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Harnessing CBG-Derived Fermented Organic Manures for Sustainable Soil Management and Circular Economy

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Abstract

Fermented Organic Manure (FOM) derived from Compressed Bio-Gas (CBG) plants serves as a sustainable alternative to chemical fertilizers, supplying essential nutrients while recycling organic waste. Studies have reported yield improvements of 15–22% in crops such as lettuce and maize and an increase in soil organic carbon (SOC) by 12% with composted FOM. Nutrient fortification and palletisation of FOM enhanced phosphorus availability by 28%–35% and improved application efficiency. FOM use in island ecosystems reduced input costs by up to 30% and supports year-round cultivation under erratic rainfall. The application also reduces greenhouse gas (GHG) emissions by approximately 1.6 tonnes CO_2 eq per tonne of FOM used. Integrating fortified FOM with ICT tools and policy support can accelerate its adoption in sustainable, climate-smart agriculture.

Key words: *Digestate - Nutrient Recycling - Circular Economy - Soil Health - Sustainable Island Agriculture*

Introduction

Organic fertilizers are valued for their ability to improve soil health, enhance soil biodiversity, and support nutrient cycling. Unlike synthetic fertilizers, which supply isolated nutrients, organic fertilizers deliver a broad spectrum of nutrients along with organic matter, thereby fostering soil microbial communities and long-term fertility. Organic inputs are increasingly integral to regenerative farming systems with growing emphasis on agricultural sustainability. The circular bioeconomy concept promotes the reuse and recycling of biological resources into products such as compost, bio-energy, and organic fertilizers. Recycled materials from biogas plants, such as composted residues, vermicompost, and digestate, are gaining importance due to their dual roles in waste management and agricultural productivity (FAO, 2019). Compressed Bio-Gas (CBG) plants are central to bio-waste valorization, converting agricultural, livestock, and municipal organic waste into renewable energy and nutrient-rich digestate. The Government of India's SATAT scheme targets the establishment of 5,000 CBG plants that produce 15 million tonnes of biogas annually. These plants help replace fossil fuels and generate Fermented Organic Manure (FOM), a valuable by-product for agriculture. CBG plants promote circular flows by using waste that would otherwise cause pollution or methane emissions. Properly processed digestate transforms waste into a productive agricultural input. Mukhuba *et al*. (2018) noted that digestate retains most nutrients from the biomass, making it suitable for agricultural reuse. FOM from CBG plants plays a multifunctional role in sustainable agriculture by supplying essential nutrients—particularly ammoniacal nitrogen—while improving soil structure, water retention, and microbial activity. Being partially stabilized, FOM offers better nutrient availability and reduced pathogen risks than raw manure. Field trials in Europe, China, and India have shown that FOM enhances yields in vegetables, cereals, and fodder crops and improves soil fertility (Slepetiene *et al*., 2020; Hammerschmiedt *et al*., 2022). It supports sustainable intensification by reducing reliance on chemical fertilizers, enhancing nutrient-use efficiency, and contributing to climate resilience. In India, where fertilizer subsidies and soil degradation are key concerns, FOM integration offers ecological and economic benefits. In island ecosystems, where input access and soil quality are constrained, FOM can significantly improve fertility, lower costs, and support sustainable farming practices. Existing studies have demonstrated the short-term benefits of fermented organic inputs on soil health, nutrient uptake, and yield. However, a systematic analysis of sustained agronomic performance, nutrient cycling, and FOM adoption across diverse agro-ecological zones, especially in resource-constrained and island regions, is lacking. Information on the integration of FOM with local nutrient management practices, its comparative effectiveness relative to other organic inputs, and its economic viability for widespread adoption within India's circular bioeconomy framework is limited. In view of this, the paper analyses the role of FOM in light of current research findings and future prospects, with the following objectives. This study aimed to assess the agronomic potential and nutrient value of Fermented Organic Manure (FOM) derived from Compressed Bio-Gas (CBG) plants, focusing on its effectiveness as an alternative to chemical fertilizers in improving soil fertility, crop productivity, and soil biological health. To evaluate the role of FOM in promoting circular bioeconomy and sustainable waste management by exploring its contributions to renewable energy integration, nutrient recycling, and environmental pollution reduction. To examine the suitability and strategic importance of FOM application in island ecosystems, where challenges such as high input costs, poor soil fertility, and dependence on imported fertilizers can be addressed through localized, organic nutrient sources like FOM.

2. Anaerobic Digestion Process and Digestate Generation

Compressed Bio-Gas (CBG) is produced through anaerobic digestion (AD), where organic biomass—such as cattle dung, agricultural residues, municipal organic waste, or food processing waste—is decomposed by microbial activity in an oxygen-free environment. This biochemical process comprises four sequential stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. During digestion, complex organic matter is converted into biogas containing 40%–70% methane (CH_4), 30%–40% carbon dioxide (CO_2), and trace gases such as hydrogen sulphide (H_2S) and ammonia (NH_3). The purified gas is then compressed to 200–250 bar to yield CBG for use as a fuel or energy source (Singh *et al*., 2023). According to data from the Ministry of Petroleum and Natural Gas, every tonne of dry organic biomass can generate approximately 55–65 m^3 of biogas, yielding 30–35 kg of CBG after purification (Mo PNG, 2023). A valuable by-product of this process is the nutrient-rich digestate, which serves as a basis for Fermented Organic Manure (FOM).

Digestate is the nutrient-dense residual output of the AD process, comprising both dissolved and particulate organic and inorganic materials. It typically contains 85% – 95% water, with significant concentrations of nitrogen (mainly in ammoniacal form), phosphorus, potassium, and micronutrients. For improved handling and application, digestate is often separated into liquid digestate (LD) and solid digestate (SD) using mechanical separators such as screw presses or centrifuges. LD contains a higher fraction of ammoniacal nitrogen (NH_4^+) and is suitable for fertigation systems, whereas SD is more concentrated in organic carbon and phosphorus, making it ideal for soil conditioning and composting (Grobelak *et al*., 2025). For example, Weimers *et al*. (2022) reported that solid digestate from source-separated organic household waste had a dry matter content of 57%, total nitrogen content of 39.5 g/kg, and phosphorus content of 46.3 g/kg, underlining its utility in long-term soil fertility enhancement.

Fermented Organic Manure (FOM) is defined as the stabilized, nutrient-rich byproduct obtained from the anaerobic digestion of biodegradable organic materials. FOM is broadly categorized into three types based on moisture content and processing stages: liquid, semi-solid, and composted. Liquid FOM (dry matter <10%) is suited for direct application through fertigation and has rapid nutrient release. Semi-solid FOM (DM 15–25%) can be spread on fields using mechanized applicators and provides a balance of available nutrients and organic matter. Composted FOM, produced by aerobic post-treatment (such as windrow composting), stabilizes the organic content and reduces pathogens. According to Szwed *et al*. (2024), the application of composted FOM from cattle slurry and food waste improved soil organic carbon by 12% and increased lettuce yield by 15–22% over untreated controls. These different forms of FOM allow flexibility in use and are increasingly incorporated into organic and integrated nutrient management systems.

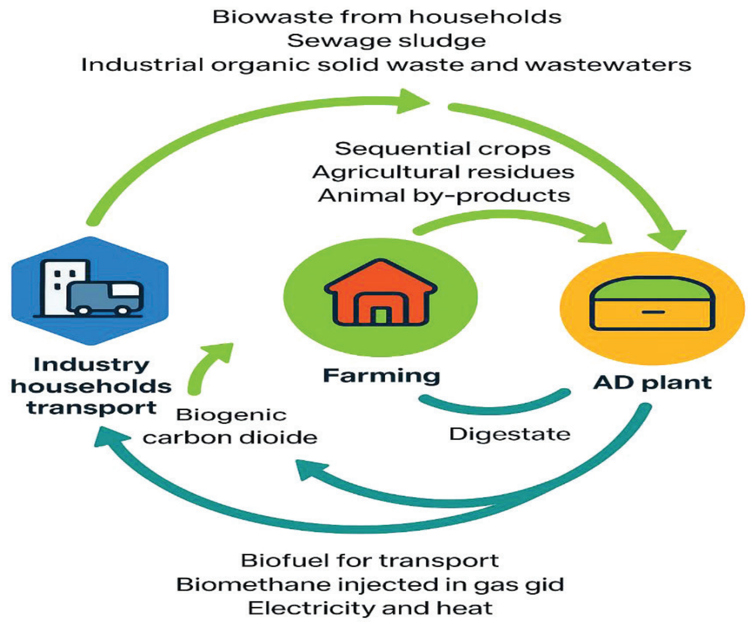

Figure 1. Schematic overview of the inputs and outputs of the biogases production process

3. Types and Properties of Digestate

Digestate, the by-product of anaerobic digestion, can be applied in agriculture as whole digestate (WD) or mechanically separated into solid digestate (SD) and liquid digestate (LD). WD and LD are more effective as nitrogen fertilizers due to their high NH_4-N to total N ratios, providing readily available nitrogen for crops. In contrast, SD is richer in organic matter and phosphorus, making it suitable for improving soil structure, humus content, and long-term fertility. The properties of each fraction are influenced by the feedstock used and the AD process parameters. Grobelak *et al*. (2025) and Sogn *et al*. (2018) found that LD contains elevated levels of ammoniacal nitrogen, while SD retains more stable organic carbon and phosphorus, which are crucial for soil conditioning and carbon sequestration.

Digestate also contains a range of macro- and micronutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), and trace elements, depending on the feedstock composition. Its C:N ratio, generally ranging from 9 to 17 for animal waste-based digestate, along with neutral to slightly alkaline pH (6.9–8.1), supports microbial activity and nutrient mineralization. Unlike traditional organic manures like farmyard manure (FYM), vermicompost, and biocompost, digestate—especially the liquid form—offers more immediate nutrient availability, particularly nitrogen, though it may require careful handling to avoid nutrient leaching. The solid fraction, due to its high dry matter and humic substances, compares well with composts in terms of soil organic matter enhancement. Thus, digestate offers a complementary balance of quick and sustained nutrient release compared to other organic inputs. Summarizes key nutrient parameters of digestate from various sources, indicating variability in nutrient profiles based on feedstock's (Table-1).

Table 1: Nutrient Composition of Digestate from Various Feedstock's

Feedstock	pH	DM%	Total N (g/kg)	NH4-N (g/kg)	TP (g/kg)	TK (g/kg)	C: N Ratio
Cattle, pig manure	7.8–8.0	4.1–6.4	1.82–4.08	0.75–2.5	2.8–4.1	4.8–20.0	9–17
Industrial/agri waste	8.1	5.3	3.7	0.25	1.25	–	–
Manure and slurry	7.3–9.0	1.6–13.2	0.57–6.07	–	1.3–16.3	–	–
Organic household waste	7.6	57	39.5	9.1	46.3	6.96	–
OHW + sewage sludge	6.9	42	53.3	16.0	8.6	7.5	–

The nutrient composition of digestate varies significantly based on the type of feedstock used in anaerobic digestion. Digestates from organic household waste (OHW) and OHW mixed with sewage sludge show the highest nutrient concentrations, with total nitrogen reaching 53.3 g/kg, ammoniacal nitrogen up to 16.0 g/kg, and phosphorus as high as 46.3 g/kg, making them particularly rich nutrient sources. In contrast, digestates from cattle and pig manure and industrial/agricultural waste contain moderate levels of total nitrogen (1.82–4.08 g/kg and 3.7 g/kg, respectively) and lower phosphorus and potassium values. The C: N ratio for cattle and pig manure ranges from 9 to 17, which is favorable for microbial activity and slow nutrient release. The dry matter (DM%) also differs widely, from as low as 1.6% in liquid slurries to 57% in solid OHW digestate, influencing storage, transport, and application strategies. These variations underscore the importance of feedstock selection and treatment objectives in determining digestate's suitability as an organic fertilizer.

4. Status of CBG and FOM Production in India

India has committed to installing 5000 CBG plants under the SATAT scheme, targeting 15 million tonnes of CBG annually. As of 2023, 46 plants have been commissioned with 272 tonnes/day capacity. These plants are strategically distributed, with major contributions from Gujarat, Haryana, Maharashtra, Punjab, Tamil Nadu, and Uttar Pradesh (Fig-2). Feedstock's include cattle dung, municipal solid waste, industrial sludge, poultry litter, and agro-residues such as paddy straw. The state-wise deployment reflects regional availability of biomass and policy incentives. Singh *et al*. (2023) reported that most plants are configured for mixed waste or cattle dung, which are abundant and cost-effective substrates for anaerobic digestion.

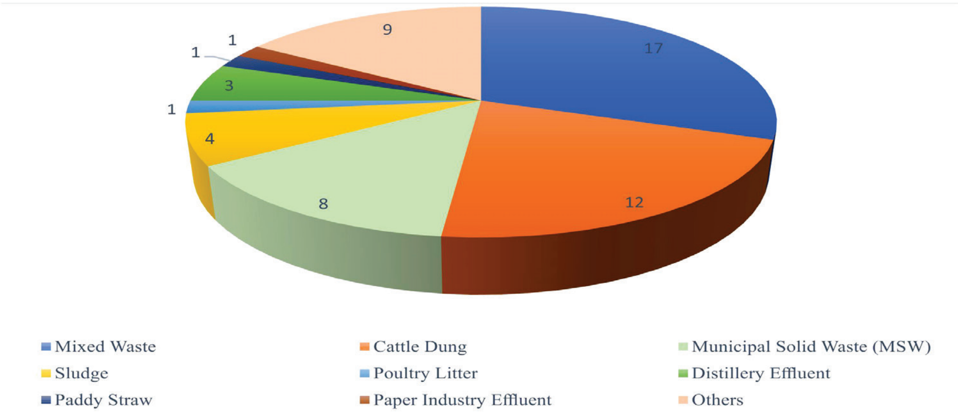

Figure 2. Feedstock Classification and Number of CBG Plants in India

5. Agronomic Benefits of FOM Application

Fermented Organic Manure (FOM) delivers a balanced supply of macronutrients (N, P, K) and micronutrients (Ca, Mg, S, Fe, Zn) while contributing to organic matter enrichment, improved soil structure, and microbial activity. Its application enhances soil fertility, particularly in degraded or nutrient-depleted soils, and supports the build-up of soil organic carbon (SOC). FOM's ammoniacal nitrogen form facilitates higher nitrogen use efficiency (NUE) compared to other organic fertilizers, enabling better nutrient synchronization with plant uptake. The neutral to alkaline pH and favourable C: N ratio (typically between 9–17 in manure-based digestate) promote microbial turnover and soil biological health. Furthermore, long-term application of digestate has been shown to improve soil aggregation, water holding capacity, and cation exchange capacity, all of which are vital for sustained soil productivity.

The effect of FOM on crop yield and nutrient uptake has been validated in several field trials. Doyeni *et al*. (2022) observed substantial increases in soil potassium concentrations—22.33 mg/kg with pig digestate, 65.67 mg/kg with chicken digestate, and 67.00 mg/kg with cow digestate—after three years of application. In another study, Slepetiene *et al*. (2020) demonstrated that applying digestate at 170 kg N/ha increased available phosphorus in soil to >300 mg/kg, moving it from a "high" to a "very high" fertility category. These benefits translated to improved yields and nutrient content in vegetables, cereals, and fodder crops, making FOM a practical component of integrated nutrient management (INM). Field studies have consistently highlighted digestate's capacity to reduce the dependency on chemical fertilizers while maintaining or even improving yield and crop quality.

Table 2: Summary of Agronomic Benefits of Digestate (FOM) from Field Studies

Study	Crop/Soil Type	Application Rate	Observed Benefits
Doyeni *et al*. (2022)	General cropping soils	Multiple applications	K increase by 22.33 (pig), 65.67 (chicken), 67.00 (cow) mg/kg
Slepetiene *et al*. (2020)	Eroded loamy Retisol	170 kg N/ha	Available P increased to >300 mg/kg
Hammerschmiedt *et al*. (2022)	Legume/maize digestate soils	85–170 kg N/ha	Improved soil enzymes, biomass, N uptake
Szwed *et al*. (2024)	Lettuce cropping system	Composted digestate	SOC increased by 12%, lettuce yield up by 15–22%
Weimers *et al*. (2022)	Soilless horticulture	Liquid digestate	Effective nutrient delivery, enhanced plant growth

6. Enrichment of FOM

To enhance the nutrient density, shelf life, and field applicability of Fermented Organic Manure (FOM), various enrichment techniques are being adopted. These include fortification with mineral nutrients (e.g., rock phosphate, urea, or potash), co-composting with high-carbon residues like paddy straw, coir pith, or sugarcane press mud, and bio-inoculation using beneficial microbes such as Azospirillum, Phosphobacteria, or Trichoderma. Fortified FOM addresses imbalances in native digestate by improving the N:P:K ratio, enhancing slow-release properties, and correcting micronutrient deficiencies (Kumar *et al*., 2022). Pelletization and drying processes are also employed to convert semi-liquid FOM into granular forms, improving ease of transport, storage, and uniform application. Sahu *et al*. (2020) reported that blending FOM with vermicompost and rock phosphate increased phosphorus availability by 28–35% and improved maize biomass yield under tropical conditions.

The impacts of enriched FOM are evident across multiple parameters. Enrichment improves nutrient-use efficiency (NUE), enhances soil microbial diversity, and increases the resilience of crops under water or nutrient stress (Sahu *et al*., 2021). Field trials in Tamil Nadu and Chhattisgarh using fortified digestate pellets showed significant yield gains in rice and brinjal compared to raw slurry applications (ICAR-ATARI, 2021). Additionally, enriched FOM contributes to carbon sequestration and reduces input costs by partially substituting synthetic fertilizers, especially in organic and low-input farming systems. Importantly, the integration of digital quality control tools (e.g., IoT-based sensors and QR-code traceability) is now enabling real-time monitoring of FOM nutrient content, maturity, and pathogen levels, ensuring product consistency and farmer confidence (Sharma *et al*., 2023). These developments position enriched FOM as a key component of India's sustainable and precision agriculture strategies.

7. Soil and Ecological Implications

The application of Fermented Organic Manure (FOM) plays a significant role in enhancing soil organic carbon (SOC) levels and supporting long-term carbon sequestration. Solid digestate, in particular, contributes to the accumulation of stable organic matter, which enhances humus formation and helps mitigate greenhouse gas (GHG) emissions associated with conventional fertilizer production and use. By displacing synthetic nitrogen fertilizers—responsible for substantial emissions of nitrous oxide (N_2O), a potent GHG—FOM reduces the overall carbon footprint of agriculture. According to the European Biogas Association (2023), each tonne of digestate used in place of urea can avoid approximately 1.6 tonnes of CO_2-equivalent emissions. This makes FOM not only a soil amendment but also a climate-smart input aligned with carbon neutrality and sustainable farming targets.

Beyond carbon dynamics, FOM positively influences soil biological health by increasing microbial biomass, enzyme activity, and biodiversity. The organic inputs from digestate stimulate microbial activity and nutrient cycling, especially in nutrient-poor or degraded soils. Hammerschmiedt *et al*. (2022) reported that digestates from legumes and maize significantly increased enzymatic activities—urease, β-glucosidase, aryl sulfatase, and glucosaminidase—which are key indicators of soil biological function. Solid digestate improves soil structure and aggregation, enhancing aeration and reducing erosion, while liquid digestate promotes short-term nutrient mineralization. However, excessive use of liquid FOM can lead to nitrate leaching and ammonia volatilization, necessitating calibrated application. Nikolaidou *et al*. (2024) also observed that FOM application increased microbial species richness, although it did not always correspond with greater microbial diversity, highlighting the need for balanced application strategies.

FOM contributes substantially to waste recycling and pollution mitigation by transforming organic residues—often viewed as waste—into valuable agricultural resources. It reduces the environmental burden of landfilling, open dumping, and untreated sewage discharge, which are major sources of surface and groundwater pollution. When used correctly, digestate prevents nutrient loss and supports improved water retention, which is critical for dryland agriculture and climate resilience. Enhanced water-holding capacity of soils treated with FOM leads to reduced irrigation demand and better drought tolerance in crops. Moreover, the incorporation of FOM into farming systems aligns with circular economy principles by closing nutrient loops and maximizing the resource value of bio-waste.

8. Circular Economy

The use of Fermented Organic Manure (FOM) exemplifies the circular economy model in agriculture by transforming organic waste into a nutrient-rich input that supports crop production, reduces pollution, and lowers reliance on fossil fuel–based fertilizers. Instead of discarding biodegradable waste into landfills or open dumps—where it contributes to methane emissions and groundwater contamination—CBG plants recover energy through anaerobic digestion and yield FOM as a secondary product. This practice closes the nutrient loop, ensuring that carbon, nitrogen, phosphorus, and other elements are returned to the soil. According to the European Biogas Association (2024), each tonne of digestate used in agriculture avoids approximately 1.6 tonnes of CO_2-equivalent emissions, primarily by substituting energy-intensive urea and enhancing soil carbon sequestration.

India's national missions—GOBARdhan, which focuses on converting cattle dung and organic waste into biogas and compost, and PM-PRANAM, which aims to reduce chemical fertilizer use—explicitly promote FOM as part of their waste-to-wealth strategy. This integration also advances the UN's Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), by reducing input-related emissions and promoting resource efficiency. The following table outlines how FOM contributes to the circular economy with real-world examples:

Table 3: FOM Integration in Circular Economy – Processes and Benefits

Circular Economy Function	Role of FOM	Example
Nutrient recycling	Returns N, P, K, and micronutrients to soil	Digestate from sugarcane pressmud used in Tamil Nadu for banana farming
GHG emission reduction	Substitutes urea; boosts carbon sequestration	1 tonne FOM = ~1.6 tonnes CO_2-eq avoided (EBA, 2024)
Waste valorization	Converts organic waste to value-added manure	Food waste digestate used in Bengaluru peri-urban farms
Support to government schemes	Aligned with GOBARdhan, PM-PRANAM	CBG + FOM units supported in Haryana and Maharashtra
SDG advancement	Contributes to SDGs 12 and 13	FOM use in tribal villages to replace chemical fertilizers

9. Waste Utilization in Island Ecosystems

Across island regions globally, the use of biogas slurry and digestate has gained attention as a sustainable nutrient source to address soil degradation, high input costs, and limited access to chemical fertilizers. In Pacific Island nations like Fiji and Samoa, small-scale biogas digesters are used to convert pig manure and kitchen waste into both cooking gas and bioslurry, which is applied to taro, banana, and leafy vegetables, improving yields and reducing fertilizer dependence (FAO, 2019). Similarly, in Zanzibar (Tanzania), pilot projects have demonstrated that bioslurry application increases maize and cassava productivity while improving soil moisture retention and microbial diversity in sandy soils (IEA Bioenergy, 2020). In the Caribbean, particularly in Haiti and the Dominican Republic, integrated biogas farming models use animal waste to produce biogas and liquid fertilizer, contributing to food security and waste management. These global island experiences highlight the relevance of FOM and bioslurry in circular agriculture, where nutrient recycling, soil resilience, and renewable energy converge to enhance sustainability under resource-limited and ecologically sensitive island conditions.

Island ecosystems such as those in the Andaman and Nicobar Islands, Lakshadweep, and other coastal regions face specific agricultural constraints like limited arable land, poor soil fertility, high input costs, and increased climate vulnerability. In these fragile zones, bio slurry, fermented organic manure (FOM), and biogas plant waste offer promising, eco-friendly alternatives to enhance crop productivity while minimizing environmental degradation. Bio slurry, a nutrient-rich effluent from household or community biogas digesters, contains ammoniacal nitrogen, phosphorus, potassium, and beneficial microbes. Often used in diluted form for fertigation, composting, or direct field application, it has shown to improve soil pH, water retention, and microbial biomass. Studies from ICAR-CIARI (in Port Blair demonstrate increased productivity of vegetables such as okra, brinjal, and *amaranthus* with regular bio slurry use.

FOM derived from cattle dung, coconut husks, or kitchen waste has been effectively used in terrace gardens, kitchen gardens, and horticulture, reducing dependence on expensive imported fertilizers in remote island settings. Biogas waste supports the circular economy by recycling local organic material, boosting soil organic carbon, and sustaining year-round cultivation even with erratic rainfall. However, to maximize its benefits, research is needed on nutrient enrichment, storage stability, and blending with locally available organics like coir pith, seaweed, or press mud. There is also a need for island-specific field trials to evaluate long-term effects on saline and sandy soils, nutrient leaching, and the potential role of FOM in pest and disease management under humid tropical conditions.

Table 4: Summary of Biogas Waste and FOM Utilization in Island Ecosystems

Aspect	Details
Source Materials	Cattle dung, kitchen waste, coconut husk, food waste
Types Used	Bioslurry (liquid), FOM (semi-solid/composted), biogas slurry compost
Key Applications	Vegetable crops (okra, brinjal), horticulture, kitchen gardens
Benefits	Improves soil pH, organic carbon, water retention, crop yield
Circular Economy Role	Recycles organic waste, reduces fertilizer imports, supports zero-waste farming
Policy Relevance	Aligns with GOBARdhan, PM-PRANAM, and island-specific organic farming missions
Challenges	Nutrient variability, lack of storage, need for application guidelines
Future Research Needs	Blended formulations, impact on pest resistance, leaching studies, salinity response

The use of bioslurry and FOM in island ecosystems is a strategic, eco-efficient solution to address soil degradation, input scarcity, and nutrient management. Its application supports climate-smart agriculture, nutrient self-sufficiency, and environmental conservation, especially critical for disaster-prone and ecologically sensitive islands. However, scaling this approach demands investment in infrastructure, awareness programs, and location-specific.

10. Challenges and Research Needs

Despite its wide-ranging agronomic and ecological benefits, the large-scale adoption of Fermented Organic Manure (FOM) is constrained by several practical and technical challenges. One key issue is the variability in nutrient composition, which depends heavily on the type of feedstock, anaerobic digestion conditions, and post-processing methods. This inconsistency limits its predictability as a nutrient source for crops. High pH levels in digestate can also lead to ammonia volatilization, resulting in nutrient loss and air pollution if not managed properly. Additionally, the lack of efficient transport, bulk storage, and field-level application systems, particularly in rural and smallholder-dominated regions, restricts the accessibility and usability of FOM. Furthermore, farmer awareness remains low regarding optimal application rates, timing, and compatibility with different soil and crop types. Addressing these issues requires the development of standardized guidelines, region-specific dosage charts, and farmer training modules integrated into existing extension services.

To improve the agronomic efficiency and usability of FOM, targeted research and innovation are essential. One promising area is the nutrient enrichment or fortification of FOM—either by blending with rock phosphate, biochar, or mineral nutrients to correct NPK imbalances, or by pelletizing it for ease of handling, transport, and mechanized application. Another approach involves co-composting FOM with other organic residues, such as crop stubble, sugarcane press mud, or kitchen waste, to improve its carbon-to-nitrogen ratio, microbial activity, and structural stability. Recent technological advances also enable the integration of Information and Communication Technologies (ICT) and Internet of Things (IoT) tools for quality monitoring, traceability, and nutrient profiling during storage and transport. Smart sensors, GIS-based nutrient mapping, and mobile advisory systems could facilitate site-specific FOM recommendations in real time. Focused research on these innovations, along with long-term field trials to assess their agronomic and economic impact, will be critical to mainstreaming FOM in sustainable agriculture.

11. Conclusion

Fermented Organic Manure (FOM) from Compressed Bio-Gas (CBG) plants presents a sustainable and nutrient-rich alternative to chemical fertilizers, offering added benefits for soil health, carbon sequestration, and organic waste recycling. While challenges such as nutrient variability, logistics, and limited farmer awareness persist, FOM aligns with India's vision for a circular bioeconomy, reduced fertilizer imports, and integrated energy-agriculture systems. In island ecosystems, where input access and soil degradation are acute challenges, the use of bioslurry and FOM promotes climate resilience, local nutrient security, and sustainable intensification. To unlock its full potential, focused investments in policy support, decentralized infrastructure, and region-specific research are essential. With technological innovation, fortified formulations, and precision-based application models, FOM is poised to become a cornerstone of climate-resilient and regenerative agriculture in both mainland and island contexts of the future.

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