepreneur Development Officer, Ehetuwewa Divisional Secretariat)	- To learn the type od products made out of WH. - To learn the processes, tools and technologies used in the production process. - To gauge the success of these businesses. - To identify any gaps and possible interventions.	- Variety of goods made out of WH. - Supply chain of the WH based goods. - Processes, tools and technologies used. - Sourcing of WH. - Challenges encountered by the SME, support required by them.
10 September 2025	In-person	Niluka Jayanthi	Entrepreneur	J.J.Products located in Galkadawala, Ehatuwewa	Thushan Wickremesinghe and Harisma Visvanathan	Chrruti Pieres	Prabuddha Batuwatte (Business), Dr. Ananda Mallawatantri (Environment)	Mr. Dhanuka Liyanagamage (Director, NEDA), Ms. Oshani Bodhiwansa (Assistant Director, NEDA), Mrs. Ayesha Liyanaarachchi (Enterprise Promotion Officer, NEDA), Mr. L.H.S.K Sudath Lamahewa (Enterprise Development Officer, NEDA Regional Office) and Mrs. W. Peshala Subhashini Wanninayake (Entrepreneur Development Officer, Ehetuwewa Divisional Secretariat)	- To learn the type od products made out of WH. - To learn the processes, tools and technologies used in the production process. - To gauge the success of these businesses. - To identify any gaps and possible interventions. - To observe the sourcing of WH from the waterbody.	- Variety of goods made out of WH. - Supply chain of the WH based goods and exporting countries. - Processes, tools and technologies used. - Sourcing of WH. - Challenges encountered by the entrepreneur, support required by them. - Employees involved in production activities like weaving. - Learn the technique followed in sourcing WH by the entrepreneurs. - Witness the presence of WH in the waterbody.
				Waterbody						
15 September 2025	In-person	Dr. Pay Drechsel	Advisor - Research Quality	International Water Management Institute (IWMI)	Harisma Visvanathan	Hafsa Jamel	Dr. Arosha Hemali (Technical), Prabuddha Batuwatte (Business) and Dr. Ananda Mallawatantri (Environment)	N/A	- To learn the involvement of IWMI in WH management in Sri Lanka.	- Types of work they are involved in controlling WH in Sri Lanka. - Learn what similar partners in other countries do in controlling WH. - Gather insights from research findings.

15.11 ANNEXURE 11 : MARKET ANALYSIS – PRELIMINARY WORK

Slide 1

Slide 2



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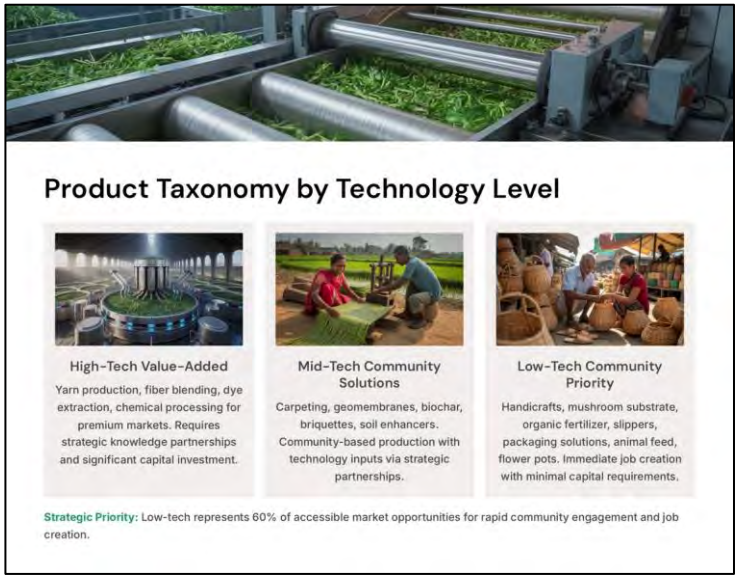


Slide 4

Supply Landscape in Sri Lanka

Ecology & Availability

Major hotspots in Colombo, Kandy, and coastal wetlands. Year-round availability with peak seasons October-March. High-quality fibers 1-2m length with 90-95% moisture content.

1 **Harvesting**

Cost: 10-20 LKR/kg wet ($0.03-0.07 USD). Labor: 500-800 LKR/day ($1.67-2.67 USD). Requires permits in protected areas.

2 **Preprocessing**

Drying and retting processes. 80-90% yield loss wet-to-dry. Cost: 50-100 LKR/kg dry. Quality control critical for downstream processing.

3 **Distribution**

Rural logistics challenges. Government support through EDB, NGO partnerships with IUCN, university R&D collaboration opportunities.

Slide 5

Scaling Through Community Layers & Job Creation

01

Access & Supply Chain Layer

Boats, barges, harvesting tools (cutters, grapples) for material collection. Creates 5-7 jobs per harvesting team. Equipment investment: 10,000-50,000 LKR per unit ($33-167 USD).

02

Transportation Infrastructure

Local vehicle networks for material movement between sites. Generates 2-3 logistics jobs per regional hub. Transportation costs: 50-100 LKR/kg processed material.

03

Preprocessing Operations

Decentralized hand-operated machinery (extractors, cutters, dryers). Creates 3-5 skilled processing jobs per community site. Machinery costs: 20,000-100,000 LKR ($67-333 USD).

04

Community Impact Model

Participatory approach ensures inclusivity and aligns with national employment policies. Potential for 100-200 regional jobs at full scale, providing sustainable rural income opportunities.

ESG Impact: Creates meaningful employment in rural areas, directly addressing poverty while maintaining low capital expenditure through community partnerships and subsidies.

Slide 6

Demand Landscape Analysis

Domestic Market Opportunities

- **Tourism Sector:** Souvenirs for 2.3M projected arrivals in 2025
- **Retail & Hospitality:** Sustainable product positioning
- **E-commerce Growth:** Online marketplace expansion
- **WH in Sectorial Utilization - Product alternatives for existing sectors/industries**

(Example: Waste Sector | Plastic alternatives for bags, bins, and baskets)

Export Market Potential

Primary markets: US, EU, Japan via wholesalers and Alibaba. Minimum orders 100-500 units, 4-6 week lead times. Sustainability certifications essential for premium positioning.

Price Band Structure

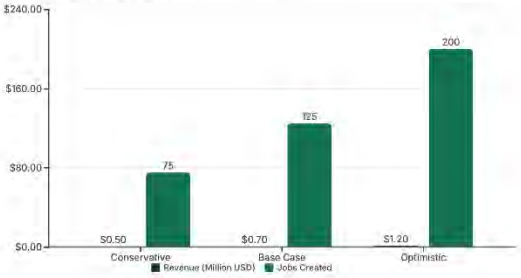
- **Low-tech:** Fertilizer 50-100 LKR/kg ($0.17-0.33 USD)
- **Mid-tech:** Biochar 200-400 LKR/kg
- **High-tech:** Yarn 500+ LKR/kg

Slide 7

Market Sizing & Growth Projections

$0.5-1M	$12M	4-6%
Current Market Size	Total Addressable Market	Historic Growth Rate
Total addressable market in USD (150-300M LKR) with low-tech representing 80% of opportunities	Including carbon credit potential with $3M serviceable addressable market and $0.6M serviceable obtainable market	Post-2020 growth driven by tourism recovery, ESG investment trends, and community job creation initiatives

Three-Year Growth Scenarios



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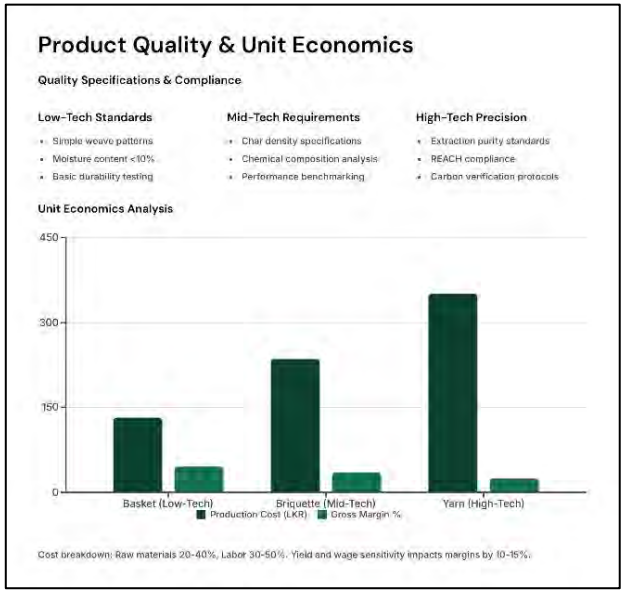
Slide 9

Slide 10



Slide 11

Slide 12

Operational Plan & Strategic Partnerships

Network Design

Community hubs in Anuradhapura region with scaling infrastructure including boats, harvesting tools, transportation networks, and preprocessing machinery for comprehensive value chain coverage.

Training & Quality Control

Standard operating procedures for participatory harvesting and quality control. Comprehensive job training programs with AQL 2.5 standards and moisture content below 10% requirements.

Strategic Partnerships

Export Development Board for programs, local councils for equipment subsidies, NGOs like IUCN for community mobilization, universities for high-tech development, impact investors for carbon financing.

Partnership Strategy: Strategic alliances enable mid/high-tech capabilities while community focus maintains low-tech job creation and long-term social impact.

Slide 13

Risk Management & Growth Scenarios

Key Risk Assessment

Biological Variability

High Risk: Seasonal quality fluctuations.

Mitigation: Diversify harvesting sites and implement quality training programs.

Compliance & Quality

High Risk: Mold contamination, export standards.
Mitigation: Regular audits and quality control systems.

Community Dependency

Medium Risk: Labor availability fluctuations.
Mitigation: Job training and community engagement programs.

Growth Scenarios Comparison

Recommendation: Pursue high-growth scenario through low-tech pilots and strategic partnerships.

ESG alignment and job/carbon potential justify investment risk.

Slide 14

Investment Recommendation & Next Steps

Invest in Sustainable Impact

Investment Thesis

Water hyacinth valorization in Sri Lanka presents a compelling ESG-aligned opportunity with 20-25% ROI potential through community-driven scaling, job creation, and carbon credit revenue streams.

Immediate Actions

- Launch low-tech pilot program
- Establish community partnerships
- Initiate carbon credit certification
- Secure strategic alliances

Expected Impact

100-200 rural jobs created, $1.0-1.5M revenue potential with carbon credits, measurable wetland restoration impact, and an authentic sustainability narrative for market differentiation.

"This investment opportunity uniquely combines financial returns with measurable social and environmental impact, positioning our portfolio at the forefront of sustainable development in emerging markets."

Slide 15

15.12 ANNEXURE 12 : NEEDS ASSESSMENT

15.12.1 SITE PROFILE

Field	Business Expert Response
Location / Water body	Ehetuwewa, Kurunegala district
Date of visit	10/09/2025
Assessor(s)	Prabuddha Batuwatte
Community / Groups engaged	Saubhagya Community Group, JJ products
Institutions engaged	NEDA HO, Ehetuwewa NEDA officer, Kurunegala Distirct NEDA Coordinator
Estimated hyacinth coverage (hectares / %)	Usually a rule of thumb is Typical inland water body is 35% to 45% covered with WH on average But there are several factors that affect this. Need to be location specific measurement if we need high accuracy .
Seasonality observations	Dry and Rainy seasons. Dry season , they harvest and keep the WH dried so then can cater for the orders in the Rainy season

15.12.2 TECHNICAL NEEDS

Category	Technical Expert's Response	Comments from the Business Expert	From the study
Current removal methods	Depends on the harvesting volume expected, This process needs partial standardization through semi-mechanized tools or low-cost platforms to improve efficiency, along with training on stem selection and safety. Regional coordination can further align biomass quality with product requirements for consistent utilization.	Manual	Harvesting is mostly done manually by using a hook attached to a long rod and by getting into the side of the water body, unless a mechanical boat harvester is used. The volumes harvested depend on the amount of biomass required for the given use. Immediately after the harvesting the main step to remove the water from the harvested material. A staged approach works best—gravity drainage or pressing first, followed by sun/thermal drying depending on the end use. The key is to combine efficiency with safeguards against regrowth, contamination, and health risks. Ref: (https://docs.google.com/document/d/16KxKkCaV6td_VxaZyF2yYFPXj3QQIprC/edit#bookmark=id.dlo1giyzsal3)
Gaps identified (tools/machines/PPE)	Few recomendation for Gaps are follows. Removal & Safety: Introduce basic PPE kits (life jackets, gloves, boots, helmets). Conduct safety training in collaboration with local authorities to mitigate drowning risks. Tools & Accessibility: Provide boats or barges with extended-reach tools (mechanical grappling hooks or long-arm rakes) to safely and efficiently access dense water hyacinth areas.	Removal - No PPE or Safety equippment, Elephant attacks, Drowning concerns Tools - Reach to water hyacinth , (Boarts or barges/grappling hooks/ long arm rakes) Machines - Lack of sewing machines, twin rollers, Transportation from an efficiency aspect	
Required infrastructure		Production floor or show case area, Under utlised building infrastructure under DS ownership	
Skill/training needs	structured training framework combining hands-on technical training, business mentoring, and market linkage support is essential	Quality controls aspects from raw material selection, product quality , product development, branding , story telling , export procedures and technical information, business process , financial literacy, design and pattern making , marketing / digital marketing/ social media marketing, Export market knowledge	
Viable product pathways	Based on market links and demand Eg. Key Hotel chains, durability of the product material need to assure	Handicrafts, Packaging solutions, Flower Pots, Paper	
Existing equipment	Capacity of the machines, scalability, and durability. Also the feasibitly of the machnary in long run and cater for constant production requirements need to asses	Sewing machines, Rolling machines, Minor tools	
Missing equipment / technology needs	Need to check on the scalable options	Sewing Machines	
Required skills (crafting/operation/QA)	Basic QA & QC process need to introduce	Quality management , Branding, Design	
	Note: Better to have strategy open for other technologies such as medium to large scalable options in the long run.		

15.12.3 FINANCIAL NEEDS

Category	Business Expert's Response	Technical expert	Comments
Estimated capital investment (Rs.)	160000	Consider on Maintanence and reparing plans also for continuous operation	Mainly the sewing machine + other minor requirements
Estimated operational costs per month (Rs.)	60000		(A group of 6, Average income per month 100000)
Current community income sources	Food preparation, Other Handicrafts making,		
Expected income potential from hyacinth products	10000		per month
Financing gaps (credit/grants/subsidies)	Financing required for capital investments (More sewing machines)		
Market linkage requirements	Export market Oriented, , Eco Friendly hotel sector,		

Background Information - Sewing Machines	At the time this program was first initiated the sewing machines were provided to the individuals at no cost. Cost per sewing machine provided was **Rs. 60,000/=.**	Got to know about second phase of the program but the sewing machines were provided by 50% rate where individual had to pay about **Rs. 30,000/=** and other 50% was borne by NEDA	Present day the sewing machine is cost about **Rs. 1,20,000/= to Rs. 1,50,000/=** range a chinese made product branded through ZOJE brand , by **Singer.** Potenital partnership: **Singer | USHA**	Hand operated two roll machine for pressing Rs. 18,000/= in 2020 Rs. 50,000/= currently Otherwise they can use the scissors to do the same function but the efficiency is low.
Work Force and Income related	Most of the time the indivduals work for about 4 to 5 hours per day. Giving the flexibility to do their other work during the day like taking care of the kids , house chores etc. They get paid for number of pieces they have completed. But there are daily rates as well like a man power model.	Daily rates - Rs. 400/= to Rs. 700/= Monthly rates - Rs. 9,000/= to Rs. 11,000/= **Need basis only** Man power - On call - Per day Rs. 900/= to Rs. 1000/= Man power - Per Month - Rs. 5,000/= **Other** WH harvested and dried - Buy at **Rs. 400/= per kg to Rs. 650/= per kg**		
Production Capacity	Some parts of the products are sewn and other components are woven. **Simple bag - 5 bags per 2 days** **Intricate fashionable bag - 5 bags 4 days** Separate functions and parts done at their individual homes or at the facility it self. This is flexible working arrnagement. Typically 4 to 5 hours per day.	Plasitc handles, zippers and other cloth materials can be purchased from Kurunegala or from colombo at times. Prices have gone up **Wooden - Rs. 480/= to Rs. 500/= range** **Plastic - Rs. 550/= to Rs. 620/= range**	Some times transportation cost is incurred for dried material transportaion through buses in sacks. A sack can contain about **4kg to 5kg** Typical cost of transportation is **Rs. 100/=** per delivery on a friendly basis Finished products are also transported to Kurunegala, Galgamuwa, Meegalaawa. Hela Bojun Hala - They have to go their twice to product delivery and checque pick up - Inefficiency!	

Sales and Market	Bag prices are in the range of **Rs. 1500/= to Rs. 1800/= range with JJ products** **Rs. 1900/= to Rs. 2200/= range with Saubhagya group**	Profit ranges **JJ products - Rs. 200/= to Rs. 500/= range per bag** **(She showcased a good understanding about profit margins. She was mentioning her target is to maintain about 30% to 40% profit margin and not more than that. Her financial literacy and business knowledge with entrepreneurial intent is resourceful.)** **Saubhagya - Rs. 300/= to Rs. 700/= range**	**Sauhbhagya** Currently put their products to **NCC cetre Kurunegala, Hela Bojun Hala**(They keep 20% for them, so 2000 sell price at 1800), **Llaama** (Eco Products place - they come and pick direct) A new order negotiation ongoing now for Maldives for slippers. Contacted through the DS. Large export order. **JJ Products** **Local online orders.** **Japanese order.** ** I have requested contact details of these channels so we can intervene when we are at that stage.	
Trainings and other	**Saubhagya Group Leader** Mrs. Dhammika seems to be doing and coordinating the DS facility at a basic level **JJ products - Mrs. Niluka** She is doing trainings with Vi.Da.Tha, Galgamuwa DS, WNPS, Military Services. etc. Her charges are (2 ay programs) **Rs. 5000/= per day - Within the district** **Rs. 6000/= per day - Close by district** Other long distant programs transportation, accomodation and food to be provided. She does trainings for making products out of similar materials, waste materials etc. Relatively strategic on youtube channels, FB pages and digital presence. Has the entrepreneurial thinking. Good resource. *** These two groups does not seem to mix with each other. JJ products Mrs. Nilusha has been asked to does training at the DS facility but she has refused. She has requested this facility to be run by her but the DS management hasnot agreed with it which probably led to this situation. These conditions to be managed accordingly when we intervene			

15.12.4 ENVIRONMENTAL NEEDS

Value Chain Stage	Key Risks	Safeguards & Mitigation	Monitoring / KPIs
Harvesting & Transport	Spread of invasive seeds; habitat disturbance; turbidity spikes	Enclosed collection & dewatering at site; thermophilic drying to neutralize seeds; staged removal to protect DO levels; silt curtains in sensitive zones	% biomass neutralized before transport; water quality (DO, turbidity) pre/post harvest
Pre-processing & Storage	Leachate contamination; pest attraction; fire hazard	Covered drying floors with leachate capture; pest control; fire safety protocols	Leachate COD/BOD; pest incidence; fire drills conducted
Fiber Extraction & Compounding	High water use; dust inhalation; chemical binder hazards	Closed-loop water systems; local exhaust ventilation; PPE; bio-based binders	Water reuse rate; airborne dust levels; % low-toxicity binder use
Coloring & Finishing	Toxic dyes; effluent pollution; high water use	OEKO-TEX/Bluesign dyes; counter-current rinsing; effluent treatment to standards	Effluent COD/BOD/metals; dye bath reuse cycles
Thermal Conversion (Biochar/Briquettes)	Air emissions; hazardous condensates	High-efficiency pyrolysis with afterburners; condensate capture & safe disposal	PM/CO/NOx levels; condensate volume & disposal records
Waste Management	Hazardous sludge; organic waste	Stabilize hazardous sludge; compost/digest clean organics	% waste diverted from landfill; compost pathogen kill verification
Occupational Health & Safety	Heat stress; ergonomic strain; injury risk	Job hazard analysis; PPE; rest breaks; ergonomic tools	Lost-time injury rate; PPE compliance rate
Community & Biodiversity	Unequal benefit sharing; biodiversity loss	Fair wage policy; grievance redress; removal plans avoiding nesting seasons	% women/youth employed; grievance resolution time

15.12.5 INSTITUTIONAL NEEDS

Category	Business Expert Response
Required permits / approvals	Technically notify the water body ownership (Agrarian Services, Mahavali, Agriculture dept,etc) or DS to notify the access and the transportation of the WH. Operating community groups are currently accessing and transporting WH but we need to check the proper approvals are taken or authorities are notified.
Local institutions to partner with	Divisional Secretary Ehetuwewa, NEDA, MAS
Identified coordination gaps	Divisional Secretary has ownership of the full scale hub operation facillity. Saubhagya Community group and other new entrants have access it for training. Other people can use the facility to get some of their processing done. But heavily under utilised it seems.
Potential for service contracts	Divisional Secretary Ehetuwewa

Stakeholder	Role & Responsibility	Gaps / SWOT Notes
Ministry of Environment / Biodiversity Secretariat Central Environment Authority	Lead agency for IAS policy, permitting, monitoring	Limited budget for IAS control; fragmented enforcement
Department of Wildlife Conservation	Protect aquatic biodiversity; enforce Fauna & Flora Protection Ordinance	Overlap with fisheries jurisdiction
Department of Fisheries & Aquatic Resources	Manage aquatic resources; issue harvesting permits	Weak integration with IAS eradication plans
Local Authorities / Pradeshiya Sabhas	Coordinate removal, disposal, and community engagement	Limited technical capacity
Community-based Organisations / Women's Groups	Manual harvesting, processing, product innovation	Need training in safe harvesting & environmental safeguards
Private Sector / SMEs	Invest in WH-based products (bioenergy, handicrafts, compost)	Require clear compliance pathways & incentives
Academia / R&D Institutes	Research on WH impacts, utilisation technologies	Research–policy gap; limited funding

15.12.6 PRIORITY SCORING

	Business Expert		Technical Expert		Environmental Expert	
Dimension	**Score (1-5)**	**Notes**	**Score (1-5)**	**Notes**	**Score (1-5)**	**Notes**
Technical feasibility	4	Knowledge, Product Expertiese, Equipment and Machinery facilities are readily available	4	Agreed	4	Possible with tight management as a large national or provincial level operation, if we were to do large scale. However, current small holder operations may not need such extensive environment and health safeguards.
Financial viability	4	A working model, community clusters, acces materials and a market is available. Financially sensible.	5	Both Market and financial feasiblity go hand in hand. For long term stratergy medium scale technological solutions need to develop	4	Room for improvent if we can get Payment for Ecosystem Services, Carbon funds and Disaster Risk Reduction options incorporated in the financial calculations. Further the incentives for exports and support for circularity will increase the financial viability. ESG programms through local banks can help the SME applications and the large scale can adopt all the blended financing systems including EU Green Deal
Market demand potential	5	They need more access to sewing machines. New orders are coming and current demand is there. Both clusters told that with right support they can 2X of what they do currently	5		5	So much room for innovation and develop subsitution products in addtion to attractive handicrafts. Use of different parts of WH (leaf, stem and roots) and mixes of WH or mixing with other fibre types could generate a series of products that are climate friendly and trendy.
Environmental safety	4		4		4	Curent level operations do not require extensive Environment and Safety procedures except avoiding the spread of IAS by adopting week kills (drying etc.) and permitted transport etc. With the WH processes are expanding and reaching industrial levels all the industry related requirements will apply. WH may need wastewater, SbTi, and other environment, social and gender safeguards as it expands.
Community interest	4	Few activated and currently operating groups are there. With earning extra income potential more community members can be attracted.	3	If the sustainable business model develops to easy access by the community, the community will automatically link with	5	No need to elaborate as communities get benefits during the process. However, communities could get exploited by the wrong type of industries that are polluting and damaging. Also there are safety aspects to be followed to keep the community interest (air quality, skills to navigate water bodies safely, use of equipment etc.). Community interest will grow if the processes are sustainable, markets are assured and benefits (especially PES and Carbon) are shared properly and transparently
Institutional support	3	This is an area where it needs to be addressed. A near fully equipped facility is there but it is under utilised at Ehetuwewa. But the currently operating group members have mentioned that they are lacking sewing machines. It is apparent the access to this DS owned facility is limited and conditional. If this issue was addressed and sorted, a major efficiency and scalability aspect can be unleashed.	3		3	This is the weakest link currently. This require good communication and advocacy backed by ecosystem, disaster risk reduction, climate impact, livelihood benefits and long-term sustainabilit including export incomes and subsitutions (garbage bags, covers for agriculture) of fossil fuel based products etc. highlighted.

15.12.7 RECOMMENDATION

Category	Business Expert	Environment Expert	Technical Expert
Top 3 immediate needs (1)	**Improve the efficiency of the current operation** Support to improve and optimise their current orders. Make current operations more efficient. Introduce novel design ideas and branding concepts	**Harvesting and Transport** 1. Adopt mechanisms to harvest the entire plant (leaf, stem and roots/mesh) 2. Pay attention to the drying process depending on the ultimate product (ex: for composting let the temperature in the compost pile rise to kill the seeds of weeds etc. and kill pathogens; Temperature controls may vary also depending on the strength and texture of the fiber, yarn or dried stems. As such each value chain needs seperate SOPs on drying 3. Finding alternative uses for leafs and roots/mesh (compost, fibre for packaging etc.) again depending on the main use (ex: if the main use is handicrafts need to decide on what to do with the other parts.	1. Develop methods to understand expected water hyacinth biomass per harvesting cycle for better planning and resource allocation.
Top 3 immediate needs (2)	**Accessing under utilised resources** Strategicially Clear out the insitutional barriers and gain access to the idling and under utilised processing facility with DS Ehetuwewa. Need to evaluate the institutional relationship between NEDA and DS for a fucntional smooth operation This will give access to more sewing machines without any capital. Immediate access to machinery. We have not met and had any communication with DS so far. Need a plan. Top down suggested.(Ministry)	**Wastewater Management and Water Quality Testing** 1. As we scale up and add value, chemicals and other materials get into the picture that can have ecosystem implecations. Each product need waste water management SOPs. 2. Decide on the water quality testing stages (ex: Before and after large scale harvesting in water bodies - this needs to be ongoing - Dissloved Oxygen, BOD, Turbidity 3. Combine water quality management with solid waste management (ex: plastic types trapped in WH can be diverted to circular pathways again using community actions	2. Upgrade current manual harvesting and processing mechanisms to enhance efficiency, safety, and productivity.
Top 3 immediate needs (3)	**Understand local and internation market requirement and relevant procedures** Explore product quality standards for the industry and the export market. Conduct a prodcut quality audit.	**Decide on the Value Chains or Product Lines and Develop Manuals** 1. Handicrafts, BioChar, Fibre extraction related applications (packging, leather subsitutes, erosion control applications, yarns etc.) 2. Develop sustainable financing modalities with Environment and Safety Standards (manuals and training 3. Develop a Sri Lanka specific large applications such as WH products subsituting agriculture covers, garbage bags and shoping bags etc. and raise a green bond and a financial mechanism to accelerate.	3. if the demand side is high start the semi mechanize operation
Suggested next steps / pilot ideas	**Develop a hub operation model centralised at the DS facility** Create separate value chain and processing groups for Extraction, Transportation, Preprocessing, Product Manufacturing , Sales and Marketing Activities. This way product manufacturing team is not going around collecting WH and their time is better utilised focusing on manufacturing which is their expertise which required skills. **Barriers/Challenges** Would need to communicate and discuss with the DS. Approach would be to come from top down with a structured plan. Once access and model is operational , we can gather resources and empower DS based eco system. **JJ Products** is the private arm where we can identify the inefficiencies of the DS eco system and channel them through the private business. Ultimately we can create a competition (friendly) among the two channels as well. Strategic level discussion is required on this. *** **Recommended Products to Focus.** Water hyacinth suits baskets, bags, and other woven goods with steady demand. Compared to rattan or palmyrah, it has a stronger story—turning an invasive weed into jobs and cleaner waterways—which becomes a clear USP when backed by traceable sourcing and simple impact metrics. Vietnam, India, and Indonesia win on volume; Sri Lanka can win on premium design and storytelling, especially for tourism and hospitality buyers. Biochar (soil conditioner/enhancer) offers dual income: product sales plus potential carbon credits. We're working with a Sri Lankan partner using a community-led, decentralized model with low-cost mini pyrolysis units. It's low-capex, village-scale, and can align with offtake deals and carbon-program pathways for agricultural users.	**Low Hanging, Ecosystem / Nature Friendly Climate Smart Applications** 1. Develop a Sri Lanka specific large applications such as WH products subsituting agriculture covers (black polethene and blue fencing), garbage bags (all sizes) and shoping bags etc. and raise a green bond and a financial mechanism to accelerate. Support to improve and optimise their current orders. 2. Work on a Payment for Ecosystem approach to fund the WH related value chains (ex: Estimate the government expenses to clean up canals and include in the proposed uses as part of the investments and get finance ministry to make a policy decision - this may have touism and plastic recycling options too. 3. Develop a Carbon Project using WH using all options and register in VERA or GOLD Standard mechanisms 4. Follow up on the Nirobi example promoted by UNEP (link provided in the WhatsAPP) combined with the Indian example of using Banana Fibre to subsititue leather (that uses extreme chemicals/metals that are toxic). 5. Deveop a set of communications materials highlighting why WH management is nature friendly activity, that also promote disaster risk reduction, carbon financing, livelihoods and export earnings. 5. Evaluate the climate change (temperature increase link in the WH growth) implecations on negative aspects of WH in waterbodies and use the case to attract climate investments (loss and damage funds and interests of Brands)	Accurate Estimation of Harvesting Volume: Conduct biomass mapping and seasonal surveys to quantify water hyacinth availability per cycle. Develop a simple monitoring system (manual logs or digital tracking) for ongoing data collection. Operational Efficiency Improvement: Assess current manual harvesting and processing methods to identify bottlenecks. Introduce low-cost mechanized tools (boats, grappling hooks, long-arm rakes) and improve processing equipment (sewing machines, twin rollers). Provide training on safe handling, quality selection, and workflow optimization. Scalable Mechanization Based on Demand: Monitor market demand and biomass availability to determine optimal scale-up timing. Plan for semi-mechanized operations with appropriate investment, ensuring cost-effectiveness and safety. Establish pilot operations to test mechanized harvesting before full-scale deployment.

Potential risks / red flags	Institutional support and Buy in from the DS Ehetuwewa	Convert Risks to Opportunities	
	There are two functional groups. One with the DS aligned Saubhagya group and the private arm (JJ products - Second visit - Entrepreneur).	1. Adopt IAS management and control to WH so it can be used in value chains. This may require a policy decision by the Cabinet if the value chains are going to expand and go to the level of hub operations 2. Convince the key companies to be part of the WH management using a watershed approach where ESG principles and SbTi uses can be practiced (required for EU Green Deal in 2028) 3. Get the buyin of large Govt. entities such as Irrigation, Dept. of Agrarian Development and SLLDC etc. to particpate in a large initiative where a transformation is possible within the agencies (more money) and national level disaster risk reduction, water use efficiency, climate smart planning etc. Also try to get Tourism also attracted to this considering the beautifications possible by taking the trapped material out and circularity.	

15.13 ANNEXURE 13 : POTENTIAL PRODUCTS AND SERVICES FROM WATER HYACINTH

Water hyacinth, though often considered an invasive aquatic weed, presents multiple opportunities for value addition across energy, agriculture, industry, and livelihoods. The following table consolidates the main product pathways identified in scoping studies and pilot applications, highlighting their potential markets and co-benefits.

Table 15: Product Development Pathways

Category	Product / Application	Description / Notes	Potential Market / Benefit
Agriculture & Soil amendments	Organic Compost	Decomposed biomass	Soil fertility, organic farming
	Vermicompost	Substrate for earthworms	High-value organic fertilizer
	Animal Feed (processed)	Detoxified protein-rich biomass	Cattle, fish, poultry feed
	Biochar	Soil amendments	Soil fertility, water holding, erosion control
Industrial & Materials	Pulp & Paper	Fiber for low-grade paper	Packaging, stationery
	Fiberboards / Particle Boards	Compressed fiber panels	Furniture, construction
	Bioplastics	Cellulose-based polymers and mixed materials WH fibre and other (plastics)	Packaging, eco-products, vehicle interior, outdoor applications
Handicrafts & Textiles	Rope, Mats, Baskets	Woven fiber products	Local crafts, export markets
	Furniture	Woven or pressed fiber	Eco-friendly furniture
	Decorative Items	Artisanal crafts	Tourism, lifestyle markets
Environmental Services	Phytoremediation	Absorbs heavy metals, nutrients	Wastewater treatment, wetlands
	Carbon Credits	Biomass sequestration	Climate finance, MRV-linked
	Erosion control support material	Fibre processed and packaged	Logs, nets and other
Innovative Uses	Mushroom Cultivation	Substrate for edible fungi	Food security, livelihoods

	Enzyme/Chemical Extraction	Cellulose, lignin derivatives	Biotech, pharma
	Wellness & Textiles	Natural fibers	Eco-fashion, wellness products
	Alternatives to Single Use Plastics	Processed fibres	Cups, Plates, and bags
	Agriculture weed control sheets	Processed fibres into sheets	Mulching support, weed control covers in green houses and open and fences
	Biochar	Absorption of toxins	Filters, modified adsorbants
	Oil adsorbing	Oil spill contingency	Oil absorbing booms and restrictions

15.14 ANNEXURE 14 : GOVERNMENT AGENCIES RELEVANT TO WATER HYACINTH ACCESS AND MANAGEMENT

At the same time opportunity exists to use the water hyacinth biomass environment challenge in a science-based approach with adequate safe-guards.

Controlled use of WH and livelihood applications require the SMEs and Community Based Organizations promoting livelihoods related to WH to work with the responsible Government Agencies to get the access to water bodies where WH can be harvested.

Further, if a business can be configured as one or more Govt. agencies to be a partner in the value chain, it may be possible to make the Government Agency having the legal ownership/access to the water bodies to be the supplier. For example, it is possible to use mechanical harvesters in large and minor tanks by Mahaweli, Irrigation or Dept. of Agrarian Development.

The below identified government entities, their role and mandates of controlling Water Hyacinth in Sri Lanka

Irrigation Department of Sri Lanka

- Oversees major and medium irrigation reservoirs, canals, and river basins across the country.
- Operates a GIS portal and real-time water monitoring systems (reservoir levels, rainfall, river flows)—these could be extended to include aquatic invasive species mapping.
- Responsible for water quality protection and pollution prevention, which directly links to controlling invasive aquatic weeds like water hyacinth.

Potential participation in the WH management may include supporting to integrate remote sensing and field surveys into their monitoring systems to map hyacinth spread at any given time, which also provides the availability of WH geographically. Irrigation could also strengthen the water quantity and water quality data collection in waterbodies. This information is already being digitalized through the Gates Foundation supported “Integrated Digital Agriculture Transformation (IDAT)” project. It can support the WH management coordination by

empowering provincial irrigation engineers for mechanical removal where hyacinth blocks canals or sluices.

Mahaweli Authority of Sri Lanka

- Manages the Mahaweli River Basin and its extensive irrigation and settlement schemes.
- Runs Integrated Watershed & Water Resources Management Projects (IWWRMP) and the Mahaweli Water Security Investment Program, which include water quality, watershed protection, and canal rehabilitation.

Potential participation may include mainstreaming aquatic weed monitoring into watershed management and canal rehabilitation projects while supporting community-based water management groups in Mahaweli settlements—these could be mobilized for weed removal. The work of Mahaweli Authority could provide the infrastructure support along with water quality improvement in the waterbodies providing a strong platform to integrate invasive species control while generating income for communities.

Both the Irrigation Department and Mahaweli Authority of Sri Lanka manage the large tanks and reservoirs where water hyacinth is a common challenge, especially in the dry zone of Sri Lanka. WH spreads rapidly due to nutrient-rich runoff from agriculture and unmanaged sewage. Impacts of WH in large tanks include reduced water storage capacity, higher evapotranspiration losses, and obstruction of irrigation intakes.

Department of Agrarian Development (DAD)

- Manages minor irrigation tanks and village-level water bodies under the Agrarian Development Act.
- Works through Agrarian Service Centers at grassroots level, directly engaging farmers.
- Runs smart farming information systems and supports farmer organizations.

Farmer organizations could be mobilized for manual removal campaigns through the department's community-based tank management that make WH management more practical and sustainable.

- Sri Lanka has 15,000+ minor tanks that are critical for paddy cultivation and rural water supply.
- Many of these smaller tanks are heavily infested, as they are shallow, nutrient-loaded, and less frequently maintained.
- Hyacinth mats block sluices, reduce water availability for crops, and increase siltation.
- Villagers often report loss of access to water for domestic and livestock use due to dense mats.

DAD participation also enhances the mapping of water hyacinth in small tanks (where it is most prevalent) through farmer reporting and Agrarian Service Center (ASC) level monitoring. A real time estimate of WH availability could be done.

Sri Lanka Land Development Corporation (SLLDC)

- Manages urban wetlands, canals, and lakes
- Runs wetland management and water quality improvement projects in Colombo and surrounding areas.
- Issues clearances for wastewater discharge into its controlled water bodies.

Potential actions to support WH management include direct removal of invasive aquatic weeds (including hyacinth) in urban wetlands and integrating WH management as a key part of restoration and Water Quality Improvement Projects in terms of ecological restoration. This will help to develop and adopt more NGOs and donor projects to explore circular economy uses of hyacinth (handicrafts, compost, bioenergy).

In addition there are several land or land use types where the ownership is mixed.

Streams and Canals - Managed by Irrigation, Dept. of Agrarian Development, Mahaweli Authority, Municipalities and Private Plantations

- Hyacinth spreads downstream through canal networks and streams, carried by water flow.

- It clogs irrigation canals, reducing water delivery efficiency and increasing maintenance costs.
- In urban and peri-urban canals, it worsens flooding by obstructing drainage and contributes to mosquito breeding.

Wetlands - Owned by the Sri Lanka Land Development Corporation

Cities, Urban Councils, Private Owners etc.

- In wetlands such as Muthurajawela and floodplain marshes, hyacinth competes with native aquatic vegetation.
- Certain paddy lands also harbour Water Hyacinth when paddy is not dense and strong
- WH reduces biodiversity, alters habitats for fish and birds, and depletes dissolved oxygen in wetlands.
- While WH can absorb heavy metals and nutrients (phytoremediation potential), uncontrolled growth undermines wetland ecosystem services.
- Phytoremedial potential can be used to adopt wetlands to refine the water quality before water gets into canals and streams.

15.15 ANNEXURE 15 : RELEVANT LEGISLATIVE INSTRUMENTS RELATED TO WATER HYACINTH MANAGEMENT

In addition, there are a number of relevant legislative instruments related to WH management. without any priority order they can be listed as:

Water Hyacinth Ordinance, No. 4 of 1909

(https://env.gov.lk/web/images/downloads/policies/national_invasive_alien_policy.pdf) - One of the earliest laws specifically targeting an invasive species WH (Eichhornia crassipes).

Fauna and Flora Protection Ordinance, No. 2 of 1937 (as amended)

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018358/ -

Provides protection for native biodiversity and regulates introduction of non-native species.

Fisheries and Aquatic Resources Act, No. 2 of 1996 (as amended)

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018359/ -

Governs aquatic resources, including restrictions on introduction of alien aquatic species.

Plant Protection Act, No. 35 of 1999

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018360/

Regulates importation of plants and plant products to prevent entry of pests and invasive species.

Prevention of Mosquito Breeding Act, No. 11 of 2007

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018361/

While primarily public health–oriented, it includes provisions relevant to aquatic weeds that create mosquito habitats.

Marine Pollution Prevention Act, No. 35 of 2008

https://www.fao.org/faolex/results/details/en/c/LEX-FAOC018362/

Addresses ballast water and marine introductions, which are pathways for invasive alien species.

National Invasive Alien Species (IAS) Policy of Sri Lanka (2016)

https://env.gov.lk/web/images/downloads/policies/national_invasive_alien_policy.pdf

Provides a comprehensive framework for prevention, early detection, control, and ecosystem restoration

15.16 ANNEXURE 16 : FIBRE EXTRACTION FROM WATER HYACINTH

Fibre extraction is mostly done by mechanical extraction + alkali/enzymatic treatment. It is the most scalable and quality-oriented pathway for industrial compounding, while manual/ret-based methods are better for community-level crafts. Safeguards are critical to prevent regrowth, pollution, and health risks.

Fiber Extraction Methods

- Manual / Mechanical Stripping
- Stems are peeled manually or with simple stripping machines.
- Low-tech, labor-intensive, but suitable for community-based enterprises.

Retting (Water or Dew Retting)

- Stems are soaked in water or left in humid conditions to allow microbial action to separate fibers.
- Produces softer fibers but risks water pollution if not managed.

Hot Water / Chemical Retting

- Boiling stems in water, sometimes with mild alkali (NaOH) or enzymes, to loosen fibers.
- Faster than natural retting, improves fiber softness, but requires safe chemical handling.

Mechanical Decortication

- Machines crush and scrape stems to separate fibers.
- Higher throughput, consistent quality, scalable for industrial use.
- Alkali / Enzymatic Treatment (Post-Extraction)
- Improves fiber strength, removes lignin/hemicellulose, enhances bonding in composites.
- Common pre-processing step before compounding.

Compounding Methods (for Products & Composites)

- Handicrafts & Textiles
- Twisting and weaving into ropes, mats, baskets, and artisanal products.
- Often combined with jute, coir, or cotton for strength.

Polymer Composites

- Fibers blended with thermoplastics (e.g., polypropylene, PLA, recycled plastics) to make boards, panels, or molded items.
- Requires fiber drying, size reduction, and surface treatment for good adhesion.
- Paper & Pulp
- Fibers pulped mechanically or chemically for handmade paper, packaging, or biodegradable products.
- Bio-boards & Panels -Compounded with resins (natural or synthetic) to create particle boards, insulation panels, or furniture components.

Safeguards to Adopt

- Prevent Regrowth - Ensure harvested biomass is fully dried, composted, or chemically treated before processing to avoid re-infestation.
- Chemical Safety - If using alkali/enzymes, provide protective gear, neutralize effluents, and avoid discharge into waterways.
- Moisture & Storage - Fibers must be dried to <10% moisture before compounding to prevent mold, decay, and poor bonding.
- Worker Health - Gloves, masks, and protective clothing to avoid skin irritation, dust inhalation, or pathogen exposure.

Environmental Safeguards

- Retting ponds should be lined and effluents treated to prevent eutrophication.
- Promote circular use of residues (e.g., compost, biogas feedstock).

15.17 ANNEXURE 17 : DETAILED ENVIRONMENTAL SAFEGUARDS ACROSS WATER HYACINTH VALUE CHAIN

Environmental safeguards across the entire value chain can be summarized along with cause and effects plus remedies.

Harvesting and transport

- Biosecurity protocol: Prevent re-seeding and spread. Require enclosed collection, dewatering at site, and thermophilic treatment (e.g., hot-air drying) to neutralize seeds before offsite movement. Document chain of custody for invasive biomass.
- Water quality protection: Stage removal to avoid sudden habitat shocks (oxygen crashes, turbidity). Maintain riparian buffers; deploy silt curtains where needed.
- Vector control: Remove mats in patterns that don't leave stagnant pockets that foster mosquitoes; coordinate with public health teams.
- Permits and reporting: Align with national invasive species and CEA requirements; log volumes, locations, and disposal/use routes.

Preprocessing, storage, and material quality

- Contaminant screening: Test representative batches for heavy metals and organics if sourced from polluted waters; segregate "clean" vs. "restricted-use" biomass.
- Leachate management: Collect and treat pressate from dewatering (screening + aerobic/anaerobic treatment) before discharge or reuse.
- Safe storage: Covered, ventilated drying with leachate capture; fire safety for dried biomass.
- Fiber extraction, compounding, and forming
- Low-impact extraction: Favor mechanical decortication and water-efficient retting; recirculate process water.
- Binder and additive choices: Prioritize bio-based or low-toxicity binders (natural latex, PLA, PHA, water-borne PU). Avoid formaldehyde-based resins and halogenated flame retardants; require SDS reviews.

- Dust and ergonomics: Local exhaust ventilation, dust collection (HEPA), and ergonomic workstations; provide PPE and training.

Coloring, finishing, and coatings

- Dye selection hierarchy: Prefer natural dyes or OEKO-TEX/Bluesign-approved low-impact synthetics; avoid azo dyes that can release amines and heavy-metal mordants.
- Closed-loop baths: Metering, bath reuse, and counter-current rinsing; capture and treat dyehouse effluents (coagulation–flocculation + biological treatment + tertiary polishing).
- Coatings control: Use water-borne systems; prohibit PFAS and high-VOC solvents; monitor VOCs and install carbon capture where needed.

Thermal conversion (briquettes, biochar, activated carbon, energy)

- Kiln and furnace controls: High-efficiency pyrolysis with secondary combustion/afterburners; continuous monitoring for PM, CO, NOx; install cyclones/filters/scrubbers as needed.
- By-product treatment: Condensates (tars) collected and treated as hazardous; ash characterization and safe disposal or beneficial use per standards.
- Feedstock compatibility: Manage high ash/alkali content of hyacinth to limit slagging/fouling in combustion systems.

Wastewater, sludge, and solid waste

- Effluent standards: Treat all processed wastewater to meet discharge norms; consider constructed wetlands only in contained systems that prevent re-introduction of hyacinth.
- Sludge management: Classify dye/metal-bearing sludges as hazardous; stabilize and dispose per regulations or co-process in cement kilns.
- Organic residues: Compost or anaerobically digest fines and offcuts; return digestate/compost to safe land applications after pathogen kill.
- Occupational health, community, and biodiversity
- OHS framework: Job hazard analyses, PPE, first-aid, heat stress and ergonomic plans; inclusive training for community harvesters and artisans.

- Community safeguards: Fair wages, grievance redress, gender equity, and benefit-sharing with riparian communities.
- Biodiversity safeguards: No cultivation/propagation; removal plans co-designed with fisheries and wetland managers to avoid nesting seasons and sensitive habitats.

15.18 ANNEXURE 18 : MATERIAL TO COMBINE ENVIRONMENT GOVERNANCE IN THE ACCELERATOR FRAMEWORK – AN ILLUSTRATIVE PROJECT APPROACH

"Community-Led Valorization of Water Hyacinth Biomass for Climate and Ecosystem Benefits in Sri Lanka" or "From Invasive Threat to Climate Asset: Sri Lanka's Water Hyacinth Transformation"

Objective

To remove invasive water hyacinth from freshwater systems in Sri Lanka and convert the biomass into valuable products like biochar, compost, handicrafts, and biogas, generating measurable climate, water, and livelihood benefits.

Type: Nature-based Solutions / Circular Bioeconomy

- GHG Emissions Reduction (via bioenergy)
- Carbon Sequestration (via biochar)
- Ecosystem Services (via wetland restoration)
- Water Benefit (optional)

Geographic Scope

- **Country**: Sri Lanka
- **Locations**: [e.g., Bolgoda Lake Basin, Maduru Oya, Mahaweli canals, etc]
- **Coordinates**: To be mapped via participatory GIS

Key Government Partners

- Department of Agrarian Development
- Mahaweli Authority of Sri Lanka
- Sri Lanka Land Development Corporation
- Irrigation Department
- Universities/ Research

Corporate Partners

- ESG related inputs from corporates
- Business partners for WH products
- Startup support groups
- Banks keen to support local efforts

Community Involvement

Stakeholders

- Local cooperatives, women's groups, youth groups, extension officers
- Divisional Secretariats, NGOs, technical universities
- Training partners for handicrafts, composting, pyrolysis

Participation Plan

- Stakeholder mapping and engagement
- Community consultations (aligned with GS Safeguarding Principles)
- Benefit-sharing model with transparent income tracking

Technology & Practices

- Manual or mechanical hyacinth removal
- Biochar production via pyrolysis kilns
- Biogas digesters for cooking fuel
- Composting and vermicomposting
- Crafting workshops for product development

Monitoring, Reporting, Verification (MRV)

Data Collection Tools

- Gold Standard Templates for PDD and Monitoring Reports
- Optional use of Veera MRV framework for co-benefits

Safeguarding Principles Assessment

Will address:

- Biodiversity and ecosystem integrity
- Health and safety in biomass handling
- Gender equity and local livelihoods
- Regulatory compliance for waste valorization

Climate and SDG Impacts

Climate Mitigation

- Reduction in CO_2 and CH_4 from unmanaged hyacinth decay
- Fossil fuel displacement via biogas and briquettes
- Sequestration via biochar application

SDG Contributions

- SDG 6 (Clean Water)
- SDG 7 (Affordable Clean Energy)
- SDG 13 (Climate Action)
- SDG 8 (Decent Work)
- SDG 12 (Sustainable Consumption)

Financial and Sustainability Plan

- Revenue from biochar sales, carbon credits, handicrafts
- Local revolving fund to support equipment maintenance and training
- External support from climate adaptation funds (e.g. Green Climate Fund, Lanka Environment Fund