**SUSTAINABLE AGRICULTURAL WASTE MANAGEMENT PRACTICES AND APPROACHES: AN OVERVIEW**

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**Abstract**

Agricultural wastes are non-product byproducts of the production and processing of agricultural products; they may contain components that are useful to humans, but their economic value is lower than the expense of collecting, transporting, and processing for such purposes. Although estimates of agricultural waste generation are uncommon, it is widely believed that they provide a sizable amount of the world's total garbage to the industrialized world. Agricultural development is frequently accompanied by waste products from the irrational use of intensive farming techniques and the abuse of cultivation-related chemicals, which have a significant impact on rural ecosystems in particular and the global environment in general. A variety of sources, most notably farming, raising animals, and aquaculture, produce agricultural wastes in general. Through the '3R' waste management system, these wastes are being employed for a variety of purposes. The six agricultural waste management functions were used to present a typical waste management option for a chicken farm and to examine the agricultural waste management system (AWMS). Agricultural waste has the potential to be hazardous to humans, animals, and plants through a variety of direct and indirect pathways. Both their management and the environmental impacts of these hazardous agricultural wastes were discussed.

1. **Introduction**

As a result of many rural operations, agricultural waste is wasted and produced. It includes fertilizer and other waste from farms, slaughterhouses, and poultry houses; waste from harvesting; fertilizer runoff from fields; pesticides that end up in water, the atmosphere, or soils; and salt and residue that has been drained from fields.

The term "agricultural waste" refers to the leftovers from the production and processing of agricultural products, including grains, fruits, vegetables, meat, poultry, dairy, and crops. Animal waste (manure, animal carcasses), food processing waste (only 20% of maize is canned and 80% is waste) (Patil SL, 1998), crop waste (corn stalks, sugarcane, bagasse, drops and culls from fruits and vegetables, prunings), and toxic and hazardous agricultural waste (pesticides, insecticides, and herbicides, etc.) are all included in agricultural waste, also known as agro-waste.

Although estimates of agricultural waste generation are uncommon, it is widely believed that they provide a sizable amount of the world's total garbage to the industrialized world. Increased levels of livestock waste, crop leftovers, and agro-industrial byproducts are a natural consequence of expanding agricultural production. If developing countries continue to expand their farming practices, there will probably be a noticeable rise in agricultural waste on a worldwide scale. The annual production of



**Figure1. Types of agricultural waste (Iqbal *et al*., 2020)**

agricultural waste is thought to be around 998 million tonnes. On a wet-weight basis, manure production on a farm can reach up to 5.27 kg per day per 1000 kg of live weight, or up to 80% of the total solid waste produced (Oreva Oghene Aliku, 2019)

1. **Sources**

Increased agricultural productivity has been required as the human population has grown. It has been estimated that agricultural output has increased by more than three times over the past 50 years. The development of green revolution-related technology and the extension of agriculturally productive soil are further factors that have improved agricultural output. Around 24 million tons of food are reportedly produced by the agricultural sector each year, but there are also associated concerns about human health and ecological threats (Krol A. *et al*., 2013). Food is a necessity that we cannot live without, but it is also clear that agriculture has an effect on the ecosystem. For instance, it is known that agriculture is responsible for around 21% of greenhouse gas emissions (Krol A. *et al*., 2013). A more effective and efficient method of processing agricultural solid wastes is required to boost agricultural production due to the detrimental effects of agriculture on the environment, aquatic life, and human health.

One of the key industries producing the most agricultural solid wastes is agriculture, which can either be exploited as raw materials for the bio-economy or allowed to pile indiscriminately and become a health hazard for everyone and a threat to food security. Recycling agricultural solid wastes has many advantages, including lowering greenhouse gas emissions and reducing the need for fossil fuels. It also has a positive impact on the growth of new green markets, the creation of jobs, the production of bioenergy, and the bioconversion of agricultural solid wastes into animal feed.

It is impossible to overstate the importance of managing agricultural solid wastes. Solid agricultural wastes come from a variety of sources. Pesticides, which include insecticides and herbicides, are one such source. If the use of pesticides were to cease, it has been calculated that the amount of food produced on a global scale would decrease by approximately 42% (Blanchet G. *et al*., 2016). All hands must be on deck to combat the threat posed by improper management of agricultural solid wastes because of the considerable impact that agricultural solid wastes have on human health, animal health, and the environment. A big part of the improper management of agricultural solid waste is ignorance. Many of the farmers and household managers who produce these wastes are not knowledgeable on how to handle them well. Most of them are unaware of the potential health risks associated with the things they play around with, and those who are aware are 'handicapped'. Agriculture produces huge amounts of solid waste each year, with production rising by around 7.5 percent annually (Gruber S. *et al*., 2008). Agricultural solid wastes are often carelessly disposed of or burned in public areas in developing nations, which pollutes the air, soil, and aquatic environment as well as produces harmful gasses, smoke, and dust. Remains may also be channelled into water sources to further contaminate the water supply.

Farming operations are the principal source of agricultural solid waste. However, it is not just production; it also includes other activities connected to farming and the food chain. Every step and stage of the agricultural food chain has the potential to produce large amounts of agricultural solid waste. The following items are included in the broad category of agricultural solid wastes:

* Solid wastes produced from the production of livestock for any purpose are referred to as "animal production solid wastes." These wastes include things like animal carcasses, broken feeders, water troughs, and bedding or litter.
* Solid wastes from food and meat processing come from facilities such as abattoirs or slaughterhouses that process crops or animal products for human use. Hoofs, bones, feathers, banana peels, and other agricultural solid wastes used in food and meat processing are a few examples.
* Solid wastes from crop production – Solid wastes from crop production are often produced during agricultural activities that involve crop production. Such agricultural solid wastes include things like crop leftovers and husks.
* On-farm medical solid wastes – Solid wastes produced as a result of using medications, pesticides, or vaccines on animals are referred to as on-farm medical solid wastes. Such wastes include, for instance, syringes, disposable needles, vaccination wrappers or containers, etc.
* Solid wastes from horticulture production are under the category of agricultural solid wastes and are produced when horticultural plants and landscapes are grown, maintained, and used for aesthetic purposes. Prunings and grass clippings are two examples of these wastes.
* Industrial agricultural solid wastes—livestock and produce are raised and generated for purposes other than human use. They are put to other purposes; thus, it is likely that these processes will produce agricultural solid wastes. Immediately coming to mind as a source of agricultural solid waste is wood processing and cuttings. A small amount of agricultural solid waste is produced during paper manufacture utilizing agricultural goods as basic ingredients.
* Chemical wastes – In this context, chemical wastes refer to agricultural solid wastes produced as a result of the use of pesticides, insecticides, and herbicides on farms and in retail settings, such as pesticide bottles or containers. Many unskilled and untrained farmers in developing nations still use pesticides, insecticides, and herbicides in agricultural activities, which leads to abuse by these uneducated farmers. Some inexperienced farmers handle pesticide containers improperly, creating unpredictably hazardous environmental conditions. According to reports, roughly 2% of pesticides still remain in the containers after use. Ignorant or untrained users may toss these pesticides into ponds or open fields, causing food poisoning, environmental damage, and water pollution, all of which lead to the loss of many lives.

Agricultural operations that involve the preparation, production, storage, processing, and consumption of agricultural produce, livestock, and their products typically result in the generation of agricultural solid wastes. Solid agricultural wastes are created by:

* Farming activities – Agriculture is the primary generator of agricultural solid waste. Agricultural waste is produced during every stage of farming operations, from clearing the land to harvest. Solid waste is produced during the entire process, from setting up the pen for the animals to arrive at the farm to setting up the pasture or paddock until the animals are killed and sold.
* Another way to produce a lot of agricultural solid waste is through a poor road system for moving harvested goods from the farm to the market or storage. This occurs mostly as a result of the poor road infrastructure in some developing nations, which may cause a traffic accident or cause a delay in the transportation of agricultural products from farms to markets. Perishable agricultural produce is readily wasted in traffic accidents, and the same thing may happen if delivery is delayed. The spoiled produce is either separated and discarded once the farmer arrives at the market or it is dumped on the side of the road.
* Insufficient electricity or lack of rural electrification—In some regions of emerging nations with extensive agricultural activity, the epileptic power supply and lack of rural electrification play a significant role in the production of agricultural solid waste. Stable electricity might have made it easier to store the harvested food in the cold, which would have decreased spoilage and, as a result, agricultural solid wastes.
* Inadequate storage facilities and drying methods—proper drying methods might stop the spoiling of a lot of agricultural produce. It would have been much easier to combat food spoilage and agricultural solid waste if farmers had access to suitable drying techniques or moisture monitoring. This would have improved food security and lessened the negative effects of agricultural solid waste on human health and the environment. Many farmers rely heavily on the erratic solar system to dry their harvest before it is stored, as well as the outdated method of moisture monitoring, which is neither accurate nor useful. Aflatoxin infestation has reportedly occurred as a result of insufficient moisture content monitoring of grain prior to storage. Aspergillus flavus is the source of aflatoxins. Aflatoxin contamination of food and livestock feed can result in large annual crop losses worldwide since it is both a cause and a product of food degradation.
* According to estimates, filamentous fungi cause the contamination of food and feed with mycotoxins, which results in the destruction of around 10% of the world's agricultural yield. According to reports, aflatoxins cause liver cancer, harm human health in underdeveloped nations, and cause significant economic losses, with corn alone costing the US $280 million each year. If other crop infestations like cotton, peanuts, and tree nuts are taken into account, the economic losses might reach $1 billion. *Aspergillus flavus* produces the aflatoxins B1 and B2, which lead to preharvest and postharvest crop infection (T. F. Doring *et al*., 2005).
* Another significant source or cause of agricultural solid waste is food spoilage. An estimated 40% of food is lost or wasted each year in the US alone. The Natural Resources Defense Council has estimated the cost of this waste to be roughly 162 billion dollars. In addition to increasing waste due to deterioration, pest and insect infestation may do so (T. F. Doring et al., 2005).
* Kitchen-generated agricultural solid wastes: Family eating is typically the end product of agricultural activities. Typically, the consumption of agricultural products at the family level results in the creation of agricultural solid wastes. Some of these wastes are produced out of necessity. For instance, many homeowners dispose of orange and banana peels as agricultural solid waste. However, inadvertent production of agricultural solid wastes may also occur as a result of food deterioration. When restaurants are counted as commercial kitchens, the amount of agricultural solid waste created by kitchens increases significantly. Agricultural solid wastes (food wastes) account for between 88 and 94% of all kitchen wastes taken into account in Chinese towns (B. V. Dien and V. D. D. Vong, 2006).

Sources table ………..

1. **Type of Agricultural Waste Management**



**Figure 2. Illustration of different sources of Agricultural waste**

 (Source: <https://www.mdpi.com/2077-0472/12/10/1737>)

The term "agricultural waste" refers to the leftovers from the production and processing of agricultural products, including grains, fruits, vegetables, meat, poultry, dairy, and crops. They are the non-product byproducts of the production and processing of agricultural products, which may contain components that are useful to humans but whose economic values are lower than the expense of collecting, shipping, and processing for such purposes. They might be in the form of liquids, slurries, or solids, and their composition will depend on the system and kind of agricultural activity. Animal waste (manure, animal carcasses), food processing waste (only 20% of maize is canned and 80% is waste) (B. O. Vincent *et al*., 2005), crop waste (corn stalks, sugarcane bagasse, drops, and culls from fruits and vegetables, prunings), and hazardous and toxic agricultural waste (pesticides, insecticides, and herbicides, etc.) are all included in agricultural waste, also known as agro-waste. Agricultural waste estimates are uncommon, but they are typically believed to provide a sizeable fraction of the world's total trash to the industrialized world. Agro-industrial byproducts, agricultural crop wastes, and livestock manure have all naturally increased in volume as agricultural production has expanded. If developing countries continue to expand their agricultural systems, there will undoubtedly be a considerable rise in agricultural waste globally. Approximately 998 million tonnes of agricultural waste are thought to be produced annually. In any farm, organic wastes can make up to 80% of the total solid wastes produced, with manure production reaching up to 5.27 kg per day per 1000 kg of live weight, on a wet weight basis (N. H. Lampkin, 1990).

1. **AGRICULTURAL WASTE GENERATION**

 As was previously said, agricultural expansion is frequently accompanied by wastes from the illogical use of intensive farming techniques and the abuse of cultivation-related chemicals, which have a significant negative impact on rural ecosystems in particular and the global environment in general. The sort of agricultural operations performed determines the trash produced.

* 1. **Wastes from Cultivation Activities**

Although a tropical climate is ideal for growing crops, it also fosters the growth and development of weeds and insects. Due to the enormous demand for pesticides caused by this condition to control the development of epidemic diseases and kill insects, farmers frequently abuse pesticides. The majority of pesticide bottles and packaging are dumped into fields or ponds after being used. About 1.8% of the chemicals are still in their packaging, according to a calculation conducted by the Plant Protection Department (PPD). Due to their long-lasting and hazardous compounds, these wastes have the potential to have unanticipated negative effects on the environment, such as food poisoning, poor food hygiene, and contaminated agriculture. In addition, pesticides that are already in use but are stagnant or unused, as well as pesticide packages that still contain residue from their original contents, can have serious negative effects on the environment if they are stored or buried improperly. These pesticides could leak or osmosis into the environment. Fertilizers, for instance, are crucial in preserving plant quality and output in agricultural production. Cheap and very productive, inorganic fertilizer has both of these qualities. The quantity of fertilizer that many farmers use on their crops, however, is greater than what the plants actually require. The severe repercussion of using fertilizer so excessively is that it is abused to boost agricultural output every year. According to the characteristics of the land, the types of plants, and the fertilization techniques used, the rate of absorption of such fertilizer chemicals (nitrogen, phosphorus, and potassium) varies. A portion of the excess fertilizer enters the groundwater, a portion is retained in the soil, a portion enters ponds, lakes, and/or rivers due to irrigation system use or surface runoff, causing surface water pollution; a portion evaporates or becomes de-nitrated, resulting in air pollution.

* 1. **Wastes from Livestock Production**

Waste from livestock operations comprises solid waste like manure and organic materials in slaughterhouses, wastewater like urine, cage wash water, wastewater from bathing animals and from keeping slaughterhouses sanitary, and odours. Since most of them are typically constructed around residential areas, the pollution brought on by livestock production is a severe issue. The digestion of livestock wastes in cages, the putrefaction of organic materials in manure, animal urine, and/or leftover food all contribute to unpleasant odours in the air. Temperature, humidity, ventilation, animal density, and animal density all affect how strong the smell is. The ratio of NH3, H2S, and CH4 fluctuates according to the phases of digestion as well as organic materials, food ingredients, bacteria, and the health of the animal. This unprocessed and nonrecyclable waste source can produce greenhouse gases, harm the soil's fertility, and pollute the water in addition to other harmful effects. In animal waste, water volume makes up between 75 and 95 percent of the overall volume, with the remaining components being organic and inorganic debris, as well as numerous types of microbes and parasite eggs. These microorganisms and compounds have the potential to harm the environment and transmit diseases to people.

* 1. **Waste from Aquaculture**

Increased usage of feeds for better productivity is a result of the expansion of aquaculture. The most significant aspect in influencing the amount of waste produced in a system is the amount of feed that is used. Metabolic waste, which can be suspended or dissolved, is one of the main wastes produced in aquaculture. Roughly 30% of the feed consumed on a farm with good management will end up as solid waste. Temperature-related factors affect feeding rates. A rise in temperature causes animals to feed more frequently, which leads to more excrement being produced. Because a suitable flow will decrease the fragmentation of fish faeces and allow for quick settling and concentration of the settleable solids, water flow patterns in production units are crucial for waste management. This is important because it allows for the fast capture of a significant portion of non-fragmented faeces, which significantly lowers the amount of dissolved organic waste.

1. **Waste management practices**

**WASTE UTILIZATION ROUTES**

A quick use of the residues is required by agricultural waste utilization technology, or they must be stored in a way that prevents deterioration or renders them unusable for processing into the intended end product. These wastes can be used for a variety of different things. They consist of:

* 1. **Fertilizer Application**

The amount of input energy needed at the farm level is directly impacted by the use of animal dung as fertilizer. Chemical fertilizer could use 19, 38, and 61% of the nitrogen, phosphate, and potassium that manure could provide. However, using large-scale confinement manures as fertilizer is associated with significant energy costs for transport and distribution, the need for storage facilities, odour issues, and the potential for groundwater contamination. According to reports, poultry dung has a significant phosphorus content that benefits crop development and productivity. When used in conjunction with mineral phosphorus fertilizer for agricultural usage, it is also effective. through enhancing the soil's physical condition, water-holding ability, and stability of the soil structure, manure improves soil fertility by enhancing the soil's nutrient retention capacity (or cation exchange capacity).

* 1. **Anaerobic Digestion**

Manure in particular can be used to make methane gas from agricultural waste. The gas works well for heating applications like operating a broiler, heating water, drying grains, etc. A two-step microbial fermentation is used in the anaerobic digestion of agricultural waste to create methane-rich gas. The volatile solids are initially broken down by acid-forming bacteria into organic acids, which are then used by methanogenic organisms to produce methane-rich gas. Methane makes up 50–70% of the normal gas generated, along with CO2, 25–45%, N2, 0.5–3%, H2, 1–10%, and traces of H2S. The gas has a heating value of 18–25 MJ/m3, on average. The high initial costs and the methane gas's explosive characteristics are two of the digestion system's main drawbacks. The benefits, however, considerably exceed the aforementioned drawbacks. The treatment and disposal of huge poultry, swine, and dairy waste are made possible by anaerobic digestion, which reduces the stench issue. The waste is stabilized, the digesting sludge is largely odourless, and the original waste still has some fertilizer value.

* 1. **Adsorbents in the Elimination of Heavy Metals**

Heavy metal pollution caused by the excessive environmental release as a result of industrialization and urbanization is a major issue on a global scale. Heavy metal ions including copper, cadmium, mercury, zinc, chromium, and lead ions do not break down into inert byproducts like organic contaminants, the majority of which are subject to biological degradation. Because heavy metal ions are hazardous to a wide variety of biological forms, their presence raises serious concerns. Adsorption has been widely utilized to remove heavy metals from waste streams as a result of studies on the treatment of effluent containing heavy metals, which have shown it to be a highly successful method. For the adsorption method used to treat effluents containing heavy metals, agricultural wastes have been shown to be a more affordable alternative. The removal of heavy metals from wastewater has been studied by a number of researchers using low-cost agricultural waste, such as sugarcane bagasse, rice husk, sawdust, coconut husk, oil palm shell, neem bark, etc.

* 1. **Pyrolysis**

A fraction of agricultural waste is heated in pyrolysis systems to temperatures between 400 and 600 °C without the presence of oxygen, vaporizing some of the material and leaving a char behind. This method for using agricultural wastes is regarded as being higher-tech. Hydrolysis and hydro-gasification are two more. They are employed in energy recovery as well as the production of compounds from agricultural waste. The manufacture of alcohols for use as fuel, ammonia for fertilizers, and glucose for food and feed are all of great relevance to the agricultural industry. Oil, char, and gas with a low heating value are produced during the pyrolysis of agricultural waste.

* 1. **Animal feed**

The issue with animal feed in the majority of developing nations is the scarcity of protein sources, despite significant attempts being undertaken to discover substitute supplements. Crop residues are low in protein, carbohydrate, and fat and abundant in fiber. As a result, it's possible that the conventional approach of raising livestock production—supplementing feed and pasture with grains and protein concentrate—will not be sufficient to fulfill future demands for meat protein. The use of protein and grains for the human diet will compete with the use of these ingredients for animal feed. Utilizing leftovers to feed farmed animals could solve these issues.

* 1. **Direct combustion**

One of the earliest methods of biomass conversion known to mankind is the straightforward act of burning agricultural waste for fuel. Agro-waste is completely burned when it "consists of the rapid chemical reaction (oxidation) of biomass and oxygen, the release of energy, and the simultaneous formation of the ultimate oxidation products of organic matter - CO2 and water." If oxidation proceeds at a sufficient rate, the energy released is typically in the form of thermal and radiant energy; the amount released depends on the biomass's enthalpy of combustion. The fabrication of these biomass wastes into a solid form is required if agricultural waste is to be used effectively during the thermal conversion process. Typically, it is burned for purposes such as heating, cooking, making charcoal, and producing steam for use in producing mechanical and electric power. The majority of biomass energy used today comes from burning, which still accounts for more than 95% of all procedures that can be employed to turn agricultural waste into energy or fuels (Isaac Oluseun and Olufemi Adebukola Adebiyi, 2020).

* 1. **Integrated agricultural waste management**

To reduce production input costs, integrated agricultural waste management systems adhere to the resource management principle. Here, two or more businesses are carefully combined so that one business' trash can be used as input by another. For instance, weeds and crop waste are used as livestock feed, animal manure is used to produce biogas, and biogas slurry is used to create vermicompost, which is then used for crop production (Management &Handbook, 2011).

Only 25 to 30 percent of the more than 620 million tonnes of agricultural waste produced in India each year is used as animal feed or for energy production. In the rice-wheat cropping system, the majority of Indian farmers burn leftovers to prepare the land for the timely seeding of the following crop. Low nutritional value and higher labour costs to clear the field are the causes. Burning crop residue releases noxious chemicals like CO2, CH4, N2O, H2S, O3, and smog, which contribute to air pollution. It has a significant negative impact on daily life and alters the physical, biological, and chemical aspects of soil by eradicating helpful soil microbes. Implementing efficient agricultural waste management will not only address the issue of air pollution but also improve crop inputs. In India, 25.94 million tonnes of chemical fertilizers (NPK) are used annually to produce 284.83 million tonnes of food grains. As a source of plant nutrients, agricultural waste contains 0.5% nitrogen, 0.2% phosphorus, and 1.5% potassium. According to Choudhary (2018), this can replace 6.5 million tonnes of chemical fertilizer or 25% of the entire amount needed for NPK. The economy of India is mostly based on agriculture and the rural sector. After the United States of America, India has the second-largest amount of arable land in the world with 159.7 million hectares (Plateau *et al*., 2018). Farmers focus primarily on crop production; nevertheless, a large variety of secondary products still fall under the category of agriculture thanks to various businesses including dairy, fishery, poultry, agro-forestry, goat, and sheep rearing that supplement their gross income. Adoption of Integrated agricultural waste management is a need of the hours.

**5.7.1) Objectives of Integrated Agricultural Waste Management (IAWM):** The intelligent application of science and technology to enhance established procedures for maximum gain with the least possible harm to natural resources;

* + Maximum employment and income generation throughout the year Minimum combination of two or more related businesses
	+ Minimum waste production
	+ Utilization of trash on or off-farm
	+ Reduce, reuse, and recycle as much garbage as possible
	+ Waste to a novel product, such as methane
	+ Long-term remedy
	+ Sustainable solution

**5.7.2) Factors to take into account when selecting businesses for integrated agricultural waste management include:**

* Features of the soil and climate in a particular location or locale, such as the presence of livestock in certain ecosystems, such as fisheries and duck farming in wet ecosystems and sheep and goats in dry ones, etc.
* The degree to which resources are currently being used
* The planned system's financial viability
* Local social practices for pre-calling

**5.7.3) Integration of Enterprises for Agricultural Waste Management:**

• The establishment of a biogas plant with dairy would produce high-quality manure for crop cultivation as well as fuel for cooking and lighting uses.

* Crop husbandry is the primary activity in agriculture that contributes to the most waste generation.
* Vermicomposting works well with biogas slurry.
* Poultry use waste grains as feed more effectively.
* Harvesting rainwater and collecting drainage water in a farm pond to irrigate crops
* To cut down on water usage and weed growth, crop residue is used as mulch.
* Agroforestry supplies wood for building purposes and shields crops from strong winds.
* Year-round revenue is generated with sustainable productivity when businesses integrate science.

**5.7.4) Advantages of Integrated Agricultural Waste Management:**

* Increase economic return per unit area per unit time;
* Enhance the health and fertility of the soil
* The recycling of business waste as energy inputs for another system led to increased profitability.
* Reduces trash accumulation (V. K. Patel *et al*., 2020)
* Greater production sustainability
* Addressing the energy crisis
* More effective use of family labour
* Reduce the use of dangerous substances.
* Resource Recycling
* An environment devoid of pollution

**5.7.5) Constraints of Integrated Agricultural Waste Management:**

I. Year-round shortages of labour and crop residual

II. Farmers may be discouraged from transitioning to multi-enterprise systems and reaping the rewards of resource integration due to high start-up expenses.

III. The nutritional value of crop leftovers is often low.

IV. Prolonged recycling can lead to nutritional losses.

V. Because it works quicker and is simpler to utilize, farmers prefer using chemical fertilizer instead of manure.

VI. FYM and vermicompost are not enough to provide the nutritional needs of crops (Choudhary, 2018).

1. **AGRICULTURAL WASTE MANAGEMENT SYSTEM (AWMS)**

For ecological agriculture and sustainable development, agricultural waste management (AWM) has recently attracted the attention of policymakers. The traditional method of managing agricultural waste has been to release it into the environment, either treated or not. To prevent the contamination of the air, water, and land resources, as well as the transfer of dangerous compounds, it is necessary to view wastes as potential resources rather than as undesirable and unwanted. Incentives and technologies that are used more effectively, a shift in mindset and attitudes, and improved methods of managing agricultural waste are all necessary for this. The quality of soil, water, and air can be significantly harmed by the incorrect management or non-treatment of organic wastes, notably manure produced by animals. Staggered wastes act as a breeding ground for insects and a vector for disease. The unchecked decomposition of organic wastes results in noxious fumes and ammonia volatilization, which causes acid rain. There are growing worries because livestock production is being intensified on a small amount of land.

Pathogens and antimicrobial substances in the manure; foul odours and air pollution from ammonia, methane, and nitrous oxide emissions; and water quality due to greater nitrogen and phosphorus loadings; the impact of potassium and phosphorus loading on soil quality.

An agricultural waste management system (AWMS) is a "planned system in which all necessary components are installed and managed to control and use byproducts of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, and animal resources" This kind of system, which is created using a comprehensive systems approach, is intended to handle all of the waste produced during agricultural output and put it to use all year long. The primary factor that affects how agricultural wastes are handled is their Total Solids (TS) concentration. The climate, the kind of animal, how much water the animal drinks, and the type of feed, for instance, all have an impact on the TS concentration in ejected dung. In the majority of systems, it is possible to predict or determine the consistency of the waste. Bedding or other solid waste can be added to waste to increase its TS concentration, water can be added to decrease it, and waste can be stabilized by being shielded from more water. The overall amount of trash that needs to be treated is impacted by the TS concentration, making it significant. Compared to solid waste management systems, liquid waste management systems are frequently simpler to automate and manage; nevertheless, the initial cost of the liquid handling equipment may be higher for solid waste systems.

AWMS has six fundamental operations. Production, collection, storage, processing, transmission, and usage fall under this category. The quantity and type of agricultural waste produced determine production. If enough waste is created to cause resource concerns, management of the waste is necessary. The type, consistency, volume, location, and timing of the waste created are all factors that go into a thorough examination of production. The act of collecting waste at its source or place of dumping is referred to as collection. The AWMS plan should specify the collection strategy, the locations of the collection points, the collection schedule, the labour requirements, any necessary structural facilities or equipment, the management and installation costs of the components, and how the collection will affect the consistency of the waste. The trash is temporarily contained or held in place by the storage function.

The control over the schedule and timing of system processes, such as the treatment and application or use of the waste, which could be impacted by the weather or interfered with by other operations, is provided by the storage facility of a waste management system. The waste management system should specify the length of time that the trash must be stored, the amount of storage that must be kept there, the kind of storage facility that must be used, its location, size, and installation costs, as well as its administration costs and the effect that storage will have on the consistency of the waste. Physical, biological, and chemical treatments are all methods used to lessen the potential for pollution or toxicity in waste. Treatment also increases the usefulness of the potential benefits. Pre-treatment activities such as analyzing the characteristics of the waste prior to treatment, figuring out the desired characteristics of the waste after treatment, choosing the kind of treatment facility to use, estimating its size and cost, choosing a location for it, and paying installation costs are all included. The management cost of the treatment process is also included. Transfer describes how waste is moved and transported from the collecting stage to the utilization stage as a solid, liquid, or slurry, depending on the total solids concentration. Utilization is the process of putting garbage to good use, which includes recycling recyclable waste and reintroduction non-recyclable waste into the environment.

**6.1) The ‘3R’Approach to AWM**

By lowering the amount of garbage produced, reusing the waste products with straightforward treatments, and recycling the waste by using it as a resource to create the same or modified products, the notion of minimizing waste minimizes the quantity and negative impacts of waste formation. This is commonly known as the "3R" method. Some waste items are recyclable because they can be used as raw materials to create the same product or other ones. The harvesting of new goods that are similar to or identical to the wastes is compensated by their repeated reuse. This prevents the exploitation of new resources and lowers the production of waste. Overall, the 3Rs individually or collectively prevent the exploitation of new resources, increase the value of the resources that have already been mined, and most significantly, decrease waste production and its negative repercussions. The three R's of waste reduction—reduce, reuse, and recycle—seek to achieve effective waste minimization through the following practices:

• Careful usage of objects to minimize waste production;

• Repeated use of items or parts of items that still have usable components.

• Using waste as a resource in and of itself.

**6.2) The ‘3R’ Hierarchy in AWM**

Reduce, which relates to the "3Rs" — i.e., reduce, reuse, and recycle — which define waste management solutions according to their desirability, claims that waste minimization efficiency can be better attained by implementing the 3Rs in a hierarchical order. The 3Rs are designed to be a hierarchy, in terms of importance. Over the past ten years, the waste hierarchy has assumed many different shapes, but the fundamental idea has remained the cornerstone of the majority of waste minimization techniques. The waste hierarchy's goal is to get the most out of items in terms of practical advantages while producing the least amount of garbage possible. The 3R strategy is typically expressed as a pyramid hierarchy, where each technique's improvement in environmental benefits is positioned from bottom to top.

1. **Technologies related to sustainable agriculture: -**

A farming technique known as sustainable agriculture takes into account the long-term health of the community, the environment, and the land. By safeguarding natural resources for future generations, it is essential to meet the world's expanding food demand. Sustainable agriculture has garnered a lot of attention lately as people around the world have grown more conscious of the value of environmental preservation. Food, fiber, or other plant or animal products are produced through sustainable agriculture while protecting the environment, general health, local communities, and animal welfare. Through these methods, natural resources for future generations, including soil, water, and air, are preserved and renewed.

Here are some methods in which technology can help in sustainable agriculture: -

**7.1.) Precision farming**: Monitoring and crop performance optimization use sensors, GPS mapping, and data analytics. Farmers may decrease their usage of pesticides and fertilizer, manage their water resources better, and boost productivity by employing precision farming techniques. In India, the notion of precision farming is still relatively new, and the rate of adoption varies by State depending on a number of variables like the accessibility of technology, agricultural methods, and governmental policy.

**7.2.) Agroforestry:** Agroforestry is a form of integrated land-use management that integrates trees, shrubs, and cattle with crops and other livestock to provide a more profitable and sustainable farming system. Soil protection, biodiversity preservation, and carbon sequestration are just a few advantages that this strategy can offer.

**7.3.) Vertical Farming:** In most cases, it cultivates crops in controlled environments while stacking the layers. An interesting alternative for urban agriculture in India is vertical farming since it has the potential to boost local food production while reducing water use and maximizing resource efficiency. In addition to raising earnings and cutting transportation costs, this approach can lessen the demand for pesticides and herbicides.

**7.4.) Hydroponics:** As a sustainable farming approach that enables year-round cultivation, effective use of water and nutrients, and a decreased reliance on conventional agricultural techniques, hydroponics is gaining popularity in a number of Indian states. Plants are grown hydroponically, or without soil, in nutrient-rich water. This strategy can decrease water use, boost yields, and enable agricultural production all year long. It has the potential to fundamentally alter how food crops are raised in India, particularly in crowded metropolitan areas with limited resources and space.

**7.5.) Robotics and Automation-based:** Agriculture is swiftly evolving into a dynamic high-tech sector that attracts new employees, businesses, and investors. Technology is evolving quickly, improving not only farmers' capacity for production but also the state of robotics and automation as we know it.

This phenomenon's core requirement is for much higher production yields. According to UN projections, there will be 9.7 billion people on the planet in 2050, up from 7.3 billion at present. The demand for food will increase significantly, and farmers will be under tremendous pressure to meet it.

Farmers' output yields are rising in a number of different ways thanks to agricultural robots. Robotic arms, autonomous tractors, and drones are just a few of the inventive applications for technology currently being used (<https://www.automate.org/blogs/robotics-in-agriculture-types-and-applications> )

 **8.) CASE STUDY**

**8.1.) Typical Options for Managing Poultry Waste**

Here, a typical waste management system that illustrates the use of each AWMS component function is described using an example of a poultry farm. A comprehensive analysis of the many waste management strategies for the production of chicken.

**8.2.) Production:** Manure and dead birds are among the wastes associated with poultry operations. Litter, wash-flush water, and waste feed might also be considered waste depending on the system.

**8.3.) Collection:** Manure from poultry operations is collected and let to build up on the floor, where it is combined with the litter. Between flocks, the dung litter pack typically forms a "cake" that is removed. The litter pack can be periodically removed to stop the spread of disease among flocks. In layer houses, the manure that falls below the cage is either gathered in large piles or frequently scraped using belt scrapers set up directly beneath the cages or a shallow pit beneath the cages for flushing scraping.

**8.4.) Storage:** Litter from poultry operations is kept either outside or on the ground inside the housing facility. It can be taken out and applied to the ground right away after being delivered to the field. It is possible to compact the litter in a pile and keep it out in the open for a brief period of time in some locations, but it is usually preferable to cover the dung with plastic or another waterproof cover until the litter may be used. However, if it needs to be kept for an extended period of time, the litter should be kept in a structure with a roof. The manure from layer operations can be stored in a covered facility if it is kept sufficiently dry. It should be kept in an earthen storage pond or a structural tank if it is moist.

**8.5.) Treatment:** You can compost chicken manure. This helps to destroy disease-causing organisms and stabilizes the litter into a largely odourless mass so that it can be utilized as bedding or as supplemental feed for cattle. Additionally, the litter can be dried and used right away as fuel. An aerobic digester may be used to manufacture methane gas from liquid manure.

**8.6.) Waste transfer:** A particular transfer method may be chosen depending on the waste's overall solid content. Waste that is liquid can be moved using pipes, gutters, or tank wagons, whereas litter that has dried up can be scraped, loaded, carted as a solid, and moved using vehicles.

**8.7.) Utilization:** Because poultry litter has a high nutritional value, it can be sold or applied to agricultural land for use as fertilizer. Furthermore, poultry manure can be used as a feed additive for animals as well as for the generation of methane gas, buried directly as fuel, used again as bedding, and more.

**Conclusion**

Agriculture is linked to the generation of significant amounts of organic waste, which, if improperly managed, can have a negative impact on both human health and environmental quality. These wastes are nutrient-rich and biodegradable, which are crucial for improving soil fertility and crop growth. Therefore, management activities comprising the collection, transfer, storage, processing, and use of agricultural wastes in organic farming may allow farmers to take advantage of the wastes' potential as bio-fertilizers for the growth of agricultural crops.

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