WASTE MANAGEMENT REPORT

Critically assess the relative advantages and disadvantages of organic wastes as environmentally sustainable alternatives to conventional fertilizers when applied directly to land used for food production.

Uttam Kumar Tamboli Waste Management Report Environmental Management

Contents

Introduction:

As per the (European Commission, 2020), Farming, forests, towns, and animal husbandry, all continuously produce organic waste. In the coming decades, it is anticipated that the amount produced will increase to 3.4 billion tonnes worldwide. The following graph (fig-1) presented by (European Environment Agency, 2020) also quantitatively signifies the issue.

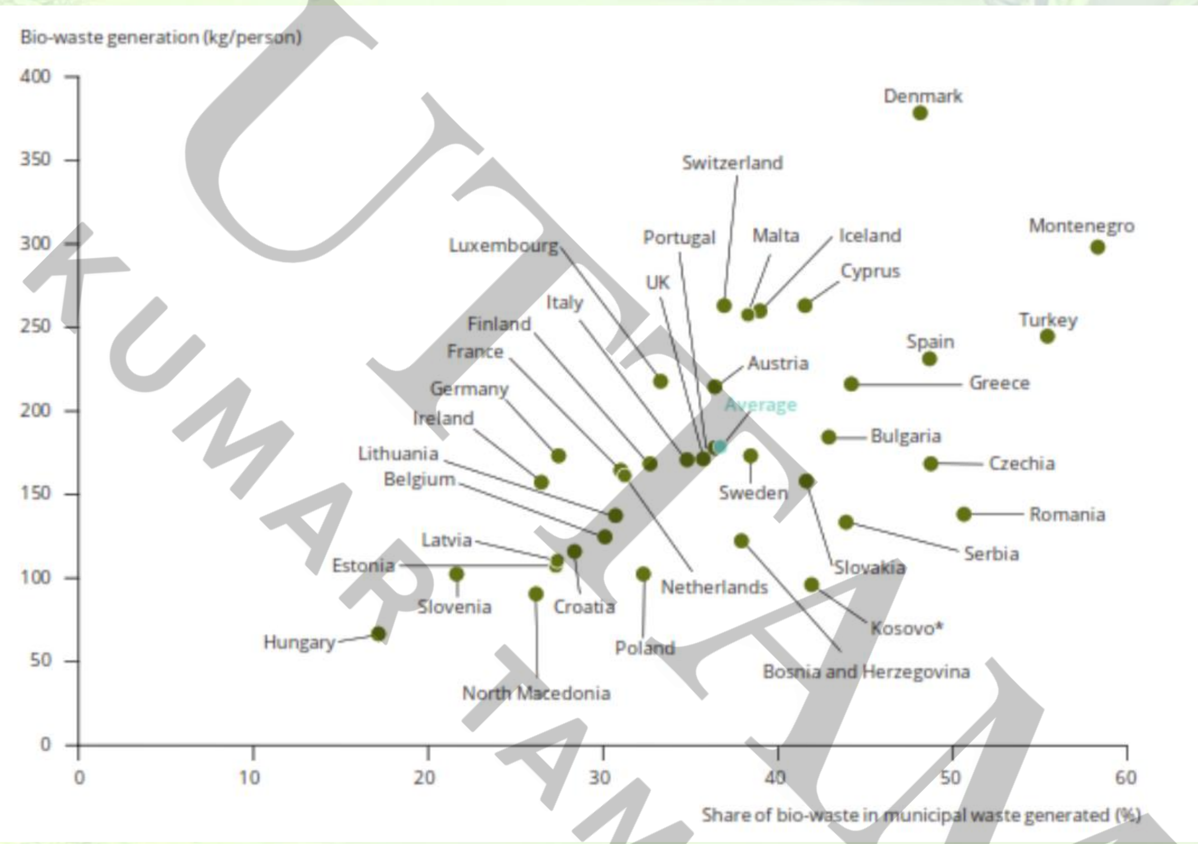

Fig-1: Municipal organic waste generation per person and share by country. (European Environment Agency, 2020)

Another important aspect to consider is the rising need for food production to feed the growing population of the world. Given that 50% of the world's population would go hungry without fertilizer, there is an enormous need for it due to the world's rising population. Up until now, to guarantee food security, this has meant using fertilizers heavily and increasing the output of NPK, the primary nutrient in fertilizers.

However, present-day fertilizers are one of the biggest global polluters and a major concern to the environment. Hence, it is evident that ignorance of this situation can result in major environmental issues both locally and globally. These issues include greenhouse gas emissions, soil and local water source contamination, and the eutrophication of freshwater reserves and riverbeds due to overabundance of nitrogen.

Nevertheless, one good option to reduce this enormous amount of waste, emissions and hazardous impacts is to transform organic waste into organic fertilizer and use it in food production. This will not only help to divert the waste but also help in the reduction of costs of importing chemical fertilizers from other countries. However, no matter how ideal this strategy may sound, there are both advantages and disadvantages to this strategy which will be discussed in this report.

Brief Overview of conventional Fertilizer and Organic waste

The paper (Ayilara et al., 2020) mentioned that any material, whether synthetic or natural, that is put in the soil to offer certain nutrients essential for plant growth is called fertilizer. The main objective is to maximize agricultural output and financial returns. Based on how they are produced, fertilizers can be classified as either organic or inorganic. Fertilizers classified as single, simple, or straight include only one of the primary ingredients. Fertilizers classified as mixed, or compound ones are those that include two or more of the major and trace elements. Phosphorus, potassium, and nitrogen (NPK) are the main nutrients that plants need.

As per (Encyclopedia.com, 2024), any material that is biodegradable and comes from living beings, such as plants and animals, is referred to as organic waste. Food scraps, yard garbage, agricultural residues, and animal manure are just a few examples of the diverse items that fall under this category.

Prominent Pollutants Discussed:

It is important to note that this topic of waste management is unimaginably vast which makes covering all pollutants and their aspects extremely difficult. Hence, the main pollutants discussed in this report are nitrogen and phosphorus.

For Nitrogen, (Kechasov et al., 2021) mentioned that around 125 billion tons of nitrogen (N) fertilizer, or animal manure, are produced worldwide each year, yet 70% of this fertilizer remains on pastures and is not harvestable. A similar percentage was also pointed out by (Xia and Yan, 2023) and (Martínez-Dalmau, Berbel, and Ordóñez-Fernández, 2021) in the form of unutilized Nitrogen by plants.

(Martínez-Dalmau, Berbel, and Ordóñez-Fernández, 2021) also stressed the point that by 2050, the amount of nitrogen pollution is predicted to have increased by 150% from 2010 levels, with 60% of this growth coming from the agriculture sector. The nature of non-point-source pollution from millions of farms and the obstacles to putting pollution-reduction measures in place, like a lack of funding and farmers' limited knowledge of nitrogen management, make mitigating nitrogen pollution from global croplands a formidable task. The distribution dynamics can be understood from fig-2 below.

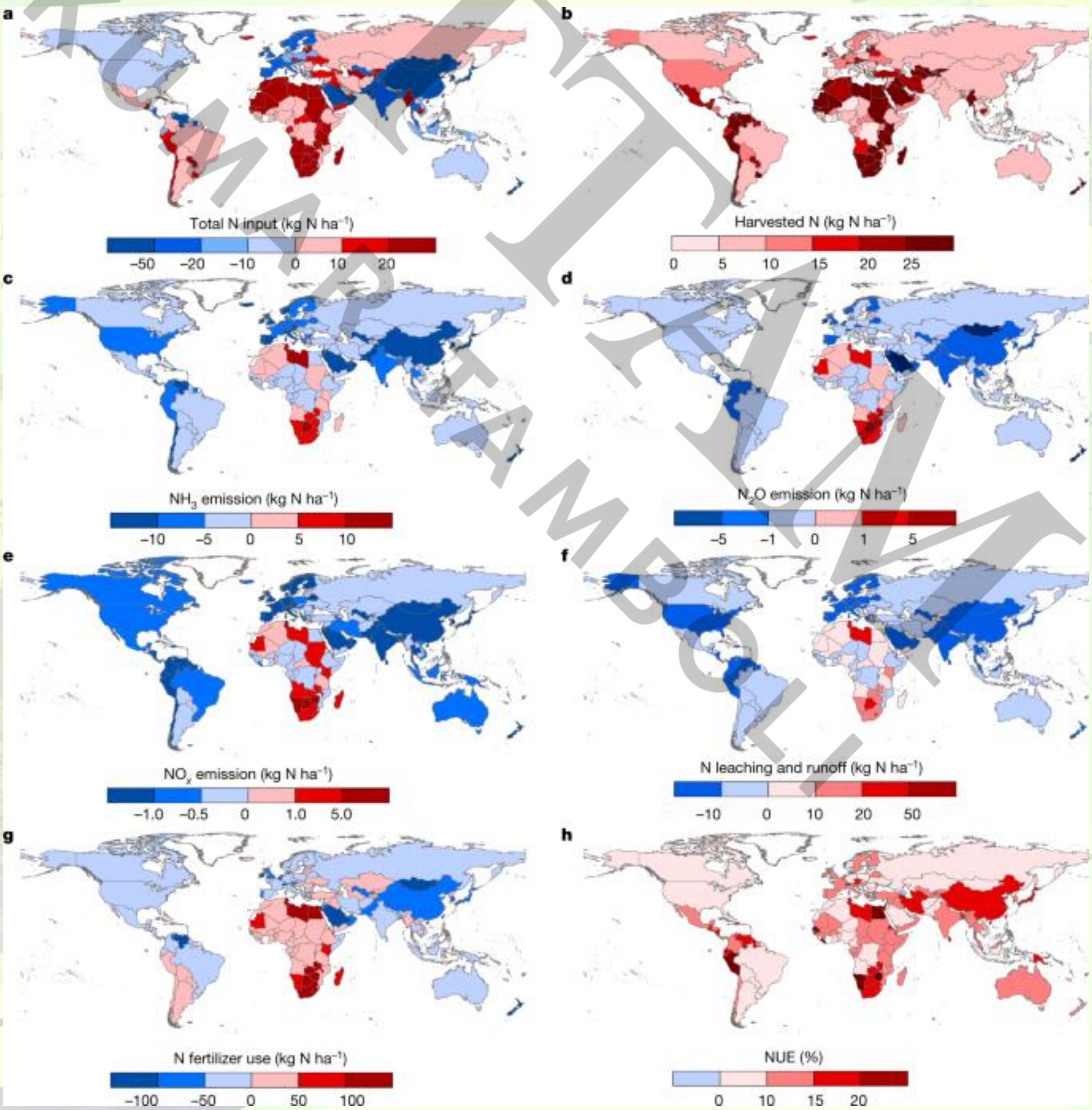

Fig-2: Nitrogen Production, Consumption and Emission on a global scale. (Gu et al., 2023)

In terms of phosphorus, (Minnesota Pollution Control Agency, 2023) has discussed that water bodies that contain too much phosphorus may experience accelerated eutrophication, a process that reduces oxygen levels and creates "dead zones" in which aquatic life cannot thrive. The authors emphasized this problem by mentioning that 25% of Minnesota's lakes have excessive phosphorus levels, which harms aquatic ecosystems and enjoyment. With regards to risk to human health, (U.S. Environmental Protection Agency, 2023) discussed in their paper that exposure to toxins can result in more serious health concerns, skin irritations, and respiratory problems. Additionally, as these algal blooms decompose, more phosphorus is released into the water, intensifying the polluting cycle.

Advantages of Organic waste as fertilizer:

Pollution Prevention through Composting:

The authors of the paper (Ayilara et al., 2020) have mentioned that one of the well-known methods of converting organic waste into fertilizer is composting. It can be defined as the controlled transformation of organic waste and degradable materials into stable products with the help of microbes in the presence of oxygen. Compared to the landfilling method of waste disposal, which could endanger underground water quality, the composting process helps prevent polluting of subterranean water. Chemicals like Persistent organic pollutants (POPs) and Endocrine Disruptors (EDRs) that are left in the soil after composting are absorbed by the helpful microorganisms. Among these are nonylphenols (NP) and polycyclic aromatic hydrocarbons (PAHs), such as fluoranthene, benzo(b)fluoranthene, and benzo(a)pyrene. Because POPs and EDRs have a detrimental impact on human health, reducing their concentration through composting is a significant feature of the process.

Increase in size and weight of the produce:

The authors of the paper (Kechasov et al., 2021) discussed in their paper the research conducted by the Norwegian Institute of Bioeconomy explored using liquid biogas by-products of pig manure digestion as fertilizer in hydroponic tomato production. They mentioned that when compared to high-mineral cultivation, the tomatoes produced with liquid fertilizer based on organic waste had slower growth rates but larger average fruit sizes. This had no discernible effect on the overall production.

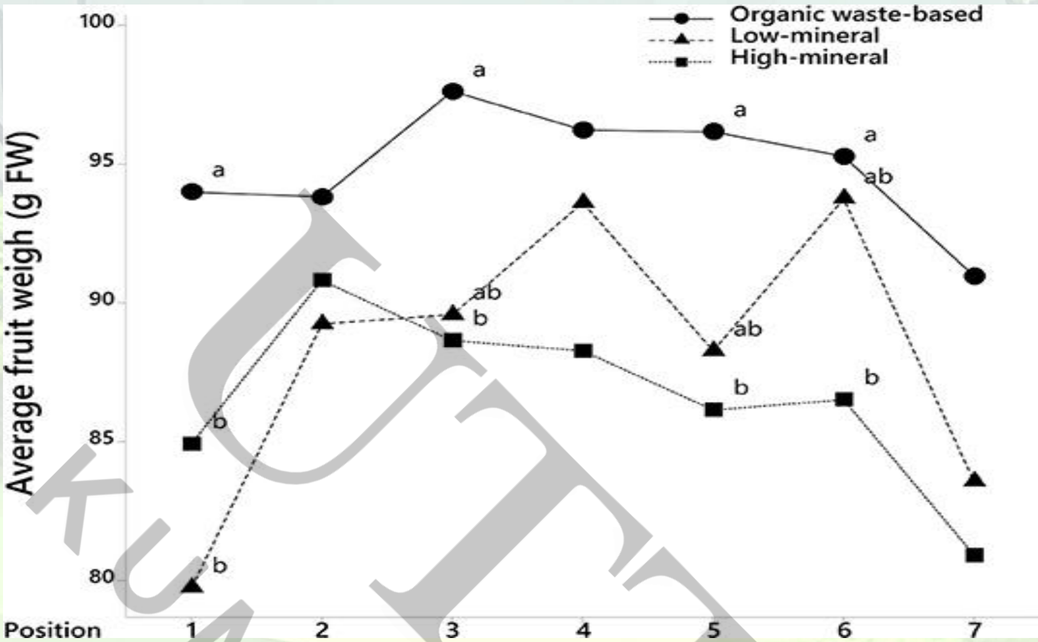

Fig-3: Graph showing the weight distribution of tomatoes produced using different fertilizers. (Kechasov et al., 2021)

Apart from this, as per the fig-3 , it is evident that the tomatoes produced using organic waste-based fertilizer had the highest weight compared to the low and high mineral fertilizer treatments. This indicates freshness and high-quality production.

Phosphate Recovery:

In terms of Phosphate, (European Environment Agency, 2020) discussed that since phosphorus is a non-renewable resource, recovering it from biowaste is becoming more and more important. Since phosphorus used in fertilizers eventually ends up in solid bio-wastes like food waste, animal manures, sewage sludges, and crop biomass, recovering phosphorus from bio-waste efficiently could lessen reliance on non-renewable resources as well as phosphorus run-off and eutrophication of water. Hence use of organic waste-based fertilizer will ensure phosphorus recycling and reduction in natural resource contamination.

Integrated Farming:

As per (Kurniawati *et al.*, 2023), in addition to serving as a future replacement for mineral fertilizer, Organic waste-based fertilizer can also be applied to integrated farming since it can be used to close the loop in agricultural farming at the regional level under various pedoclimate conditions. This may also help ensure a circular economy. Moreover, the optimization of energy resources could be achieved by the integration of industrial waste, crop production, and animal husbandry. The authors also presented an economic statistic that an integrated farming system can raise family income for rural communities by up to 41.55% while also increasing agricultural output and reducing waste.

Climate Change Mitigation:

Organic waste-based fertilizers can enhance the amount of soil organic matter (SOM) and so reduce the effects of climate change. From the perspective of soil health and fertility, increase in soil organic matter/soil C content are very advantageous and contribute to a reduction in atmospheric CO2 concentration. Moreover, increasing soil organic carbon (SOC) is thought to be a possible means of sequestering soil carbon as well as enhancing crop output and quality. The authors reported statistics where vegetable crop yields were consistently higher than or comparable to mineral fertilization when SOC concentrations in compost-amended treatments ranged from 1.2 to 1.4%. (Kurniawati *et al.*, 2023)

Disadvantages & Challenges of Organic waste as fertilizer:

Slow production time:

Considering executing composting directly on the farm field, it's important to note that among the wastes generated on farms, a significant portion consists of agricultural wastes such as leaves, plant remains, and dead plants. Some of them have low nutrient content and resistant chemicals, which makes composting them challenging. To be specific, plant wastes with high levels of cutin, polyphenol, suberin, and lignin take longer to decompose in a compost pile. When such waste is added to a compost pile, other materials' rate of decomposition is slowed down. (Ayilara et al., 2020).

Lower Yield and nutrient levels:

Apart from the advantages, the tomato production research done by (Kechasov et al., 2021) pointed out in their research that plants grown using fertilizer derived from organic waste had lower levels of phosphorous (P) and sulfur (S) and higher levels of starch and soluble carbohydrates in their leaves. When compared to plants grown in high-mineral solutions, the fruit quality of the plants produced in low-mineral or organic waste-based media was noticeably lower. They also pointed out that tomato plants grown organically (e.g., in organic waste or manure) typically yield yields that are comparable to or slightly lower than those of plants grown with conventional fertilizer. Hence, to enhance fruit quality and yield growth, more nutrient supply adjustment is needed.

High Salinity levels:

Another important result shared by (Kechasov et al., 2021) was salinity issues. They can also arise from using organic waste as fertilizer, particularly in closed irrigation systems. Salt toxicity may harm the uptake of nutrients, particularly Ca^{2+} and K^{+} ions, which could lower the commercial quality and yield of tomatoes as well as severely impact the growth and photosynthetic efficiency of tomato plants.

Odor Issues:

(Kurniawati *et al.*, 2023) pointed out that in the absence of appropriate analysis of each batch of production, no biochemical activities are involved. This makes organic waste-based fertilizers less stable as compared to mineral-based fertilizers. Furthermore, they can create air pollution since they retain their smell even after processing, particularly in cases where improper storage leads to contamination. Ammonia gas is the primary cause of the odour, and it can also lead to element loss and lower the quality of compost. This also becomes a hindrance in acceptance by farmers to be used for their cultivation.

Comparative Analysis:

Raw material	Technology	Main finding

Food wastes	Hydrolysis	Produced solid residue showed high quality in NPK and low heavy metals, suitable for direct biofertilizer conversion.
Meat and bone meal (MBM)	Called tankage was obtained from Baker Commodities Inc.	Effective nitrogen source for sweet corn in the tropics; split application reduces groundwater pollution risks.
Poultry litter biochar	Not mention	Enhances plant growth, yield, nutrient uptake, and soil fertility in sandy soils.
Struvite	Crystallization	Valued as fertilizer for high potassium oxide content (>20%) and low heavy metal levels.
Biowastes (olive mill wastewater sludge, poultry manure, and green waste)	Composting	Application of biowaste compost significantly increases soil organic matter and carbon in Mediterranean soils.
Energy crops (e.g., silage maize and silage winter wheat) and animal wastes (e.g., poultry manure, cattle and swine slurry)	Digestion	Perform comparably to mineral fertilizers, viable as substitutes in intensive cropping systems.

Table-1 : Compilation of Organic Fertilizers prepared from different types of waste and their findings. (Kurniawati *et al.*, 2023)

A remarkable comparison of performance was made by (Kurniawati *et al.*, 2023) of the fertilizers prepared from organic waste obtained from different sources (table-1) . This can be significant for the adoption of waste-to-fertilizer conversion programs in different sectors and industries altogether. This can be both residential and commercial outlets can be targeted for waste collection and transformation. Moreover, different soils have different nutritional needs, adoption of fertilizers from multiple sources of organic waste can be used to get the required proportion of nutrients thereby getting closer to the desired performance as compared to conventional fertilizers.

Type of Fertilizer	Benefits	Limitations
Chemical Fertilizer	Immediate nutrient availability, efficient placement, cost-effective, high nutrient density for minimal use.	Can cause nutrient oversupply leading to plant damage, soil degradation, environmental pollution, and health risks from continuous use.
Biofertilizer	Provides balanced nutrients, enhances soil biological activity and structure, supports nutrient cycling, offers sustainable ecological benefits.	Lower nutrient content requiring higher volumes, variable composition, potential nutrient deficiencies, odor issues, longer production time.

Table-2: Comparison table derived from data in (Chew et al., 2019) who gave a commendable comparison of the benefits and limitations of chemical fertilizers and biofertilizers which is of direct relevance to this report and is self-explanatory.

Economic Situation:

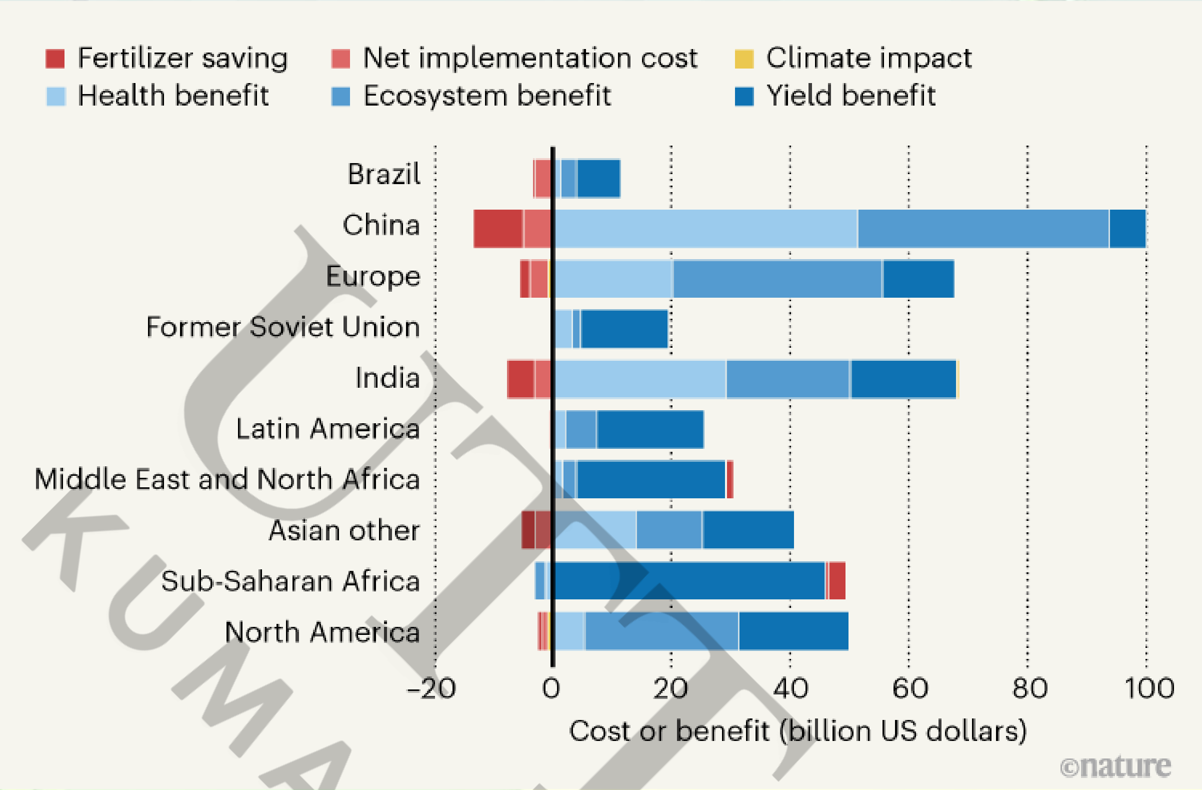

Fig-3: Economic distribution with respect to different countries on various factors. (Xia and Yan, 2023)

As per fig-3, (Xia and Yan, 2023) mentioned that in many countries, the biggest obstacle to the general adoption of nitrogen management is the expense of implementation—farmers must commit money, time, and labour before they can completely apply such approaches to their own land. The benefits to global society of lowering agricultural nitrogen pollution are greater than fifteen times the costs of implementation when one considers increased crop yields, a decrease in early death from respiratory illnesses brought on by air pollution, and the ongoing services that clean ecosystems.

However, solving this problem is not easy because changing farmers' nitrogen management methods is extremely difficult, particularly for smallholders who frequently work part-time in non-agricultural industries (whose revenue can easily surpass that of agriculture). This was also emphasized by (Gu *et al.*, 2023) in terms of the low agricultural income ratio of small stakeholders. Thus, strong legislative interventions are required to incentivize farmers to implement cutting-edge nitrogen-management technologies.

Regulations

(Mendes et al., 2023) explained that the Landfill Directive (Directive 1999/31/EC) (Buratti et al. 2015) established targets for a reduction in the volume of bio-waste landfilled and required the collection of the gases created therein, marking the first steps towards sustainable bio-waste management. After nine years, the Waste Framework Directive 2008/98/EC (which did not specifically address bio-waste) established the fundamental principles (polluter pays principle) of the European legislative framework. These principles can be found in various waste management schemes, such as "pay-as-you-throw", "pay-as-you-own", and "pay-as-you-differentiate". These schemes have been studied and suggested ways to encourage household sorting. Other concepts include producer extended responsibility and waste hierarchy.

Regarding the management of biowaste, Directive 2018/851 emphasized the necessity for selective biowaste collection and said that Member States must guarantee this by December 31, 2023, by separating biowaste from other types of waste. Hence, this law essentially mandated the installation of a brown-bin system. There is still much work to be done in terms of sustainable bio-waste management, even though the Waste Framework Directive (and amending Directive 2018/851) are acknowledged as having played a major role in the notable advancements in waste management—and specifically, bio-waste management—that have been recognized in Europe.

The responsibility for choosing how Member States should handle trash collection and treatment is delegated to the European Directives, while regions and municipalities oversee creating and overseeing the execution of their waste management policies. Therefore, public organizations in the European Union are required to enact legislation and implement public policies targeted at transitioning to more sustainable waste-management systems within the legislative framework provided by these Directives.

Recommendations and Best Practices

(Gu *et al.*, 2023) emphasized in their research that policies can facilitate the implementation of organic waste to fertilizer transforming in several ways, including by strengthening non-market social regulating factors, facilitating smallholder adoption by providing access to financial capital and extension services for knowledge transfer, or restoring price signals through the internalization of pollution costs.

As per the (European Commission, 2020), it is evident that regulating industrial waste management and ensuring the proper handling and disposal of organic waste is becoming harder. Hence, the European Union (EU) and its citizens have devised a European Green Deal to address this environmental strain on Europe's agricultural resources. The Commission's plan to carry out the Sustainable Development Goals and the 2030 Agenda of the United Nations includes the Green Deal as a key component.

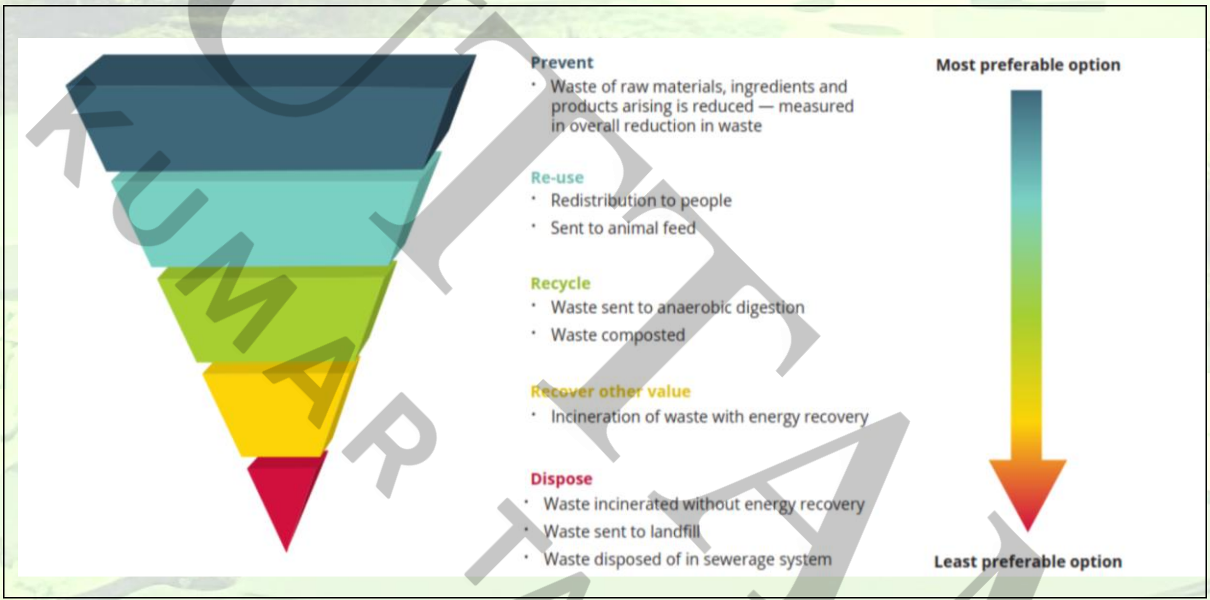

Fig-4 : Food waste Hierarchy and Biowaste Generation & Treatment Capacity of EU countries. (European Environment Agency, 2020)

Fig 4 shows that countries from the EU have more than sufficient treatment capacity. Hence if the food waste hierarchy is followed religiously along with proper treatment of organic waste, then it will be easier to ensure source reduction of organic waste, better organization of the waste flow, good quality output, and minimization of cross-contamination of organic waste.

(Kechasov et al., 2021) mentioned in their paper that liquid organic waste from animals can be utilized as fertilizer for closed soilless cultivation of greenhouse crops in places where both livestock and greenhouse agriculture are practised. Most importantly, the lower requirement of disinfection for soilless agriculture and close to zero risk of eliminating the rhizosphere's inherent microbial richness make the use case favourable for liquid organic waste.

To solve the economic problem related to nitrogen reduction strategies, (Xia and Yan, 2023) introduced the concept of the "nitrogen credit system" which is about encouraging communities that gain from reduced nitrogen pollution and more food availability to contribute money to support farmers that use cutting-edge nitrogen management techniques.

The authors mentioned that securing the funding budget is essential to putting a nitrogen credit system into place. They suggested that the money could come from levies on agricultural products or activities that cause pollution, or it could come from taxes on food consumers or businesses that use farming as a commercial source of food. In low-income sub-Saharan African nations, where agricultural nitrogen pollution is not the cause of food shortages but rather a lack of nitrogen fertilizers, additional funding should come from the generous donations of nearby industrial businesses and other partners. A nitrogen credit board should be established by law to oversee money collection and distribute subsidies to farmers. They ought to be able to impose penalties on farmers who have received funding even when their nitrogen management is deficient.

(Martínez-Dalmau, Berbel, and Ordóñez-Fernández, 2021) addressed the "4R Nutrient Management" framework for sustainable fertilizer management that was created by the International Plant Nutrition Institute, the International Fertilizer Industry Association, the Fertilizer Institute, and the Canadian Fertilizer Institute. This framework, which is being used globally, combines best practices for fertilization, such as applying the appropriate amount of nutrients at the appropriate time, location, and pace, to increase sustainability.

Conclusion

The switch to organic waste as fertilizer is a viable way to lessen agriculture's environmental impact as the world's population continues to rise and demands on agricultural systems increase. Significant advantages like pollution avoidance, nutrient recycling, and support for circular economies—all of which are in line with the UN Sustainable Development Goals—have been brought to light by the rigorous study. However, it is impossible to ignore the drawbacks, which include possible nutritional imbalances, delayed production periods, and problems with salinity and odours.

In conclusion, even though the move to fertilizers based on organic waste has its challenges, it is a crucial advancement for sustainable agriculture. To maximize these practices, stakeholders from many agricultural sectors must work together with the assistance of well-informed legislation and ongoing research. To achieve long-term sustainability in food production, localized, context-specific techniques that mitigate the drawbacks of organic waste fertilizers must be developed. Adopting strict management procedures, boosting government support through subsidies and regulations, and educating farmers and the public about the advantages of organic fertilizer could all help to accelerate the adoption of this environmentally benign approach. Thus, agriculture could be drastically changed to become more sustainable for coming generations if it began to view organic waste as a resource rather than a problem that needed to be disposed of.

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