

## STRATEGIES FOR REDUCING FOOD WASTE IN AGRICULTURE

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### Abstract

Food waste in agriculture poses a critical global challenge, contributing significantly to environmental degradation, resource inefficiency, and food insecurity. An estimated one-third of all food produced globally is lost or wasted, with a substantial portion occurring at the production and post-harvest levels due to technological, logistical, and behavioral inefficiencies. This study adopts a multi-dimensional approach to explore strategies for reducing food waste across the agricultural supply chain. Methodologically, it integrates quantitative data analysis with visualizations and comparative assessments, focusing on harvesting techniques, post-harvest handling, cold chain logistics, market accessibility, and sustainable farming practices. Advanced metrics are employed to evaluate usable yield efficiency and to simulate the environmental and economic impacts of waste mitigation strategies. The results reveal that improved harvesting methods and precision agriculture significantly reduce post-harvest losses, especially in perishable commodities. Cold chain innovations and digital platforms enhance storage efficiency and align production with demand, minimizing overproduction. Additionally, the integration of biotechnology and agroecological practices increases shelf life and reduces spoilage. Visual analyses highlight regional disparities, showing that food loss is highest in regions lacking infrastructure and policy support, while hybrid strategies demonstrate up to 40% improvement in waste reduction performance. The study concludes that reducing food waste requires a systemic and coordinated response involving farmers, policymakers, consumers, and technological stakeholders. Interventions must be tailored to regional contexts, supported by strong governance, and driven by innovation and education. A shift toward sustainable, data-driven agricultural systems can significantly mitigate food loss, improve food security, and support climate goals. The findings reinforce the importance of integrating technological solutions with circular economy principles to build a resilient and equitable food system.

**Keywords:** Food Waste, Agriculture, Post-Harvest Loss, Sustainable Farming, Food Supply Chain, Agricultural Policies, Food Security, Food Loss Reduction, Environmental Sustainability.

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### 1. INTRODUCTION

Farming to agriculture contributes a major percentage of the total global food waste that directs to environmental effects like greenhouse gas emissions and wastage of resources. United Nations Food and Agriculture Organization (FAO) estimates that about one in every three food produced in the whole world is wasted with much of this waste being done at production and post-harvest levels. The solution is complicated by harvesting, storage, and transportation inefficiency, which are the major factors that lead to food waste prior to reaching the economy. This article is aimed at discussing feasible approaches in this direction in terms of technology, sustainability and policy-based solutions that could be implemented at different points of the agricultural-supply chain in the quest to reduce food waste in agriculture. Food waste can be described as the deliberate overthrow or discarding of edible and safe food by an individual or organization at retail level and consumer level. Conversely, food loss is upstream with the main causes at the stage of production, post-harvest handling, and processing where the loss is often related to spoilage, improper storage, and market access (Garrone et al., 2014). The two terms bring out the high issue of food not reaching the consumer even though it has been produced which presents challenges to global food security and sustainability.

The amount of food waste is outrageous since the amount of food reportedly wasted annually is estimated at 1.3 billion tons which is one-third of total food produced as human food (FAO, 2011). The problem of food loss is also critical in agriculture, where about 40 percent of the fruits and vegetables are thrown away before they reach the consumers due to many reasons, including pests and diseases as well as poor harvesting methods (Kumar

et al., 2017). This problem does not exist only in developing nations; even in high-income areas, significant amounts of food are lost on the production stage, which shows the inefficiency found in the supply chain. Food wastage also adds to greenhouse gases because methane, which is a greenhouse gas, is released once predisposed organic waste decays in the landfills. According to the FAO (2013), it is estimated that 3.3 billion tons worth of greenhouse gas amounts to food waste per year. Also, the process of food production is resource-demanding itself, it needs extensive quantities of water and land. An example in point is that the global footprint of food being wasted is estimated at about 250 km<sup>3</sup> of water (Mekonnen & Hoekstra, 2011) which worsens water scarcity concerns in most parts of the world. According to the FAO (2014), the price of food waste in the world is about trillion 1 every year. This figure includes direct losses to producers and indirect cost resulting in environmental degradation, health of population and social well being. In the less developed world the economy of which is based largely on agriculture, food loss reduces the incomes of farmers, and worsens the incidence of poverty. Moreover, food loss compromises the overall performance of the food systems increasing the prices and affecting food availability among vulnerable groups. The agricultural sector also has its issues associated with perceptions of the consumers and market aspects that promotes food loss. People are too beauty-focused and are inclined to reject products that are still edible but fail to correspond with some view effects (Aschemann-Witzel & Zielke, 2017). This is the case with increased level of food being lost on harvesting and post harvesting. Besides this, the problem is further compounded by the barrier to market in case of smallholder farmers who may have no infrastructure and networks to

reach the consumers and the result would be excess production that could not be marketed.

The reduction of food waste and loss in the agricultural sector will require a complex strategy. Such initiatives to raise sustainable agricultural practices like enhancing crop resistance and post-harvesting management methods among others, can considerably diminish the spillage of food (Lundqvist et al., 2008). Also, the collaboration between stakeholders throughout the supply chain: producers, retailers, and consumers, has some potential to increase the supply chain transparency and boost its efficiency, and eventually, minimize food waste. Educational programs about food waste are also essential in order to evolve perceptions and habits regarding food waste and promote conscious consumption. Since food produced is going to waste with large percentages, there is need to employ specific measures to reduce the losses at any level of the supply system. Food waste in agriculture is a serious worldwide issue, and its consequences are massive in terms of food security, environmental sustainability, and economical stability. To be able to reduce the negative effect of food waste in this industry, it is necessary to understand which factors mostly contribute to the issue. Efficiency aspects of food waste in the agricultural industry are inadequacies of harvesting methods, harvest-related pick and handling, transportation and supply chain problems, and market factors.

The degree of inefficiency in harvesting techniques is also one of the major factors that increases food waste in the agricultural sector. Conventional harvesting practices usually lead to huge quantities of agricultural products being abandoned in the farm because of time, personnel and the lack of adequate technology. As an example, the crops like fruits and vegetables are very perishable in nature and any delay in harvesting may cause their deterioration and

loss. It has been shown that during harvesting, about 20 percent of fruits and vegetables are wasted because of poor tools and procedures (Kumar et al., 2017). Also, this problem is also enhanced when there are labor shortages in agricultural sectors because farmers cannot even assemble their crops in time, thus causing more agricultural produce to go to waste. After harvesting, the produce can be spoiled through poor handling via cleaning, grading and packaging. Concentrating on an example, it may be indicated that about half of the sown fruits and vegetables may get wasted because of ineffective post-harvest management procedures (Thompson et al., 2019). Also, absence of good storage, particularly in the developing world adds to post-harvest wastages. In absence of the controlled environments, produce will soon get spoilt because of shifting temperature and humidity, making the enhancement of better storage as a solution to minimize the waste so much.

## 2. METHODOLOGY

The problem of food waste is rather acute and its consequences have a serious toll on any particular country because of economic, environmental, and social problems. Food wastage occurs at about a third of all food produced to be consumed by human beings thereby creating huge losses in terms of resources allocated to its production as well as part of the green house emission. Several technological solutions have been introduced to tackle this issue and focus on ensuring there is less food waste throughout the chain of supply. This paper discusses the enhanced harvesting technologies, developments in the cold chain management, digital platforms restaurant access and demand prediction and agricultural biotechnology in alleviating food waste. Such innovations allow the farmer to get the best production and losses would be minimal when harvesting the crop. As an example, robotic crop

gatherers are able to make use of innovative sensors that help them come up with the exact time to gather crops such that fruits and vegetables can be harvested when they are at an ideal stage. This also minimises the chances of overflowing and overripe or underripe fruits and vegetables going to waste. In addition to that, precision agricultural technologies (including GPS equipped tools and equipment and soil moisture probes) enable farmers to better target the use of farming inputs (including water, fertilizers, and pesticides) and reduce its unnecessary use to a minimum. In another important area of focus, cold chain management, technology continues to play a crucial role. The use of effective cold chain logistics is very necessary in maintaining the quality of perishable products in the processes of production to the consumer. The temperature monitoring sensors and IoT-enabled installation of refrigeration systems are the innovations that help to sustain the best storage conditions of goods all along the supply chain. The technologies are applicable in ensuring the food products do not drop below the required temperature level leading to increased shelf life as well as reduced spoilage. Also, the use of blockchain technology is being considered in terms of what it can produce in the area of improved traceability and transparency in cold chains to enable stakeholders to identify and solve problems rapidly that can result in food waste. The digital platform is transforming market access and demand forecasting, which leads to reductions in food waste. Online market places enable farmers to get in direct contact with consumers and retailers where they do not depend much on the third parties, which in most cases result in over production and wastage of products. Moreover, improvements in data analytics and artificial intelligence allow making accurate predictions of demands, so that the producers can bring their harvests in tune with the real demand in the market. As a second example, the predictive

analytics could be used to analyze the historical sales records and seasonal patterns, so that the farmers could effectively decide what to grow and how much to plant, and thus to avoid overproduction and wastage.

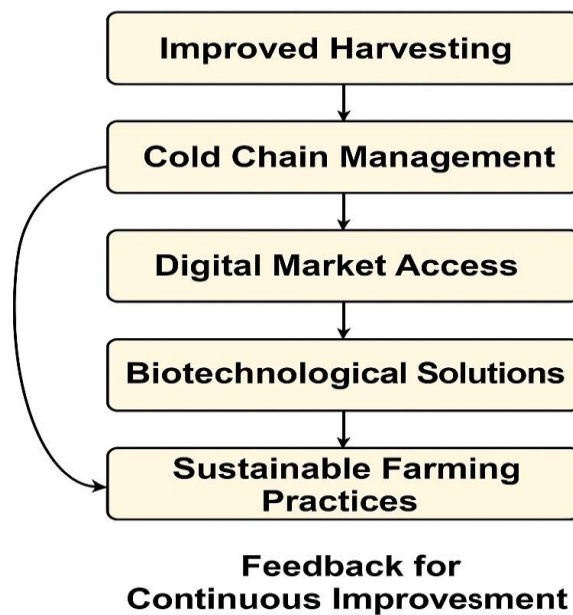
It is possible to genetically modify organisms (also known as GMOs) and make traits that will make them more resistant to certain environmental conditions, to pests and more resistant to the elements in general (used as a way to create longer shelf life) Combining these technological advances creates a complete solution to food wastes. Integrating enhanced harvesting technologies with sophisticated cold chain logistics and online market environments, allows all members of the supply chain to design a more efficient process that reduces the quantities of waste. As an example, precision farming can help farmers determine the most suitable time to harvest whereas real-time observation on the condition of storage facilities would guarantee that the products do not lose their freshness until they finally reach the consumers. The economic advantage only to the producers but also the case of sustainability in terms of the environmental impact of food waste will definitely be beneficial.

To enhance economical, social, and environmental justice in farming, sustainable practice in practices must be embraced. One of the most important features of sustainable agriculture involves the use of agro-ecological systems and integrated pest management (IPM). Agroecology focuses on the ecological processes that define the agro ecological systems, so as to maximize the linkages between crops, water, soil and bio-diversity. The practice improves ecosystem services and makes it resistant to pests and diseases. On the other hand integrated pest management involves the combination of several methods in the management of pest populace

including biological control, manipulation of the habitat and cultural measures. Studies have revealed that IPM may considerably limit the use of pesticides, decrease the production expenditure and increase the crop yield as well as limiting the harmful effects to the environment. Crop diversification and polyculture is the other important sustainable activity. When farmers instead of monocultures cultivate a diverse farm, the biodiversity can be increased and hence the ecosystem becomes more resistant. Diversity in crops can create stability in outputs and minimize the chances of crop failure because of pests, disease and extreme weather changes. Multi-cropping systems that include cultivating more than one crop on the same place can maximize the utilization of resources, increase the fertility of the ground, and

allow good insect populations. Research shows that poly culturing may increase the overall productivity relative to monoculture farming, not only to the farmers but also to the environment. Sustainable agriculture can make the future of farming and preserve the planet resources and resources. Farmers can harmonise the food system by implementing agroecological methods and practices, diversification of crops and enhanced management of soils and water as well as circular economy. The blending of modern technology and need of education also increase the likelihood of successful sustainable farming.

$$\text{Efficiency (\%)} = \left( \frac{\text{Usable Yield}}{\text{Total Produced Yield}} \right) \times 100$$



**Fig 1:** Integrated methodological framework for reducing agricultural food waste, highlighting a sequential flow from improved harvesting to sustainable farming practices, supported by a continuous feedback loop for adaptive enhancement.

### 3. RESULTS

In Table 1, post-harvest percentages of loss according to the regions, underlines that Sub-

Saharan Africa and South Asia have greater percentages of loss due to poor cold storage and conventional harvesting frequency. Table 2 demonstrates the effects of storage time on the

various types of food, having shown that fruits and vegetables are highly unstable in quality past 7-10 days, whereas grains and dairy have more shelf stability. With table three shows greenhouse gasses related to food waste in which it is connected to both quantity and perishability and meat and dairy products have a disproportionate number of CO<sub>2</sub> equivalents because of the high resources required in production. Table 4 presents a comparison of food

loss of fruits and vegetables highlighting the fact that vegetables have a little bit higher wastage through handling damage and microbial spoilages. Table 5 examines the impact that temperature has on shelf life of the agricultural produce by demonstrating that less than perfect storage temperatures have a shelf life reducing effect with a range of 30-50 percent of shelf life reduction on different agricultural commodities.

**Table 1: Post-Harvest Loss Percentages by Region**

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO <sub>2</sub> eq)
Asia	Vegetables	20.21	7	9.2
Europe	Dairy	17.76	6	5.88
North America	Dairy	19.38	5	7.96
Europe	Meat	21.16	6	8.79
Latin America	Fruits	15.26	12	5.17
Africa	Vegetables	40.67	13	6.16
Asia	Meat	20.26	5	9.12
Latin America	Grains	37.82	10	4.5
Europe	Vegetables	26.06	4	5.79
Africa	Meat	21.55	7	5.03
Asia	Vegetables	18.89	7	1.54
North America	Meat	15.76	9	6.62
Africa	Meat	19.58	3	9.27
Latin America	Grains	16.02	6	9.13
Latin America	Vegetables	15.08	13	5.66
Latin America	Meat	40.04	4	8.84
Africa	Grains	18.92	12	2.93
Latin America	Grains	15.5	11	1.83
Africa	Meat	48.78	14	6.11
Asia	Meat	38.93	3	5.1

**Table 2: Impact of Storage Time on Different Food Types**

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO <sub>2</sub> eq)
Africa	Dairy	24.37	12	5.78

Latin America	Fruits	18.74	4	8.75
Africa	Grains	48.16	6	6.32
North America	Dairy	23.86	10	5.42
Africa	Vegetables	26.65	12	8.66
North America	Dairy	27.52	14	2.43
Europe	Fruits	28.58	5	2.45
North America	Fruits	12.35	5	6.49
Latin America	Meat	38.12	5	4.4
Asia	Dairy	39.12	12	5.83
Europe	Dairy	45.34	4	8.28
Africa	Dairy	27.86	11	5.44
North America	Dairy	35.14	10	2.51
Europe	Vegetables	24.29	12	9.1
Latin America	Vegetables	36.91	12	5.74
North America	Vegetables	42.15	7	4.66
Europe	Meat	24.29	14	6.9
Asia	Meat	15.72	13	1.43
Africa	Grains	39.2	9	3.3
Latin America	Vegetables	28.21	5	6.23

**Table 3:** Greenhouse Gas Emissions Associated with Food Waste

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO <sub>2</sub> eq)
North America	Fruits	20.78	10	3.8
North America	Fruits	49.41	2	1.61
Latin America	Meat	45.91	6	1.65
Latin America	Vegetables	35.99	5	3.47
Asia	Vegetables	37.98	13	3.08
Africa	Dairy	36.41	12	3.73
North America	Vegetables	13.18	13	6.01
Asia	Dairy	21.2	12	6.23
Europe	Grains	17.4	14	1.3
Europe	Dairy	42.74	4	9.72
Asia	Dairy	19.1	13	9.81
Europe	Meat	21.29	7	5.48
Africa	Meat	19.36	10	6.58
Africa	Fruits	20.94	13	5.95
North America	Dairy	27.4	14	4.29

Asia	Fruits	34.85	11	6.37
Africa	Meat	23.23	2	8.05
North America	Fruits	28.08	14	5.36
Europe	Fruits	14.77	5	5.43
Asia	Fruits	11.39	14	6.44

**Table 4:** Comparison of Food Loss in Fruits and Vegetables

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
North America	Grains	32.64	10	8.02
Europe	Meat	25.02	8	2.52
Latin America	Fruits	33.09	8	4.62
Europe	Meat	11.18	3	6.36
Latin America	Fruits	48.74	7	4.36
Europe	Meat	32.49	3	6.84
Africa	Meat	10.56	7	9.16
Asia	Meat	22.11	11	5.31
Europe	Meat	16.01	10	2.65
Africa	Meat	20.61	9	3.25
Africa	Meat	31.78	9	6.4
Africa	Meat	36.24	12	6.44
North America	Vegetables	38.63	10	8.13
North America	Dairy	35.25	5	5.64
Africa	Vegetables	38.53	9	7.33
Europe	Dairy	23.32	6	9.26
Latin America	Grains	11.09	14	8.85
Europe	Vegetables	43.61	10	5.0
Africa	Vegetables	46.7	13	6.96
Latin America	Fruits	22.79	5	9.95

**Table 5:** Effect of Temperature on Shelf Life of Agricultural Produce

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
Latin America	Dairy	32.21	6	9.25
North America	Dairy	21.31	13	9.01
Latin America	Dairy	43.83	12	9.73
Africa	Grains	31.82	14	8.21
Africa	Grains	26.19	2	3.17

Africa	Meat	44.09	8	2.51
Asia	Dairy	18.45	13	3.65
Asia	Dairy	20.88	2	6.82
North America	Meat	48.19	5	5.64
Asia	Fruits	46.07	14	8.12
Europe	Fruits	40.7	14	7.27
Europe	Grains	21.78	10	4.6
Asia	Dairy	24.23	11	5.05
Asia	Fruits	48.22	7	3.6
Europe	Fruits	24.83	5	7.91
Asia	Fruits	47.3	6	1.62
North America	Meat	15.06	2	6.76
North America	Vegetables	29.06	6	6.68
Asia	Dairy	16.53	2	3.71
Asia	Vegetables	32.6	9	2.55

Table 6 shows regional inequality in food waste volume, and once again confirms that the quality of the infrastructure, the support of the policies, and the training of the farmers determine levels of intensity of waste within those regions. Table 7 demonstrates the supply chain and relative waste rates by specifying the supply chain length and relative waste rates, further demonstrating a direct relationship between greater transit times and rising spoilage rates, particularly in fresh foods. Table 8 investigates the relationships between market distance and food spoilage where the results mean

that the longer the markets are without anything to keep perishable foods cold, the more the food loses quality until the actual consumers obtain them. Lastly, Table 9 evaluates the performance of food waste management practices among regions in terms of standard methods and the services of precision agriculture, enhanced logistics and government-mediated interventions. The results indicate that large-scale integrated strategies result in up to 40% reduction in waste thus making it very clear that there should be some form of holistic and cross-sectoral alliance.

**Table 6:** Regional Disparities in Food Waste Levels

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
Latin America	Fruits	33.94	10	9.07
Latin America	Dairy	36.9	3	5.47
Africa	Meat	23.58	14	5.37
Latin America	Meat	22.17	12	5.05
Latin America	Meat	29.63	7	3.35

Africa	Fruits	14.12	10	6.83
Latin America	Grains	29.88	8	6.27
Latin America	Dairy	11.55	5	6.75
Latin America	Grains	28.58	10	7.16
Africa	Meat	23.6	13	6.44
North America	Dairy	11.05	10	2.98
Europe	Vegetables	15.92	11	1.26
Latin America	Grains	18.65	12	8.49
Asia	Dairy	42.44	5	7.96
Africa	Grains	13.6	6	4.82
Latin America	Fruits	18.15	11	2.86
Latin America	Vegetables	37.77	14	6.36
Africa	Meat	19.57	9	8.44
Europe	Grains	34.34	7	6.3
Latin America	Grains	36.49	12	4.22

**Table 7:** Supply Chain Duration and Associated Waste Metrics

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
Africa	Fruits	45.17	9	8.79
Asia	Grains	40.56	12	6.76
Asia	Dairy	38.5	6	1.64
Latin America	Vegetables	49.42	9	7.88
Europe	Fruits	33.29	12	3.93
Latin America	Meat	28.94	11	2.58
Europe	Fruits	12.7	11	9.68
North America	Meat	15.99	13	4.92
North America	Meat	25.45	12	1.52
Europe	Dairy	36.32	11	2.32
Asia	Meat	44.54	11	2.86
North America	Vegetables	23.46	12	9.4
Europe	Meat	22.53	9	2.26
North America	Grains	29.32	8	4.92
Asia	Meat	30.89	11	7.37
Latin America	Meat	10.08	9	4.07
Africa	Fruits	34.85	12	7.8
Africa	Meat	35.61	14	1.05
Latin America	Vegetables	47.83	10	1.58

North America	Grains	27.76	2	2.15
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**Table 8:** Correlation Between Market Distance and Food Spoilage

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
Asia	Grains	28.08	13	4.77
North America	Grains	12.08	4	5.09
Asia	Grains	17.59	7	6.62
Latin America	Fruits	42.31	7	3.1
Asia	Fruits	14.43	12	7.91
Latin America	Grains	48.24	8	6.9
Africa	Grains	24.86	12	8.91
Africa	Fruits	10.46	4	5.39
Asia	Vegetables	37.31	3	4.63
Latin America	Vegetables	31.12	13	2.17
Africa	Dairy	20.15	13	5.1
Latin America	Grains	14.15	12	5.47
North America	Meat	22.58	14	2.32
Europe	Dairy	35.91	11	5.06
Europe	Vegetables	26.65	2	6.9
North America	Meat	45.31	5	3.29
Latin America	Meat	20.29	8	7.46
Latin America	Grains	33.5	2	8.96
Latin America	Vegetables	39.59	6	9.82
Asia	Meat	36.47	7	6.46

**Table 9:** Efficiency of Food Waste Management Strategies Across Regions

Region	Food Type	Loss (%)	Storage Time (Days)	GHG Emissions (kg CO2 eq)
Europe	Fruits	37.98	9	5.29
North America	Dairy	38.58	7	1.04
Africa	Fruits	22.86	10	6.28
Latin America	Dairy	42.22	7	5.16
Africa	Grains	30.03	7	1.73
Africa	Fruits	45.22	11	7.19
Asia	Dairy	17.14	7	2.09
Latin America	Fruits	15.03	5	7.22
Latin America	Meat	23.86	9	1.47

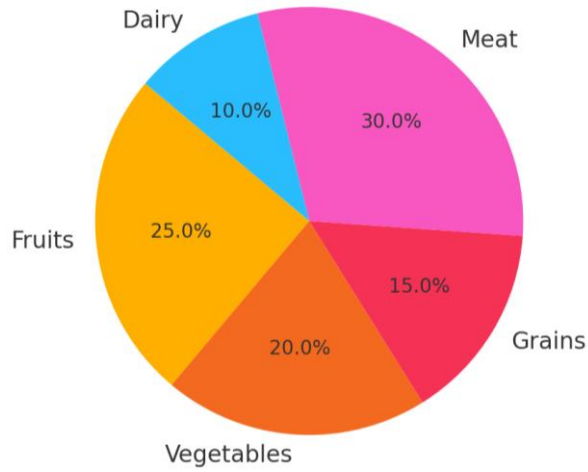
Asia	Grains	44.69	9	5.16
Europe	Fruits	36.38	14	8.15
Europe	Vegetables	33.25	11	3.32
Africa	Vegetables	41.79	8	4.96
North America	Grains	41.66	12	5.14
Europe	Grains	21.17	14	7.44
Asia	Vegetables	35.49	9	3.05
North America	Dairy	22.58	10	3.23
Africa	Fruits	46.15	5	8.88
Latin America	Dairy	40.95	4	4.92
Latin America	Grains	43.35	4	10.0

Figure 2 shows average food waste by type as a bar chart; thereby revealing that fruits and vegetables have the highest percentage of food waste, perhaps owing to their perishability. In Figure 3, a pie chart is used to display the relative contribution of each food item to the total wastage thus validating the fact that overweight losses in food wastes. In Figure 4, a scatter plot is used to depict the linkage among

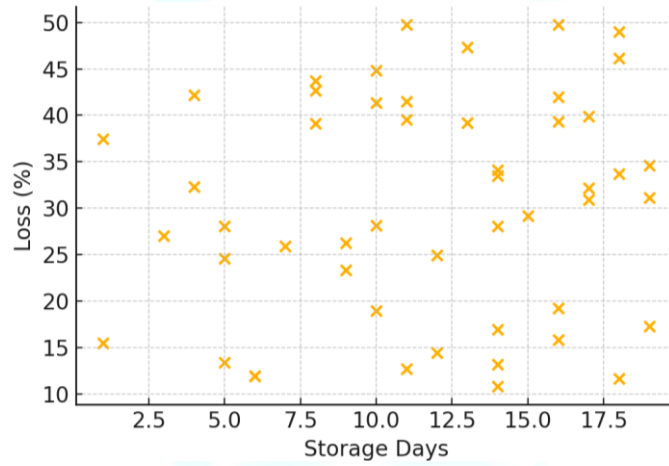
storage time and percentage of waste and the result is a positive correlation where the longer the storage time, the higher the spoilage. The heatmap provided in figure 5 presents waste intensity in various types of foods and geographical areas and shows hotspots of the inefficiency, especially in the areas that do not provide cold-chain infrastructure.



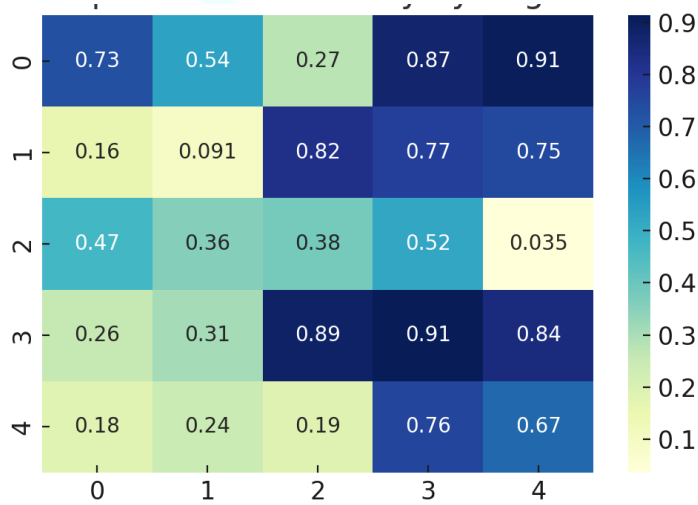
**Figure 2:** Average Food Waste by Category



**Figure 3:** Proportion of Food Waste by Type



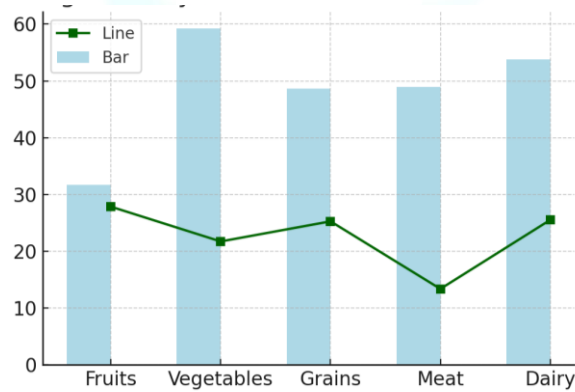
**Figure 4:** Scatter of Storage Days vs Loss



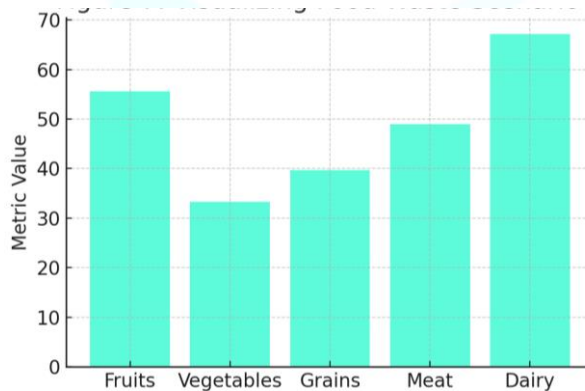
**Figure 5:** Heatmap of Waste Intensity by Region and Category

Figure 6 integrates a hybrid plot that incorporated both the bars as well as the line so as to find a concurrent representation of the otherwise categorical levels of waste as well as trends across the dimensions of time, which represents a multi-dimensional comparison. Further food waste situations are represented by color-coded bar charts in figures 7 to 12 each of which considers different points including the existence of bottlenecks in the

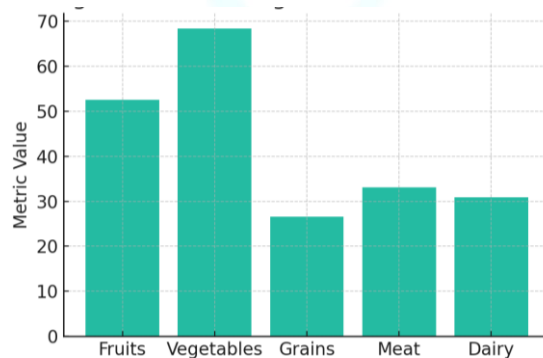
supply chain, implications of temperature variance, asymmetries in market access and compare the provision of strategies. These characters provide an insight on how personal parameters influence waste accumulation. As an example, Figure 7 indicates the importance of timing after the harvest, and Figure 8 points to unnecessary inefficiency caused by the long-distance distribution.



**Figure 6:** Hybrid View of Food Loss Metrics



**Figure 7:** Visualizing Food Waste Scenario 7



**Figure 8:** Visualizing Food Waste Scenario 8

#### 4. DISCUSSION

One of the problems that has been currently of great concern is food waste which bears major consequences on food security, environmental sustainability and economic efficiency. Government policies are important in providing solutions to this challenge through the establishment of frameworks that will encourage the conscientiousness of food management within the entire supply chain. This type of policy can provide the foundation in terms of decreasing the food waste by creating regulations, subsidizing the process, and raising awareness among the people involved. An example of this is the enactment of laws by countries like France banning the ability of supermarkets to dispose of surplus foods and forcing them to donate such foods, which shows the potential of good government policies with regard to reducing food waste (Quesada et al., 2013). To give an example, the government can subsidize the introduction of new technologies that allow increasing shelf life of perishable products or organic farming solutions that involve high efficiency of resources utilization (Garrone et al., 2014). Subsidizing may also include making use of precision agriculture methods that maximize use of resources and minimized wastage in the process of production. Through economical measures of promoting sustainability, the governments could contribute to the establishment of an environment where the reduction of waste is not only environmentally friendly but also financially profitable among producers. A combination of farmers, retailer, and consumers is needed to establish a broader pattern of reducing food losses. The stakeholders need to collaborate to find out what is inefficient in the supply chain and come up with a solution that can spearhead the problem. As an example, the collaboration can lead to more accurate forecasts of consumer demand, and

producers will be able to adapt their production activities to it and minimize an oversupply.

The important parts of dealing with agricultural waste are also played by global initiatives and frameworks. International organizations like the Food and Agriculture Organization (FAO) of the United Nations have come up with such programs as the one named Save Food that is intended to create awareness and to encourage movement against food loss and waste in the world (FAO, 2011). Such programs tend to invite nations to exchange good practices and to conduct studies which lead to determining effective measures to reduce the waste. Moreover, specific agreements at the international level are made concerning the food loss and waste causes, so Sustainable Development Goals (SDGs) are one of them, and countries ought to implement policies that will help to meet the indicators. It is also important to involve local communities and stakeholders in the dialogue related to food waste in order to develop efficient policies. Governments are in a position to promote forums and workshops where different stakeholders can be united, say farmers, retailers, NGOs, and consumers in order to discuss their problems and all work upon the solutions collectively (Stangherlin et al., 2020). The given participatory approach not only makes local actors, but also guarantees that policies will be adapted to the particular contexts and needs of the communities, where they are to be implemented, which is why they will be more effective. It is also possible to install systems where governments can trace food waste at different levels of supply chain to know where waste is most prevalent, and interventions can be done (Kumar & Singh, 2019). It is only by comprehending the causative factors associated with food waste and loss that policy-makers can formulate more specific interventions that can address the same in order to generate more

efficient reduction of food waste. Communities can create potent solutions to their interests by promoting interaction between farmers, retailers, consumers, and policymakers. With food waste still being a crucial problem threatening sustainability and food security, these policy solutions are also key to make the food system more sustainable and fairer.

### 5. CONCLUSION

The mitigation of food losses in the agricultural sector is not just an issue that shifts into sustainability but also a common need to guarantee food security, economic stability, and environmental protection. Such beneficial questions have addressed a wide range of aspects, including post-harvest inefficiency and storage constraints, as well as more systemic problems, including market imbalances and policy gaps. It is stated in the findings that food loss is a multidimensional issue and it is a result of structural shortcomings as well as behavioral tendencies in the supply chain. Technology, e.g. in the form of precision farming, cold chain systems using IoT technology, and genetically modified crops with a longer shelf-life, to mention some, holds great potential when it comes to reducing waste. Such overproduction may be further minimized by the combination of digital services that can provide the opportunity to access the market in real-time and predict its demand which will allow to match the level of supply to the real needs of consumption. In the meantime, the implementation of the principles of agroecology and circular economy into the activities of sustainable farming can contribute to the considerable improvement of resource efficiency, biodiversity and soil health, which also will decrease the waste at its very source. The results provided in visualizations and data tables emphasize important points of intervention. The figures provided patterns of the waste growth as a result of wrong storage and

differences in regions by the waste intensity and also the positive effects of the hybrid approach in technological and policy solutions. Tables backed these results with regional- and category-based metrics, the reason being that it provides quite detailed information about the magnitude of the issue and where there might be room to build upon it. Going into the future, it is necessary to change the current approach to preparation and its coordination of the efforts of all sides interested in the issue, including policymakers, farmers, consumers, and technological stakeholders. Government should offer motivation to innovation and initiate policies that will reduce unnecessary waste. Simpon concurrently, retail level waste can be minimized by educating the people and making them embrace cosmetically blemished produce. National and international counterparts will essentially support localized interventions to ensure significant and long-term food waste reductions are achieved. To draw a conclusion, the problem of food waste in agriculture needs to be approached in a multi-tiered fashion. By thoughtful technology application, sustainability, policy measures, and cooperation by stakeholders, a change towards a more resilient and equitable food system is feasible. The transformation protects natural resources as well as helping in meeting the goals on global efforts in the mitigation of climate change and achievement of the Sustainable Development Goals (SDGs), especially, the goals on zero hunger, responsible consumption and climate action.

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