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RESEARCH ARTICLE

Solid and Liquid Resource Utilization for Zero-waste Agriculture

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ABSTRACT

Agriculture, in addition to sustaining human life, is a major producer of solid residues and nutrient-rich waste materials. Mishandling of agricultural waste causes greenhouse gas emissions, contaminates water sources (groundwater and rivers), climate change, and reduces soil fertility. On the other hand, when harnessed, they become important inputs for circular farming. This study will discover an integrated pathway to convert natural burdens into resource flows, analysing the challenges and opportunities of agricultural waste. The present study will also evaluate options for biological and physicochemical treatment of solid and liquid wastewater and discuss the technology that will reduce gaps in current adoption and policy support. In this current study, we will critically discuss some recent field investigations, life cycle assessments, and case studies related to composting, anaerobic digestion, and constructed wetlands. Findings indicate that while individual technologies work well in isolation, systemic integration at farm scales remains limited, especially for smallholder farmers. This exposes a research gap in designing modular, low-cost, and farmer-friendly systems that manage both flows simultaneously. Future opportunities lie in combining waste assessment with renewable energy generation, digital monitoring, and incentive-driven policies that can accelerate adoption. AI models are used to get better results in waste management in agricultural sectors. Ultimately, solid and liquid waste management in agriculture is not just a technical intervention but a strategic step toward a sustainable food system – one that can reduce pollution, conserve resources, and equally improve the rural economy.

Key words: Agriculture, climate change, soil fertility, sustainability, waste management

INTRODUCTION

Waste is defined as the residue material developed from any technological or household process. Waste material is mainly the worthless or useless part of any product. They should be removed from day-to-day life as they threaten human health. Agricultural activities generate a significant amount of both solid and liquid waste. If they are not handled in a proper way, they can cause many environmental problems as well as health problems. Solid wastes in agriculture mainly refer to crop residues (straw and husks), animal manure, poultry manure, farm plastics, sugarcane bagasse, leftover pesticide containers, and food processing waste. They can cause various environmental problems, for example, crop residue releases methane, which is a potent greenhouse gas in the environment, burning of rice straws causes air pollution, climate change, and respiratory problems, pesticides and fertilizers carried by the rainwater to the nearby water sources (rivers and lakes) pollute them and harm the aquatic organisms.[1] In addition to that, much of the solid waste causes soil degradation, soil infertility, and contamination. The sources of liquid wastes are irrigation runoff, livestock buildings, dairy farms, and agro-industries. These wastes can pollute soil and water, release greenhouse gases, and develop

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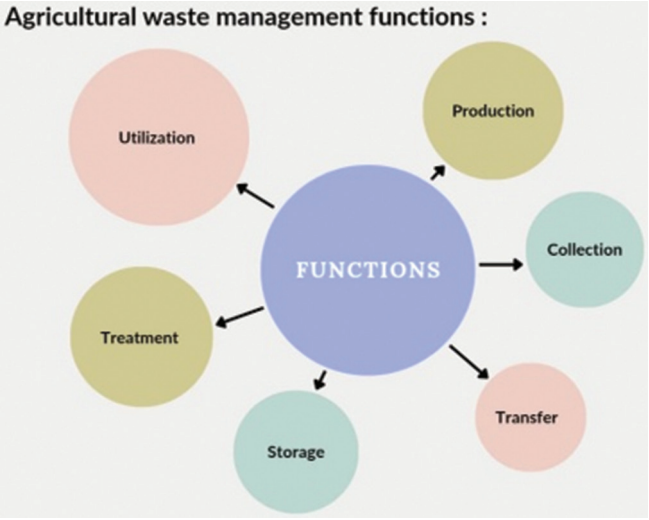
pathogens if left untreated. Furthermore, they cause foul smells, health risks, and overall food security. From the studies, it has been noticed that about 998 million tons of agri-residue waste is produced every year.[2] On the other hand, agricultural wastes have that potential which can be used in a sustainable way. Composting solid residues such as manure and crop biomass can be composted into bio fertilizers and biogas, which will improve soil fertility and provide renewable energy. Similarly, liquid waste can be treated first, then reused for irrigation, and can also be processed to recover nutrients by reducing chemical inputs.[3] Therefore, sustainable waste management in agriculture involves many steps, such as collection, treatment, recycling, and safe disposal methods that reduce pollution while improving resource recovery. Adopting these systematic, solid, and liquid waste management practices not only protects the environment but also enhances farm productivity, supports circular economy principles, and contributes to long-term agricultural sustainability.



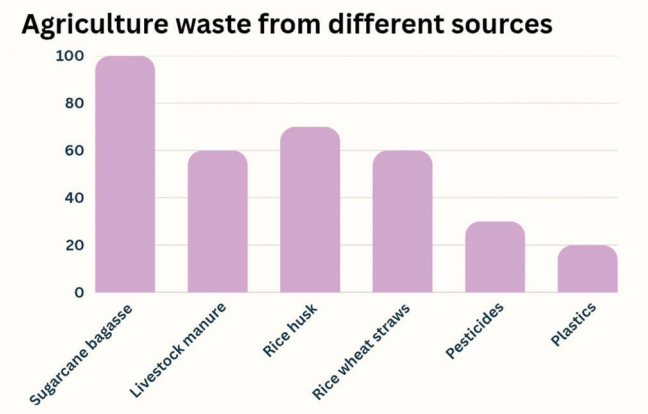
METHODOLOGY

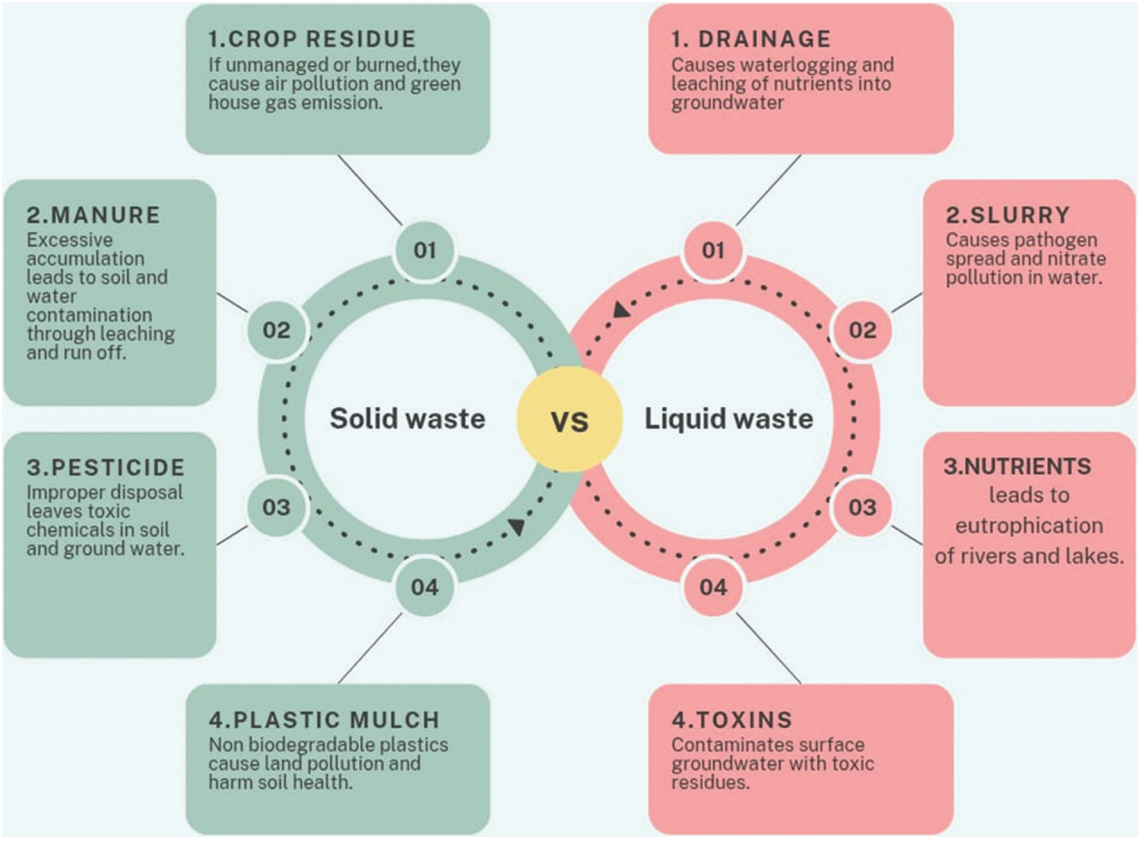
Agricultural waste is made up of all sorts of matter, such as animal excreta, found in slurries and farmyard manures, as well as spent mushroom compost, muddy water, and silage effluent. There is also waste from animals and waste from plants. Managing these wastes is crucial since they are essential for farming and preserving the environment.[4] When agricultural waste is handled properly, it not only reduces pollution but also helps recover valuable resources. In farming, there is a lot of waste that can be put to use. Various techniques and materials are used to manage waste and get something out of it. When crops are harvested, they often leave behind a trail of residues, things such as straw, husks, and stalks. This kind of waste also includes the remnants of fruit and vegetables, plus other plant materials that get discarded in the process.[5] Everything, from the bits of wheat straw scattered across a field to the apple cores and peach pits tossed aside after a summer harvest, falls into this category. Livestock farms are a source of animal manure. This natural byproduct turns out to be incredibly useful. It is packed with nutrients, making it a fantastic organic fertilizer. Mulching is a way to reuse waste. When you use waste as mulch, it helps keep the moisture in the soil and also stops weeds from growing, which can choke out plants. It even helps the soil hold on to nutrients, making it a fertile ground for crops to grow. Composting is a way to break down the matter.[6] This process happens either with or without air, using reactions to decompose the waste into a nutrient soil additive called humus. Anaerobic digestion is a process that occurs naturally where organic matter breaks down in the absence of oxygen. This decomposition happens with the help of microorganisms. It produces two things: biogas, which is mostly made up of methane, and a nutrient-rich substance called digestate.[7] The biogas that is produced can then be put to use as a source of energy. Solid crop waste can be a resource for generating power and electricity. For instance, leftover plant material can be used to produce biofuels, such as biodiesel and biogas, which can then be harnessed to create energy. If these remnants are processed and treated properly, they can serve as a substitute for feed sources, which in turn helps cut down on the need for conventional types of feed. For instance, waste can be used to produce bioplastics as chemicals and materials that come from plants. This shift could reduce our need for materials that come from fuels, which is a good thing. It is an approach that uses leftover waste to create something useful. When you heat up biomass in the absence of oxygen, it breaks down into a thing. You get biochar, which can be mixed into soil to help it retain water and nutrients. Then there is bio-oil and syngas.[8] These can be turned into all sorts of products, such as fuels for cars and trucks. Numerous wastes are produced by aquaculture, including metabolic waste

that can be dissolved or suspended. A productive farm will generate solid waste from about 30% of the feed it consumes. More waste is produced as a result of increased feeding brought on by a rise in temperature.[9] Water flow patterns in production units are essential for waste management because they will reduce the fragmentation of fish feces and allow for quick settling and concentration of the settleable materials. The amount of dissolved organic waste is greatly reduced as a result of the quick capture of a sizeable majority of non-fragmented feces. Aquatic weeds like Water hyacinth grow luxuriantly in ponds and lakes, affecting transport, agriculture, and human health. It can be used for biogas production, composting, mulching, and manuring.[10] Sludge and sewage are used in agriculture. A good source of food for fish growth is cellular algae. Slurry produced from biogas plant waste can be utilized by farmers for composting and manure. Agro-industrial waste from the milling of grains, sugar, cotton, tea, and non-edible oil cakes, as well as trash from the oilseed sector, can all be used to create biogas by being chopped. For real change to happen, it is crucial that farmers and everyone involved in the industry are aware of the ways to handle waste.

RESULT

Cost component (all figures in Indian National Rupee	Biogas production	Vermicomposting	Composting
	Based on the case study, tons (Mt) per cattle		
Total fixed investment	30450.00	24000.00	500.00
Total fixed cost	6155.62	5200.00	156.25
Total variable cost	13071.64	21102.29	8946.00
Total cost	1227.26	26302.29	9102.25
Total returns	33915.68	54000.00	11132.5
Net return	14688.42	276970.71	2030.25





CONCLUSION

Food wastage is an important source of agricultural solid wastes, which is inevitable. Awareness about waste management can prevent further agricultural waste production, and this awareness should be distributed to farmers, consumers, and everyone in between. Sharing fresh food with those in need, feeding animals with scraps, and using byproducts wisely are simple steps that make a big difference. Converting waste into useful sustainable resources not only makes the environment waste-free but also contributes to a smart economy.[1] In developing countries, agricultural waste can be a goldmine if managed properly. Managing waste can also contribute to creating job opportunities, reducing poverty, and even calming unrest by giving idle youth meaningful work. The government should take initiatives by building roads, storage facilities, and markets, and by supporting policies that promote recycling and sustainability. Last but not least, agricultural waste is not an issue, but it needs a bit of attention to unlock the resources.

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