Decentralized Solid Waste Management Through Pit Composting: A Community Integrated Approach for Soil Restoration In Dodaballapura Taluk, India.

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***Abstract*—Solid waste management (SWM) is a growing environmental concern in rapidly urbanizing towns like Doddaballapura city of Karnataka. This study presents a decentralized waste management model through pit composting, focusing on community participation and soil restoration. Biodegradable waste from selected households and farms was composted in pits layered with cow dung slurry and soil. After 45–60 days, the resulting compost was applied to their own agricultural fields. To assess its impact, soil samples were tested before and after composting for pH, electrical conductivity, organic carbon, nitrogen, phosphorus, and potassium. The results showed a significant improvement in soil quality, mainly in organic carbon and potassium content. The organic carbon increased from 0.23% to 0.63%, and potassium from 120 kg/ha to over 300 kg/ha. In addition, Information, Education, and Communication (IEC) activities raised awareness about waste segregation and composting. Community-led pit composting is a low-cost, sustainable solution that improves soil health, reduces landfill pressure, and promotes environmental awareness. This model can be replicated in similar towns for effective waste management and ecological restoration.**

***Index Terms*—Compost, Management model, Pit, Soil quality, Organic Carbon, IEC.**

I. INTRODUCTION

Solid waste refers to unwanted or discarded materials generated from human activities, including households, industries, agriculture, and institutions. It includes biodegradable waste such as food and garden waste that decomposes naturally, and non-biodegradable waste like plastics and metals that persist in the environment for decades [1][4]. Due to increasing urbanization and consumption, solid waste generation has significantly risen. Improper management can lead to pollution of air, water, and soil, and pose serious public health risks through the spread of disease.

Proper management of solid waste is essential to protect environmental and public health. Understanding its types, sources, and impacts helps in planning effective collection, segregation, recycling, and disposal methods. Sustainable solid waste management promotes resource recovery, reduces pollution, and supports a cleaner and healthier ecosystem [1][4]. It also requires active public participation, supportive policies, and efficient governance systems. [13]

Composition of Solid Waste

The composition of solid waste refers to the types and proportions of different materials present in the waste stream. It varies depending on location, season, economic status, urbanization, lifestyle, and waste management practices. Understanding waste composition is essential for designing suitable treatment, recycling, and disposal methods [2][3].

Table 1: Composition and Proportion of Solid Waste (CPCB (2020) World Bank (2018).

Waste Component	Typical Proportion (Urban India)	Description
Organic Waste	40–60%	Food scraps, vegetable peels, garden waste; biodegradable.
Paper and Cardboard	5–10%	Newspapers, packaging, office paper.
Plastics	4–8%	Carry bags, bottles, wrappers; non-biodegradable.
Glass	2–5%	Bottles, broken windows, jars.
Metals	1–5%	Tin cans, aluminum foils, scrap metals.
Textiles	1–4%	Clothes, rags, synthetic fabrics.
Inert Waste	10–20%	Dust, construction debris, ash, sand.
Others	2–5%	E-waste, rubber, leather, batteries, sanitary products.

Overview of Solid Waste Management and Generation

Global Scenario

Global municipal solid waste generation reached approximately 2.1 billion tonnes in 2023, and this volume is projected to rise sharply to 3.8 billion tonnes by 2050. The primary drivers of this increase include rapid population growth, urbanization, and evolving consumption patterns. In 2020, the global cost of waste management was estimated at USD 252 billion. If current waste handling practices continue unchanged, this figure is expected to more than double to USD 640 billion by 2050 [3][7]. However, a transition to a circular economy, one that prioritizes waste reduction, reuse, and recycling offers a promising alternative. Such a shift could convert this financial burden into a net economic gain of USD 108 billion annually, while also advancing both economic growth and environmental sustainability [13]

National Scenario – India

India currently produces approximately 170,000 tonnes of municipal solid waste (MSW) daily, amounting to about 62 million tonnes annually (2021–22). Out of this, about 70% is collected, roughly 12 million tonnes (~19%) are treated, and around 31 million tonnes are disposed of in open and unsanitary landfills [4][12]. Due to increasing urbanization, industrialization, and lifestyle changes, per capita waste generation is projected to rise, with total MSW generation expected to reach approximately 165 million tonnes per year by 2030. These trends highlight the urgent need for integrated and sustainable solid waste management systems across the country [12].

State Scenario – Karnataka

Karnataka has demonstrated significant progress in the management of hazardous waste, underpinned by a steadily improving waste treatment infrastructure. In the financial year 2022–23, the state generated approximately 542,000 metric tonnes of hazardous waste. Of this total, around 89% was effectively treated, recycled, or disposed of through authorized channels. However, nearly 27,000 metric tonnes remained unaccounted for, indicating existing gaps in tracking and reporting systems. The state's management infrastructure comprises 148 authorized recyclers, 47 registered utilizers, two captive treatment units, and nine cement plants engaged in co-processing, collectively handling about 370,000 metric tonnes of hazardous waste. Furthermore, ten Common Treatment, Storage, and Disposal Facilities (TSDFs) managed over 100,000 metric tonnes during the same period. While these developments reflect substantial progress, further efforts to improve waste accountability and strengthen monitoring mechanisms are essential to ensure environmental compliance and sustainable hazardous waste management in the state [12].

Bengaluru City Scenario

Bengaluru, one of India’s fastest-growing metropolitan cities, faces significant challenges in managing its rapidly increasing solid waste. The city generates approximately 6,000 tonnes of solid waste per day, amounting to over 2.1 million tonnes annually. To address this, Bengaluru has adopted a comprehensive waste management strategy that emphasizes the segregation of wet and dry waste at the source. This system is supported by three major waste processing facilities located at Bingipura, Mavallipura, and Kudlu. In addition to these, the city operates seven wet-waste processing units, thirteen bio-methanation plants, and one active landfill site. Following the closure of outdated and environmentally harmful landfill sites, four new landfill locations were approved in 2024 to accommodate the increasing volume of waste [12].

As part of its commitment to sustainable urban development, Bengaluru is an active participant in the C40 Cities Global Green New Deal. Under this initiative, the city has implemented decentralized bulk waste management systems, requiring large waste generators such as apartment complexes and commercial establishments to treat their biodegradable waste onsite. This localized approach not only reduces the carbon emissions associated with long- distance waste transport but also fosters inclusive and environmentally responsible waste management practices. These efforts reflect the city's growing commitment to sustainable urban living and improved environmental governance [11].

Table 2: Waste generation and management overview (CPCB and UNEP data (2023–24/2024)

Level	Waste Generation	Collection & Treatment	Noteworthy Trends/Highlights
Global	2.1 b t → 3.8 b t by 2050	USD 252 b spent → USD 640 b (projected)	Circular economy: +USD 108 b opportunity (unep.org, en.wikipedia.org)
India	170,000 tpd (~62 Mt/yr)	70% collected; ~19% treated; rest landfilled	Per-capita MSW rising; expected 165 Mt by 2030
Karnataka	Hazardous: 542,000 MT/yr	89% treated/recycled; 27,000 MT not tracked	Strong industrial recycling capacity
Bengaluru	~6,000 t/day	Segregated streams; 7 wet, 13 bio-CNG plants; new landfills	Bulk waste pilot under C40 strategy

Project Profile of city farmer partnership

The City–Farmer Partnership in Doddaballapura can build upon the successful model piloted in Chikkaballapura, implemented in collaboration with the Chikkaballapura City Municipal Council (CMC), the Indian Institute for Human Settlements (IIHS), and Godrej Properties Limited. In this model, wet waste collected from urban households is diverted from landfills and distributed to nearby farmers, who establish small compost pits on their fields. In Chikkaballapura, this approach has engaged over 250 farmers across 21 villages, resulting in the processing of more than 4,000 tonnes of wet waste into high-quality compost benefiting around 109 farmers directly.

In Doddaballapura, the replication follows the same community-focused, low-cost structure: the municipality organizes door-to-door segregation of wet and dry waste, routes the wet waste to farmer-constructed compost pits, and farmers mix it with cow dung slurry and microbial cultures. This results in a 30% compost yield over 3-4 months, delivered back to the farmers at no cost.

Implementation in Doddaballapura involves extensive community engagement, with outreach campaigns, street plays, and training sessions conducted by IIHS and CMC staff. Regular training ensures farmers and sanitation workers understand composting processes, and consistent engagement ensures ongoing source segregation by households. Early results have shown improvements in soil pH and organic carbon content boosting yields for crops like roses and potatoes—and delivered significant environmental and economic benefits to farmers and the local municipality alike.

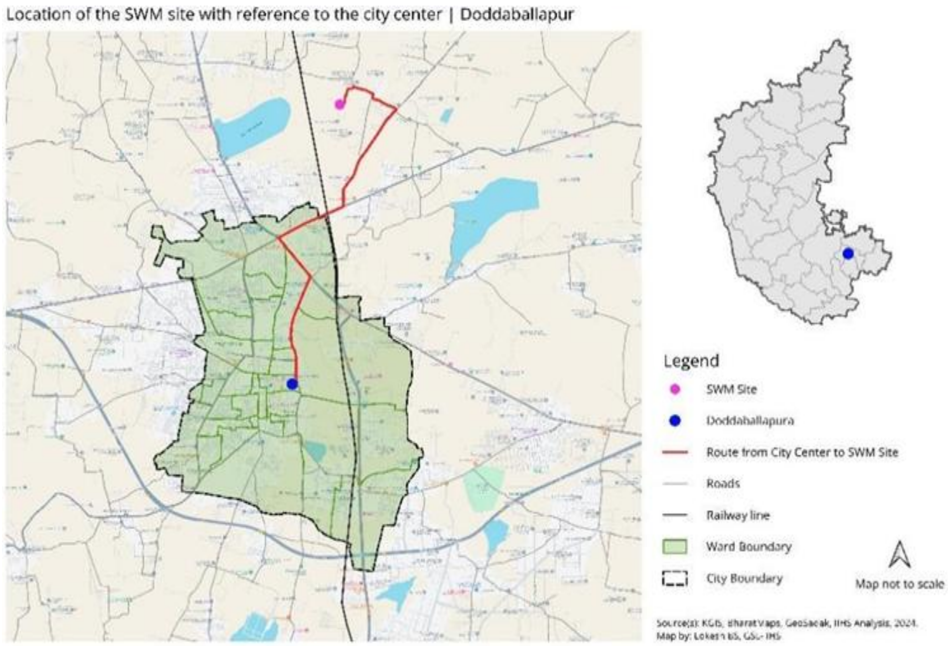

Figure1: Location map of Dodaballapura from QGIS

Objectives

1. To study the management of wet waste through pit composting method in Doddaballapura city.
2. To study the soil health before and after composting.
3. To educate the public of Doddaballapura on solid waste management techniques through IEC activities.

II. MATERIALS AND METHODOLGY

Study area

Doddaballapura is a city and district headquarters of Bengaluru of Karnataka, India. Dodda means "big" in the native language Kannada. It is an industrial city which houses several national companies, and lies 40 km away from Bengaluru. It is located at latitude 13.29°N and longitude 77.53°E. Bengaluru Metropolitan Region Development Authority (BMRDA) has taken in charge of the city. The area contributes significantly to Bengaluru's peri-urban growth, as urbanization and industrialization have caused quick changes in land use.

The Geographical area is nearly 2,259 sq.km and the district lies stretched between the latitudinal parallels of 12’ 15’ N and 13’ 35’ N on the one hand and the longitudinal meridians of 77 05’ E and 78 E on the other. The district is on the plateau with an average elevation of 629 to 950 meters from mean sea level has ranges of hills which are actually spurs of the Eastern Ghats, Stretching northwards with peaks like the Banantimari Betta, Mudawadi Betta, Bilikal Betta, Siddadevara Betta, etc. in the South-West side. The Savandurga and Shivaganga peaks are another row of Hill ranges, spreading up to the Nandi Hills running across the Bengaluru (Urban) district. Bengaluru Rural District had many prehistoric sites at places like Jadigenahalli (Hosakote Taluk).

The district lies in the southern maiden region of the State and is by and large an open country which is lacking in natural barriers. Bengaluru Rural District is bounded on the North by Tumkur, Chikkaballapur and Kolar Districts on the South by Bengaluru Urban District, east by Kolar District and Tamil Nadu State and on the West by Tumkur and Ramanagar Districts. The outline map of the district seems to roughly resemble a human ear, the hollow in the center and the portion connecting the ear to the head representing the Bengaluru (Urban) district. Bengaluru Rural District consists of four taluks namely:

- Devanahalli
- Doddaballapura
- Hosakote
- Nelamangala

Geographic location

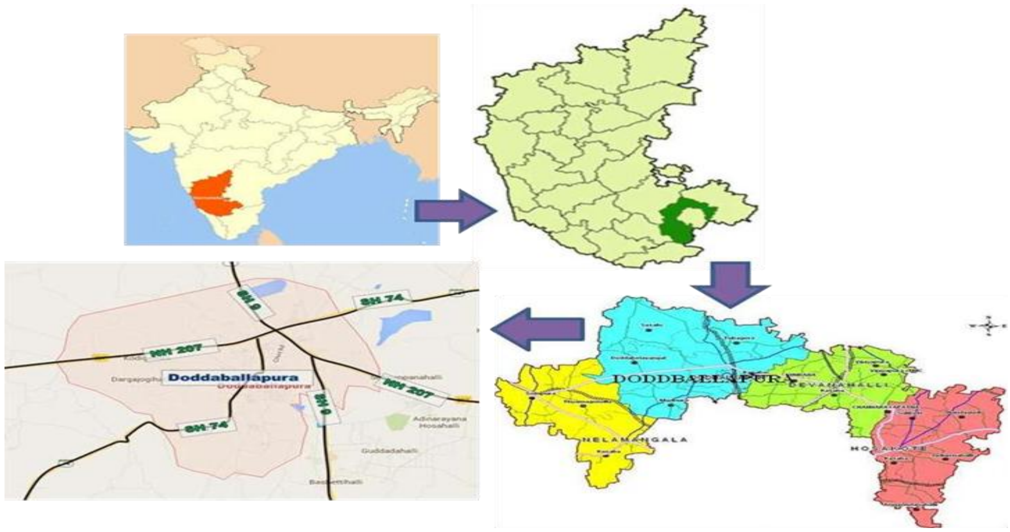

Figure 2: Map of Doddaballapura Town.

Waste management in Doddaballapura taluk

Waste management in Doddaballapura undergoes door-to-door collection using color-coded auto-tippers and compactors that prevent spillage. Waste is segregated at source into wet, dry, and mixed fractions. Mixed waste is routed to a sanitary landfill, while dry recyclable waste goes to DWCCs for sorting, baling, and dispatch to recyclers or for RDF conversion if combustion-quality is sufficient. Wet organic waste is being sent to farmers for composting. Total waste generated in Doddaballapura city above 40 tonnes out of which 35 tonnes is collected by door-to-door vehicles from different sources

Methodology: Pit Composting Site Selection

A well-drained, shaded area was chosen to prevent overheating and waterlogging, while ensuring easy access for heavy machinery and avoiding flood-prone zones.

Pit Excavation

A rectangular pit measuring 5 m × 4 m × 1 m total 20 square meter was dug using a JCB excavator. This size supports thermophilic microbial activity while allowing efficient aeration and heat retention [5].

Layered Material Filling

Composting followed a layered structure: Coarse vegetable and fruit scraps (green, nitrogen-rich) Organic waste dryer compost (microbial inoculant) Dried/woody waste (brown, carbon-rich) Cow dung (activates microbial decomposition) These layers were alternated until the pit was full, balancing the C: N ratio to approximately 20–40:1 for optimal microbial growth [5].

Moisture Management

Water was sprayed to maintain moisture at 40–60% enough to feel like a wrung-out sponge ensuring microbial activity without causing anaerobic conditions.

Protection

A fence was put up around the pit to keep animals like cows and dogs away.

Aeration & Turning

After ~2 weeks, the pit materials were turned using a JCB to reintroduce oxygen; this process was repeated every 10–15 days to sustain aerobic conditions and maintain temperatures between 131–160 °F (55–71 °C) ideal for decomposition and pathogen reduction

Composting Duration

The pit contents decomposed over 2–3 months, culminating in dark, and crumbly compost with an earthy aroma— consistent with microbial stabilization timelines.

Compost Application

Finished compost was applied to farmland, enriching soil fertility and structure without chemical fertilizers.

Soil sampling

Soil is one of the most vital natural resources for life on Earth. It provides essential nutrients for plant growth, supports ecosystems, stores carbon, regulates water, and serves as a foundation for agriculture. Healthy soil is key to sustainable farming, food security, and environmental balance. Monitoring and improving soil health is therefore crucial, especially when applying practices like composting, which can enhance soil fertility and structure [2].

This approach ensures that the collected samples are representative of the overall waste characteristics or site conditions, which is crucial for accurate analysis, monitoring, and decision-making in SWM operations [14]. Samples were promptly submitted to a soil testing laboratory for analysis of key parameters including pH, organic matter, macro and micronutrients, and texture.

Information, Education and Communication (IEC)

The Information, Education, and Communication (IEC) activities aimed to raise awareness about waste segregation and composting through creative, community-based approaches [6]. In households, organized "Walk to Ward" campaigns, where the interactions with residents along with ward members and health inspectors, explaining the importance of separating wet and dry waste. Showed how mixed waste harms composting and leads to pollution, while proper segregation helps produce useful compost and reduces landfill burden. Awareness to schools and colleges students used fun and interactive sessions to teach students about waste types, composting, and eco-friendly habits [15]. Farmers meet explained the impact of chemical fertilizers harm the soil over time and compost from wet waste improves soil health naturally. These efforts inspired people of all ages to take small but meaningful steps toward source segregation, sustainable living, building a cleaner environment.

III. RESULT AND DISCUSSION

Pit formation

Each farmer has received a composting unit to manage organic waste on their farms. Pit of dimensions 5 meters (length) × 4 meters (width) × 1 meter (depth). The pits were dug at suitable locations within their farms, ensuring accessibility for regular monitoring. Over a period of time, wet waste was fed into these pits F1 received 20.43tonnes, F3 15.65 tonnes, and F2 21 tonnes respectively. This waste primarily included kitchen waste, vegetable peels, fruit residues, and other biodegradable organic matter. The composting process was carefully monitored and managed. To ensure aerobic decomposition, the waste was turned every 15 days using farm machinery [5]. This regular turning helped to maintain air circulation and prevent the pile from becoming anaerobic, which is essential for healthy composting. In addition, bio-culture was added to accelerate microbial activity and enhance the breakdown of organic material. These bio-cultures contained beneficial microorganisms that improved the decomposition process and helped in odor control [6].

After a period of 3 months, the waste had completely decomposed into nutrient-rich compost. The final compost produced was dark, crumbly, and had an earthy smell—indicating its maturity and quality [6]. The total volume of the original wet waste was reduced by approximately 30% during the composting process. This reduction is significant as it directly translates to lesser waste being sent to municipal landfills, thereby saving landfill space and reducing methane emissions from unmanaged waste [7].

The compost generated was directly applied to the respective farmers' fields. It played a crucial role in improving soil fertility, increasing organic carbon content, and enhancing microbial life in the soil. Farmers observed better soil texture, improved moisture retention, and healthier crop growth. Unlike chemical fertilizers, compost does not harm the soil in the long term; instead, it enriches it naturally. The practice also contributed to reducing dependency on synthetic inputs, thereby cutting costs and promoting sustainable farming practices.

This decentralized composting initiative demonstrates a scalable and replicable model for rural and peri-urban areas [8]. By involving farmers directly in the composting process, the project fostered community ownership, environmental responsibility, and sustainable agriculture. It also served as a practical demonstration of how wet waste, when managed effectively, can be transformed into a valuable resource rather than becoming a burden on urban waste infrastructure. Pit composting in the fields of Farmers not only diverted several tonnes of wet waste from landfills but also generated compost that rejuvenated their soil. Such initiatives represent a simple yet powerful solution to address both solid waste management and soil degradation challenges simultaneously [5].

Soil health assessment

To assess the impact of pit composting on soil quality, soil samples were collected from three different farms in Doddaballapura both before and after compost application. Key physicochemical parameters and nutrient levels were analyzed, including pH, electrical conductivity (EC), organic carbon, macronutrients (N, P, K), secondary nutrients (Ca, Mg, S), and micronutrients (Zn, Fe, Mn, Cu, B) [9].

Table 3: Overview of composting practices and outcomes

Farmer Name	Pit Dimensions (m)	Wet Waste Fed (tonnes)	Waste Reduction (30%) (tonnes)	Composting Duration (months)	Compost Characteristics
Farmer 1	5 × 4 × 1	20.43	6.13	3	Dark Crumbly, Earthy Smell
Farmer 2	5 × 4 × 1	15.65	4.70	3	Dark Crumbly, Earthy Smell
Farmer 3	5 × 4 × 1	21.00	6.30	3	Dark Crumbly, Earthy Smell

Before application of Compost.

Before applying compost, soil samples from three farmers were tested. The results showed poor soil fertility across all fields. Organic carbon levels were low, indicating low organic matter in the soil. Potassium (K_2O), a key nutrient for plant growth, was also found to be deficient. Many essential micronutrients like zinc, boron, and iron were below the recommended levels. Although the pH values were mostly within normal range, EC was very low, showing limited nutrient availability. This poor nutrient status pointed to degraded soil that required organic improvement.

After application of Compost.

After the application of compost, there was a noticeable improvement in soil quality. Organic carbon levels increased significantly, showing that the compost helped in adding organic matter to the soil. Nitrogen, which was completely missing before, was now present in all fields. Potassium levels improved drastically, especially in F3s field, where it crossed 500 kg/ac. Micronutrients like manganese, iron, and copper also increased, improving the soil's nutrient balance. EC values rose slightly but remained within safe limits, indicating higher nutrient availability without risk of salinity. However, a slight increase in sodium was noted, which should be monitored to prevent long-term soil issues. Despite improvements, phosphorus and zinc remained low in some areas, suggesting the need for targeted supplementation.

Table 4: Comparative Soil Test Results Before and After Compost Application

Sl. No	Parameter	Arun Kumar (F1)		Suresh (F2)		Gangadharayya (F3)	
		Before	After	Before	After	Before	After
1	pH	7.99	7.52	7.72	7.13	6.36	5.26
2	EC (dS/m)	0.102	0.191	0.113	0.216	0.129	0.518
3	Organic Carbon (%)	0.19 (Low)	0.65	0.14	0.32	0.15	0.75
4	Available N (Kg/ac)	84	94	82	88	82	96
5	Available P_2O_5 (Kg/ac)	0.67	0.21	0.88	0.10	0.67	0.41

6	Available K_2O (Kg/ac)	8.50	158.69	8.59	180.86	18.62	552.29
7	Sulphur (ppm)	6.72	7.82	7.82	9.47	9.69	8.70
8	Zinc (ppm)	0.73	0.57	0.73	0.51	0.6	0.16
9	Manganese (ppm)	1.11	27.63	2.32	50.68	12.39	26.55
10	Iron (ppm)	0.02	14.28	0.35	25.43	4.6	65.36
11	Copper (ppm)	0.06	0.97	0.16	1.62	1.15	3.39
12	Boron (ppm)	0.21	0.16	0.23	0.23	0.19)	0.31
13	Sodium (ppm)	94.55	137.9	34.05	126.05	31.9	287.3

The soil test comparison reveals changes in various parameters after compost application for all three farmers [10]. Soil pH, which reflects acidity or alkalinity, slightly decreased for F1 and F2, remaining within the neutral range. However, F3's soil pH dropped from neutral (6.36) to acidic (5.26), indicating increased soil acidity. Electrical Conductivity (EC), which measures salt concentration, increased for all three farmers but stayed within the normal range, suggesting better nutrient availability without reaching harmful levels.

Organic Carbon, a critical indicator of soil fertility, improved in all cases: F1 's OC increased from 0.19% to 0.65%, F2's from 0.14% to 0.32%, and F3's from 0.15% to 0.75%. This shows a positive impact of compost on organic matter content. Available Nitrogen (N) increased slightly for all three farmers but remained in the low category, suggesting that although compost helped, additional nitrogen sources may be needed.

Available Phosphorus (P_2O_5), essential for root development, actually declined in all cases, possibly due to soil fixation or crop uptake, remaining low throughout. In contrast, Available Potassium (K_2O) showed a dramatic increase for all farmers, moving from low to high levels — F1's from 8.50 to 158.69 kg/ac, F2's from 8.59 to 180.86 kg/ac, and F3's from 18.62 to 552.29 kg/ac — reflecting the strong potassium-enriching effect of compost.

Sulphur levels slightly improved or remained similar but stayed in the low range. Zinc, initially sufficient in all three cases, became deficient after compost use, which could be due to dilution or imbalanced uptake. However, Manganese levels increased significantly for all farmers and remained sufficient. Similarly, Iron improved drastically from deficient to sufficient in F1 Kumar and F2's soil, while it remained sufficient but rose sharply for F3. Copper, too, showed strong improvement from deficient to sufficient levels in F1 Kumar and F2 soil while F3's soil was already sufficient and improved further.

Boron remained deficient across all three farmers, showing little to no improvement post-compost, indicating the need for targeted supplementation. Lastly, Sodium levels increased significantly for everyone, rising from medium or low to high — this could pose salinity risks over time and should be monitored or managed.

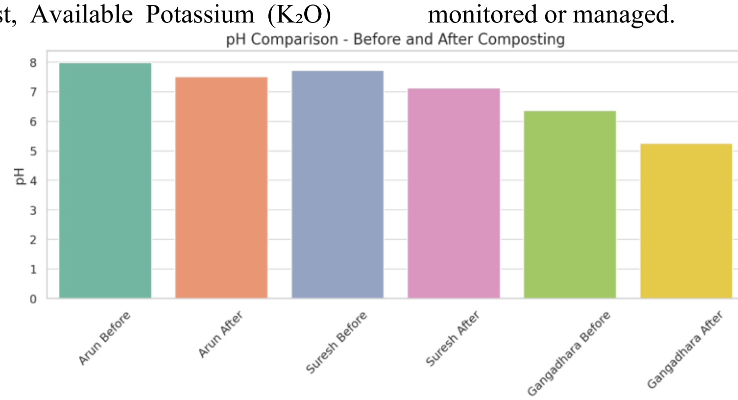

Figure 3 – Comparison of Soil pH: Before and After Composting

The graph shows that after composting, the pH levels for F1, F2 and F3's all decrease, indicating that the material becomes less alkaline or more acidic. F1's pH drops slightly, F2's soil drops a bit more, and F3's shows the greatest decrease. This suggests that composting generally lowers pH levels, likely due to the formation of organic acids during the process. Overall, composting results in a more acidic material for all participants in the study.

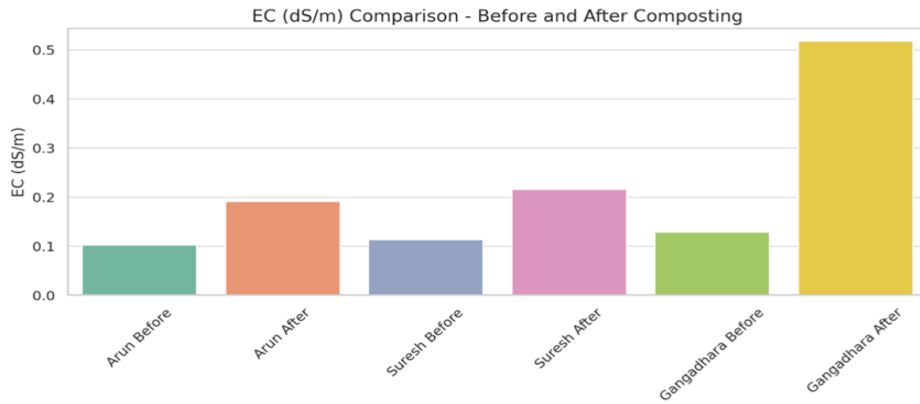

Figure 4 – Comparison of Electrical Conductivity (EC) Before and After Composting

The result indicate that Electrical Conductivity (EC) of soil increased for all three farmers soil after composting. This means composting added more salts and nutrients to the soil. F3''s soil showed the highest increase in EC, going above 0.5 dS/m, indicating a strong improvement in soil fertility.

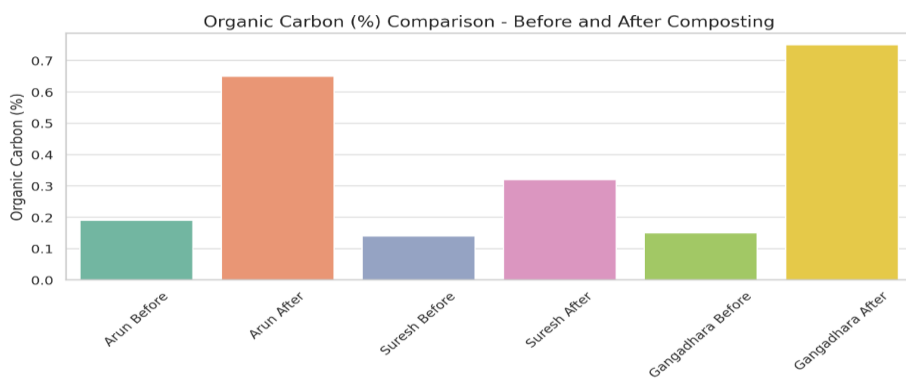

Figure 5 – Comparison of Organic Carbon Before and After Composting.

The results show that after composting, the organic carbon in the soil increased in the soil of all the farmer's land.F1 and F2 started with low levels but saw a clear rise, especially F1, whose level went up to about 0.65%. F3 had the biggest increase, reaching about 0.75%. Overall, composting helps improve soil health by boosting organic carbon.

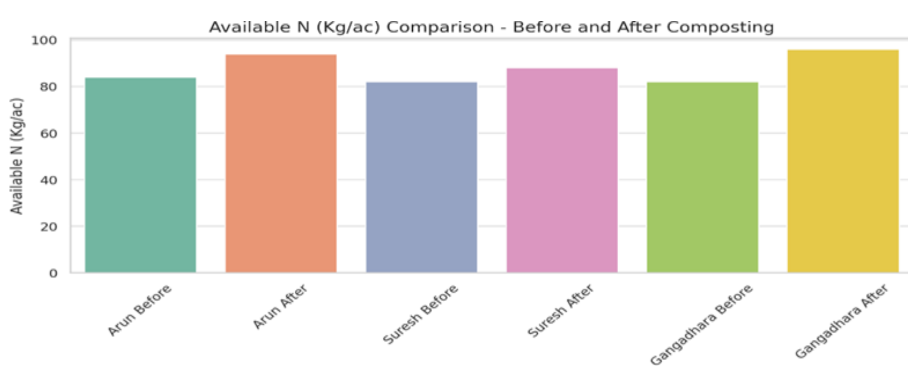

Figure 6 – Comparison of Nitrogen (N) Before and After Composting

The graph declaring that available nitrogen (N) in the soil increased for all the farmers land after composting. This means composting helped add nitrogen to the soil, which is important for plant growth. The highest increase is seen in F3's soil, showing composting had a strong positive effect.

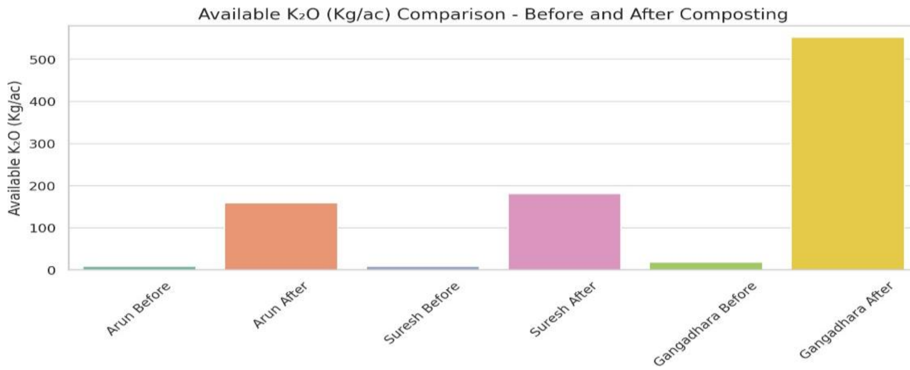

Figure 7 – Comparison of Potassium (K) Before and After Composting

The obtained result shown that the composting increases the potassium levels in soil. After composting, all of them have more potassium in their soil, and F3's increase is the highest, going over 500 kg/acre. This means composting is very helpful for adding potassium to the soil.

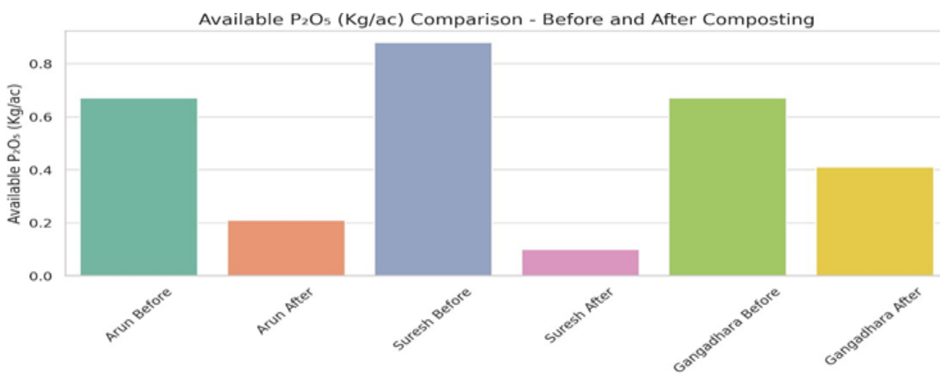

Figure 8 – Comparison of Di phosphorus (P_2O_5) Before and After Composting

The available Phosphorus in the soil decreased after composting. This means composting may have led to phosphorus being used up by microbes or not fully released during the process.

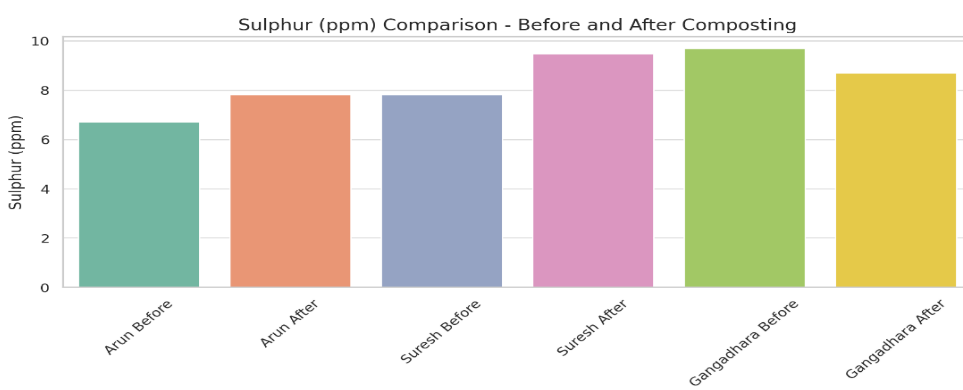

Figure 9 – Comparison of Sulphur (S) Before and After Composting

The result shows that after composting, the Sulphur content in the soil went up F1 and F2, but went down a little for F3. This means composting usually helps increase Sulphur in the soil, though it might not always work the same for everyone.

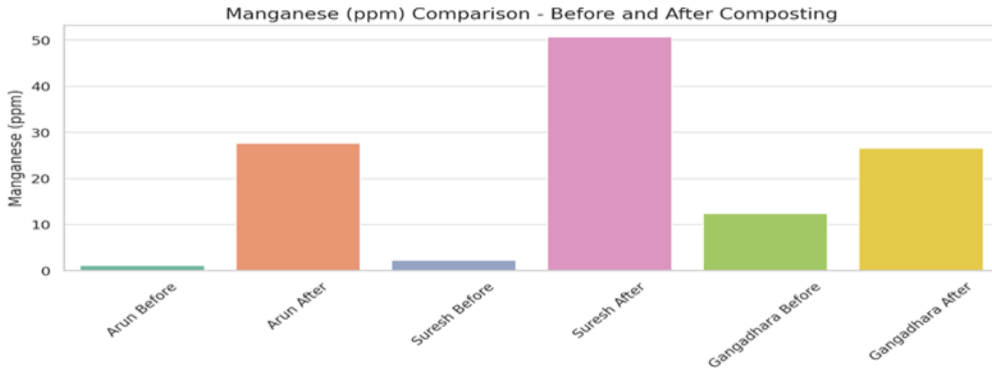

Figure 10 – Comparison of Manganese (Mn) Before and After Composting

The graph shows that after composting, the amount of manganese in the soil increased for all three farmer's soil. F2's soil had the biggest increase, reaching the highest level. F1 and F3 also had more manganese in their soil after composting. Overall, composting clearly boosted the manganese content in all the samples.

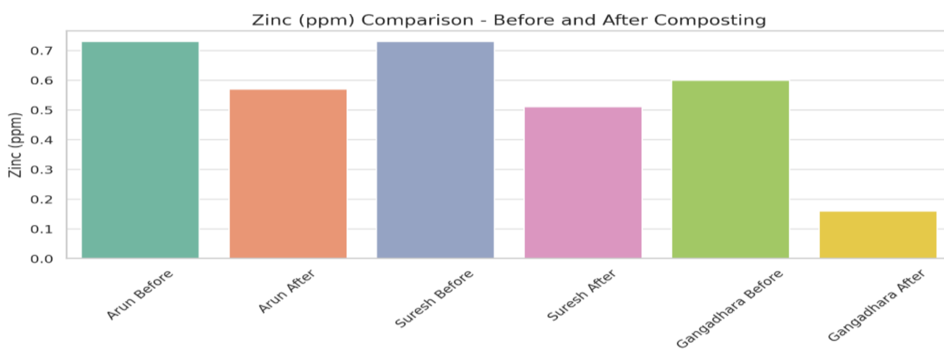

Figure 11 – Comparison of Zinc (Zn) Before and After Composting

The graph shows that Zinc levels in the soil decreased after composting for all three farmers. F1 and F2 had a slight drop, while F3's zinc level reduced sharply. This means composting in this case reduced zinc availability in the soil.

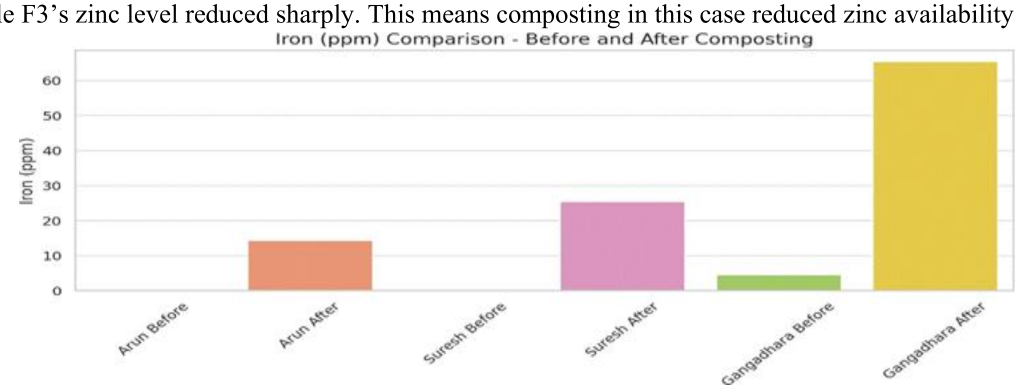

Figure 12– Comparison of Iron (Fe) Before and After Composting

The graph represents that composting increased iron levels in the soil for all three farmers. F1's soil iron concentration rose about 13 ppm, F2's to 26 ppm, and F3s had the highest jump to nearly 65 ppm. This suggests composting boosts iron in soil.

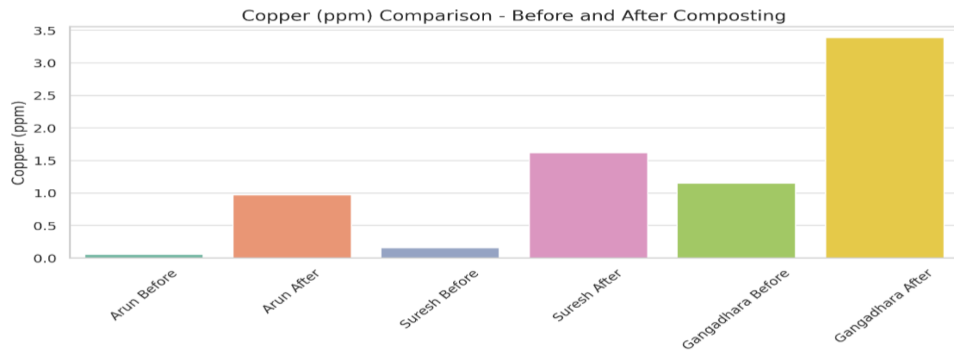

Figure 13– Comparison of Copper (Cu) Before and After Composting

After composting, copper levels in the soil increased for all three farmers. F1's soil went from nearly 0 to 1 ppm, F2's from 0.2 to 1.5 ppm, and F3's from 1.1 to over 3.2 ppm. This shows that composting improves copper in the soil.

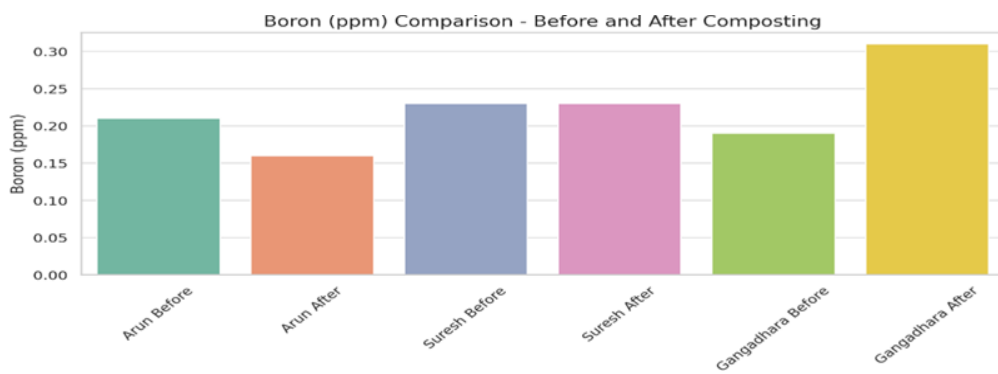

Figure 14– Comparison of Boron (B) Before and After Composting

The result showing for boron level in the soil before and after composting for three farmers. F1 observed a slight decrease, F2's levels stayed nearly the same, while F3had a significant increase. This suggests composting can improve boron.

Information, Education, and Communication (IEC) Activities play a powerful role in building it help people see, hear, and understand how small actions—like segregating waste at source, reducing plastic—can help for better composting. Instead of just giving facts, we used creative methods like wall paintings, walk to ward, school talks, and farmers meet to connect with people in comfort interactions and sharing a knowledge making them aware. These activities break complex topics into simple messages that stick in people's minds. It inspires real behavior change, turning awareness into action [11].

Household and Community Awareness on Wet Waste Segregation

To create awareness among households and communities, we conducted "Walk to Ward" campaigns by visiting selected wards and interacting with local residents with respect to their Ward member and Health inspector. Our main message was about segregating wet and dry waste at the source. We explained that when wet waste is mixed with plastic or other non- biodegradable materials, it cannot decompose properly and produces foul smell, attracting pests. Moreover, such mixed waste cannot be composted effectively. We emphasized that wet waste is not waste but a valuable resource if segregated, it can be turned into organic compost which improves soil health. We demonstrated how plastic in mixed waste blocks aeration in compost pits, leading to poor compost quality. People were also made aware that proper segregation reduces the burden on landfills, and helps in reducing the black spots or open dumping of waste which leads to rise of mosquitoes and flies which otherwise emit methane a major greenhouse gas contributing to climate change. We encouraged the use of home composting bins and community compost pits and gave examples of successful composting models. This activity helped households understand their role in sustainable waste management and how their small efforts can make a big difference to the environment and public health.

Awareness Programs in Schools and Colleges

An awareness programs was conducted in both schools and colleges to promote sustainable waste management practices. In schools, we used simple and interactive methods to teach children about different types of waste wet, dry, and hazardous and the importance of segregation at source. We explained why burning waste is harmful and encouraged eco-friendly habits like using cloth bags, steel bottles, and tiffin boxes instead of plastic. In colleges, we went deeper into the environmental impact of improper waste disposal, the science of composting, and the role of youth in promoting sustainability. Students were encouraged to organize waste audits, eco-clubs, and install compost bins in hostels and canteens. We also addressed the dangers of single-use plastics and motivated them to adopt low-waste lifestyles. The sessions were interactive, using demonstrations, discussions, and real-life examples. These educational efforts not only increased awareness but also inspired action. By targeting both schools and colleges, we aimed to build environmental responsibility from a young age and carry it into adulthood. Young people are powerful changemakers, and equipping them with the right knowledge and habits ensures a more sustainable future. Many students expressed interest in continuing these efforts in their homes and communities.

Farmers' Awareness on Compost Use and Soil Health

Conducted sessions with local farmers to educate them on the benefits of using compost over chemical fertilizers. Most farmers were unaware that excessive use of chemical fertilizers depletes the natural fertility of soil over time, killing beneficial microorganisms and leading to long-term productivity loss. We explained how organic compost from wet waste through pit composting field enriches the soil naturally, improves its structure, and increases water retention capacity. Farmers were also shown how composting wet waste from markets, homes, and even animal sheds can reduce waste going to landfills, thus cutting methane emissions. We connected the dots between climate change and agriculture, telling them that by adopting sustainable practices, they not only improve their crop yield but also contribute to environmental protection. Some farmers were surprised to learn that composting reduces weed growth and supports healthier plant growth without harmful residues. We also showed practical methods of pit composting and vermicomposting. Farmers appreciated the idea as it reduced their dependence on costly fertilizers. Our interaction-built trust and offered them a low-cost, eco-friendly solution that benefits both their land and the planet. This initiative bridges waste management with sustainable agriculture and promotes a circular economy.

IV. CONCLUSION & RECOMDENDATIONS

To showcase pit composting as a decentralized wet waste management strategy was met through practical implementation in three farmers' fields. Collectively, 57.08 tonnes of wet waste were diverted from landfills and processed into nutrient-rich compost. The simple, low-cost pit design and community participation ensured high replicability, showcasing an inclusive model for peri-urban and rural waste treatment. Comprehensive soil analysis before and after composting revealed notable enhancements in critical soil parameters. There was a measurable increase in organic carbon content, indicating improved soil fertility. Electrical conductivity and pH were stabilized, micronutrient availability (Zn, Fe, Cu, and Mn) improved, and overall texture and microbial health were enhanced. This confirms the role of compost in reviving soil ecosystems and reducing dependency on chemical fertilizers.

IEC (Information, Education, and Communication) activities played a crucial role through targeted awareness programs in schools, colleges, farmer meetings, and street plays. These creative outreach efforts were essential in educating communities on the significance of source segregation and the environmental and agricultural benefits of composting. Feedback from the field indicated positive behavioral changes among residents, improved segregation at source, and increased farmer interest in adopting composting.

The convergence of results proves that decentralized composting not only addresses the issue of organic waste disposal but also rejuvenates degraded soils and enhances local agriculture. Furthermore, the project-built community awareness, ownership, and a sense of environmental stewardship. In conclusion, this initiative showcases the strong connection between urban waste management and rural soil improvement. By linking organic waste from cities with the needs of local farmers, it has demonstrated a circular and community-based approach to sustainability. Pit composting turns organic waste into valuable compost, helping to reduce pollution, lower reliance on landfills, and strengthen agricultural practices. With the right training, support, and implementation, the city–farmer model adopted in Dodaballapura offers a simple, low-cost solution that benefits both urban and rural areas. Its success makes it a practical and replicable model for other cities with nearby farming communities.

V. RECOMMENDATIONS

Digital Waste Tracking App

People can monitor how successfully they separate their waste at home with the use of a smartphone app. The software can offer composting advice, display the amount of garbage that has been cut down, and even award users with badges or points. This helps people maintain regular positive habits and makes waste management more enjoyable.

Green Influencer Campaigns

Young people today spend a lot of time on social media. Therefore, collaborating with well-known local environmental influencers can help the message get out there more quickly. They may make it seem exciting and simple by generating entertaining films and articles about composting, waste separation, and organic plant growth.

Smart Collection Scheduling

Use technology (like GPS and route maps) to plan better paths for waste collection vehicles. This saves fuel, reduces pollution, and makes sure waste is picked up on time. It also avoids repeat visits and delays, especially in busy areas.

Elimination of black spots

In the context of waste management, a "black spot" is an area where trash is frequently disposed of in the open, such as by roadside drains, vacant plots, or street corners. These spaces get unclean, odorous, and unsanitary. When appropriate collection or dumpsters are absent or being exploited, people frequently dispose of their waste there.

Replicability advantage

The city–farmer partnership in Dodaballapura is a simple and successful way to manage waste. City waste like vegetable peels and kitchen scraps is given to nearby farmers, who turn it into compost using pits on their farms. This helps reduce waste going to landfills and gives farmers good compost for their soil. The process is easy, low-cost, and brings city and rural communities together. Because it works well and needs less money and effort, this model can be easily repeated in other towns and cities where farmers are nearby. It is a good example for other places to follow for clean and green waste management.

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