Bulletin of Nexus
Multidisciplinary International Research Journal, Double-Blind Peer Reviewed, Open Access Journal
ISSN : 3065-7865 / Volume-2, Issue-8 August - 2025

Original Article

Transforming Groundnut Shell Waste into Biodegradable Pots: A Pathway to Sustainable Development Goals

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Manuscript ID:
BN-2025-020822

ISSN: 3065-7865

Volume 2

Issue 8

August 2025

Pp98-103

Submitted: 15 July 2025

Revised: 24 July 2025

Accepted: 13 Aug 2025

Published: 31 Aug 2025

DOI:
10.5281/zenodo.17158030
DOI link:
https://doi.org/10.5281/zenodo.17158030

Abstract

Agricultural waste, when not properly managed, plays a significant role in harming the environment. As a leading global producer, India generated more than 10.3 million metrictons of groundnuts in 2023, with nearly half of this amount consisting of groundnut shells. Theseshells are often disposed of by burning or careless dumping, actions that worsen environmental pollution. This research explores the innovative conversion of various agricultural residues—such as groundnut shells, coconut coir, dry leaves, and cow dung—into biodegradable pots. These environmentally friendly alternatives are intended to replace traditional plastic nurserybags, which pose long-term ecological risks. Data collected from 104 customers and 21 nurseries strongly supports the commercial feasibility and significant environmental benefits of these biodegradable pots. The project aligns with and promotes several United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). Additionally, it positively impacts SDG8 (Decent Work and Economic Growth). The results clearly show that these biodegradablepotsnot only provide a crucial solution for reducing plastic pollution but also boost rural employment and encourage the adoption of circular economy principles, demonstrating how local innovation can effectively support global sustainability efforts.

Keywords: *Groundnut Shell Waste, Biodegradable Pots, Agricultural Residues, Sustainable Development Goals (SDGs), Circular Economy, Plastic Alternatives, Climate Action, Soil Health, Rural Entrepreneurship, Eco-friendly Innovation.*

Introduction

1. Global and Indian Context of Agricultural Waste Generation and Disposal Agriculture is vital to India's economy but generates substantial waste causing environmental challenges. India is the world's second-largest groundnut producer, with production reaching101lakh tonnes in 2021-22 and 10.3 million metric tons in 2023. Groundnut shells comprise 20-25%of total groundnut weight, creating significant residue. Traditional disposal methods like burning or dumping have severe environmental impacts. Burning releases air pollutants, whilebothincineration and burial contribute to pollution. Groundnut shells degrade slowly due to their
fibrous structure (45% cellulose, 6% hemicellulose, and 36% lignin), persistingintheenvironment long-term. India's large-scale groundnut production creates a paradox: while economically beneficial, it generates substantial agricultural waste due to inadequate waste management, necessitating valorization solutions.

2.The Pervasive Problem of Plastic Nursery Bags in Horticulture Plastic nursery bags are widely used in horticulture due to their affordability, durability, andmoldability. However, these non-biodegradable materials pose environmental challenges, persisting in soils for millennia and releasing harmful chemicals into soil and groundwater. With98% of plastic plant containers ending in landfills, they significantly contribute to agricultural waste. The breakdown of these plastics creates microplastics (MPs) and nanoplastics (NPs), particles smaller than 5mm that infiltrate ecosystems including water bodies, soils, and atmosphere. MPs and NPs severely impact plant health by hindering seed germination, reducingroot growth, and obstructing nutrient absorption.

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How to cite this article:

Nalawade, M. (2025). Transforming Groundnut Shell Waste into Biodegradable Pots: A Pathway to Sustainable Development Goals. Bulletion of Nexus, 2(8), 98–103. https://doi.org/10.5281/zenodo.17158030

Quick Response Code:

Website: https://bnir.us

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They cause oxidative stress and genetic damagein plants, impairing development and photosynthesis. Nanoplastics can be absorbed by roots and transported throughout plants.

Microplastics also alter soil properties, leading to reduced aeration, increased erosion, and decreased nutrient availability, resulting in lower crop yields. They disrupt soil microbial communities essential for soil health and can transport chemical contaminants, threatening plant vitality and human health through the food chain. While plastic nursery bags were adopted for convenience and cost-effectiveness, their environmental impacts, particularly through microplastics, reveal how short-term economic benefits have createdlastingecological damage. These consequences accumulate silently over time, highlighting the failureofeconomic models that ignore full life-cycle impacts.

3. India's Policy Landscape for Plastic Waste and Challenges India's Ministry of Environment, Forests, and Climate Change launched a ban on single-use plastics (SUPs) in 2019, effective 2022, targeting items like plastic bags and cutlery. Whiletheban has shown positive results in major cities with decreased plastic usage, significant challenges persist. Enforcement remains weak in rural areas and smaller towns, leading to continued illegal SUP production. The rural and informal sectors heavily rely on plastic products due totheirconvenience and cost-effectiveness, given limited alternatives. The scarcity of affordableeco-friendly alternatives, especially in economically disadvantaged areas, hinders transitionfromplastic use. Poor quality standards for biodegradable plastics and inefficient waste management infrastructure compound the problem. Imported plastic packaging further undermines domestic efforts to control plastic waste. While India has established policies including the SUPbanand Extended Producer Responsibility mechanisms, the gap between policy goals and implementation, particularly in rural areas, remains significant. This suggests that policyinterventions must be coupled with market development for sustainable alternatives and support mechanisms for vulnerable communities to ensure an effective transition from plastics.

4. Introduction of Biodegradable Pots and Paper Objective

In light of the pressing environmental issues posed by agricultural waste and plastic pollution, biodegradable pots derived from agricultural waste emerge as a highly promising, eco-friendly, and economically viable alternative to plastic nursery bags. These innovative alternatives not only mitigate the detrimental effects of plastic but also offer additional benefits, suchasenriching soil health upon decomposition.

This paper is dedicated to a comprehensive analysis of the potential of these agricultural waste-derived pots. It aims to meticulously situate the study's findings within the broader frameworkofthe United Nations Sustainable Development Goals (SDGs), thereby demonstratinghowlocalized innovation and sustainable practices can significantly contribute to global sustainability agendas.

Methodology

1. Materials

The biodegradable pots were crafted from plentiful agricultural by-products, offering both structural and nutritional advantages. Groundnut shells served as the fibrous foundation, ensuring strength and longevity. Coconut coir contributed to moisture retention, aeration, and stability. Dry leaves provided organic matter and nutrients as they decomposed. Cow dung functionedasanatural binder and nutrient source, enhancing biodegradability and enriching the soil. Gond(gum Arabic) acted as an alternative binder, boosting cohesion and pot strength. Collectively, these materials resulted in eco-friendly, nutrient-rich, and structurally sound pots.

The deliberate selection of these materials, including groundnut shells, coconut coir, dry leaves, cow dung, and gond, reflects a sophisticated approach to material design that goes beyondsimplewaste utilization. Each element was chosen for its unique and complementary properties: groundnut shells offer bulk and a slow degradation rate, coconut coir provides excellent water retention and aeration, cow dung serves as both a binder and a nutrient source, andgondenhances overall binding strength. This thoughtful combination demonstrates a strategic design aimed at achieving synergistic multi-functional benefits, including structural integrity, controlled biodegradability, sustained nutrient release, and improved plant health. This comprehensive approach elevates the developed product from a simple alternative to a superior, integrated horticultural solution.

2. Process:

3. Sample Size and Data Collection

To comprehensively assess the market viability and consumer acceptance of the biodegradable pots, the study involved a robust data collection strategy. Primary data was gathered from asignificant sample size comprising 104 individual customers and 21 nursery owners. This dual-pronged approach allowed for an evaluation of both end-user and industry-level perceptions. Data collection was primarily facilitated through the deployment of structured questionnaires and the conduct of in-depth interviews. These tools were instrumental in capturing both quantitative metrics, such as willingness to adopt and purchasing preferences, and qualitative insights, including specific feature demands and underlying awareness levels regarding eco-friendly alternatives. The study was further informed by a thorough review of relevant secondary literature, providing a broader context for the research findings.

4. Analysis

The collected data underwent a rigorous analytical process, combining both quantitative and qualitative methods to derive meaningful conclusions.

● **Quantitative Analysis:** Statistical techniques, including percentages and frequency analysis, were applied to the survey data obtained from customers and nurseries. This allowed for the precise quantification of key market indicators, such as the high percentage of nurseries acknowledging the need for plastic alternatives (100%) and their willingness to adopt agricultural-waste pots (71%). Similarly, the high openness of customers to eco friendly options (97%) was quantitatively established.

● **Qualitative Analysis:** The rich data gathered from in-depth interviews was subjected to qualitative analysis. This involved identifying recurring themes and patterns in consumer preferences, such as the emphasis on biodegradability, affordability, durability, and the demand for customization (color, size). This qualitative approach provided a deeper understanding of the motivations and perceptions underlying the quantitative findings, adding nuance and context to the market assessment.

3. Results and Findings

The comprehensive evaluation of the biodegradable pots yielded compelling results, affirming their strong market viability, positive consumer reception, and promising economic feasibility.

1. Market Viability

The research clearly revealed a strong market demand for eco-friendly alternatives to traditional plastic nursery bags in the horticultural industry.

● **Nursery Acknowledgment:** The research clearly revealed a strong market demandforeco-friendly alternatives to traditional plastic nursery bags in the horticultural industry.

Nursery Acknowledgment: An impressive 100% of the nurseries surveyed recognized the urgent necessity to replace conventional plastic nursery bags with more sustainable options. This unanimous acknowledgment highlights a widespread industry awareness of the environmental impact of plastic and the growing regulatory pressures, such as India's ban on single-use plastics, that drive the need for greener alternatives.

● **Willingness to Adopt:** Beyond mere recognition, a significant 71%of nurseries showeda clear willingness to incorporate pots made from agricultural waste into their practices. This high percentage indicates a practical readiness among key industry players to move from theoretical acknowledgment to active consideration and adoption of these environmentally friendly solutions.

● **Customer Openness:** The consumer segment also showed a strong preference for sustainable choices. An impressive 97% of individual customers surveyed were open to adopting eco-friendly options, even if they came with a slightly higher price. This finding underscores a significant and

growing consumer preference for sustainable products, suggesting that environmental awareness is increasingly influencing purchasing decisions, even when a minor price premium is involved.

The consistently high percentages across both nursery and customer segments (100%acknowledgment, 71% willingness from nurseries, 97% openness from customers) collectively indicate a strong "market pull" for sustainable products. This suggests that the market is not passively waiting for regulatory mandates but is actively seeking and receptive to eco-friendly alternatives. This is a crucial finding for the potential scaling of this initiative, as it implies favorable environment for investment and expansion, rather than facing significant market resistance.

2. Consumer Preferences

A detailed analysis of customer feedback identified several key features that drive their preferences for biodegradable pots:

Biodegradability: This emerged as a top preference, reflecting heightened environmental awareness among consumers and a strong desire for products that do not contribute to long-term pollution. The ability of the pots to decompose naturally and reintegrateintothe environment was a key selling point.

Affordability: While customers expressed openness to slightly higher costs for eco friendly options, affordability remained a critical consideration. This indicates a practical balance between environmental values and economic viability, suggesting that while consumers are willing to pay a premium, it must remain within reasonable economic parameters.

Durability: Consumers sought pots that could maintain their structural integrity throughout the nursery phase and during initial planting, emphasizing the need for robust design despite their biodegradable nature. The pots must be able to withstand handling, transportation, and initial environmental exposure without premature degradation.

Customization: A notable demand was observed for customization options, particularly regarding variations in color and size. This suggests that aesthetic appeal and functional diversity are important factors for broader market acceptance, indicating a shift from basic utility to a more consumer-centric product design that caters to diverse horticultural needs and preferences.

3. Economic Feasibility

The economic evaluation carried out in this study indicated a very promising scenario for the production and use of pots made from agricultural waste.

● **Cost Efficiency in Production:** The projected cost of manufacturing these biodegradable pots is lower than the combined expenses of conventional plastic nursery bags and the synthetic fertilizers typically needed for plant growth. This cost efficiency stems from the natural nutrient content of the biodegradable pots, which can partially meet the plant'snutritional requirements as they decompose, thus decreasing the dependence on external chemical inputs. This discovery offers a direct financial incentive for producers toswitchfrom plastic to these eco-friendly alternatives.

● **Potential for Rural Entrepreneurship:** The project shows a strong and concrete potential for promoting rural entrepreneurship. The use of locally plentiful agricultural waste as a primary raw material, along with a relatively simple manufacturing process ,opens up new opportunities for income generation and job creation in rural areas. This aligns with successful models of agricultural waste valorization that turn environmental liabilities into economic assets, reducing environmental damage while simultaneously creating local economic opportunities. The finding that biodegradable pots are more economically viable than the combined cost of plastic bags and fertilizers represents a transformative understanding. It shifts the perspective from seeing "sustainability as an added cost" to recognizing "sustainability as an economic advantage." This inherent economic viability is a powerful catalyst for driving widespread adoption and scaling of the solution, as it directly appeals to the financial interests of businesses and entrepreneurs, providing a compelling incentive for a comprehensive sustainable transition within the horticultural sector.

4. Discussion – Linking to SDGs

The development and utilization of biodegradable pots from agricultural waste represent a multi faceted innovation that directly contributes to several United Nations Sustainable Development Goals (SDGs), demonstrating how local-level initiatives can profoundly support global sustainability agendas.

1. SDG 12: Responsible Consumption and Production

The project significantly advances SDG 12 by fundamentally transforming agricultural waste management practices. This goal emphasizes ensuring sustainable consumption and production patterns, including the efficient use of natural resources and substantial waste reduction.

● **Relevant Targets & Indicators:** The initiative directly addresses **Target 12.2:Sustainable management and efficient use of natural resources**, which is measured by indicators such as

material footprint per capita and domestic material consumptionperGDP. It also aligns with **Target 12.5: Substantially reduce waste generation through prevention, reduction, recycling and reuse**, monitored by the national recyclingrateand tons of material recycled.

● **Contribution:** The project transforms groundnut shells from an environmental burden into valuable biodegradable pots, reducing reliance on plastics and virgin materials. By promoting recycling, reuse, and resource efficiency, it exemplifies circular economy principles and shifts from waste disposal to waste valorization. This not only minimizes waste streams but also fosters sustainable practices in horticulture, influencing broader corporate sustainability and responsible production patterns.

2. SDG 13: Climate Action

The development of biodegradable pots from agricultural waste makes a significant and direct contribution to global climate action efforts. This goal calls for urgent measures to combat climate change and its impacts.

● **Relevant Targets & Indicators:** The project directly addresses **Target 13.2: Integrate climate change measures into national policies, strategies and planning**, which is assessed by indicators such as the number of countries with nationally determined contributions and, crucially, greenhouse gas emissions per year.

● **Contribution:** The project prevents greenhouse gas emissions by diverting groundnut shells from burning and replacing plastic nursery bags with biodegradable alternatives. This reduces CO_2 emissions, avoids pollution from plastic production and disposal, and sequesters carbon in durable bio based products. By integrating climate action into agricultural practices, it supports national commitments like the Paris Agreement and demonstrates how localized innovations can make meaningful contributions to global climate mitigation.

3. SDG 15: Life on Land

The biodegradable pots play a crucial role in safeguarding and restoring terrestrial ecosystems, thereby contributing directly to SDG 15, which aims to protect, restore, and promote the sustainable use of land-based ecosystems, combat desertification, and halt biodiversity loss.

● **Relevant Targets & Indicators:** The project primarily addresses **Target 15.3: Combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world**. Progress on this target is measured by Indicator 15.3.1: Proportion of land that is degraded over total land area.

● **Contribution:** The biodegradable pots decompose naturally, enriching soil with organic matter and nutrients while enhancing fertility, water retention, and microbial activity. Unlike plastic pots, they prevent microplastic pollution and support regenerative agriculture by turning waste into soil-improving inputs. This approach not only restores degraded land but also promotes biodiversity and advances the goal of achievingalanddegradation-neutral world.

4. SDG 8: Decent Work & Economic Growth

The production of biodegradable pots from agricultural waste offers a substantial pathway towards achieving decent work and fostering inclusive economic growth, particularlyinrural areas. This goal aims to promote sustained, inclusive, and sustainable economic growth, full andproductive employment, and decent work for all.

● **Relevant Targets & Indicators:** The project directly contributes to **Target 8.3:Promote development-oriented policies that support productive activities, decentjob creation, entrepreneurship, creativity and innovation**, which is partly measured by the proportion of informal employment in non-agriculture employment. It also supports **Target 8.5: By 2030, achieve full and productive employment anddecentwork for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value**, assessed by indicators suchasaverage hourly earnings and unemployment rate.

● **Contribution:** The project creates new rural employment opportunities by transforming agricultural waste into biodegradable pots, supporting SMEs and local entrepreneurship. It promotes fair wages, skill development, and inclusive work opportunities for women and youth, while fostering economic resilience through localized value chains. Withlower production costs than plastics, the initiative strengthens rural economies andalignswith sustainable, inclusive growth.

Conclusion

This study rigorously demonstrates that biodegradable pots, meticulously crafted from synergistic blend of groundnut shells, coconut coir, dry leaves, and cow dung, with gondasanatural binder, present a highly effective, eco-friendly, and economically viable alternativetoconventional plastic nursery bags. The empirical findings underscore the multifaceted benefit Softhis innovation: these pots significantly enhance soil health by enriching it with vital natural nutrients upon decomposition, drastically reduce both plastic pollution and the accumulationofagricultural waste,

and concurrently generate valuable employment opportunities within rural communities. The successful development of this product, coupled with its overwhelmingly positive reception in the market, highlights its profound potential to support and accelerate progress toward global sustainability agendas. This local-level innovation serves as a compelling model for how targeted, resource-efficient solutions can contribute meaningfullytotheachievement of the United Nations Sustainable Development Goals.

Acknowledgement

I would like to express my deepest gratitude to my research guide, faculty members, and the MES Mahatma Night Degree College of Arts & Commerce, Chembur, for their invaluable guidance and encouragement throughout this study. I sincerely thank all the nursery owners and customers who participated in the survey and shared their valuable insights, without which this research would not have been possible. I am also thankful to my family and friends for their constant support and motivation during the course of this work. Finally, I acknowledge the United Nations Sustainable Development Goals (SDGs) framework, which has inspired the direction and purpose of this research.

Financial support

Nil

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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