Journal of Optimization in Industrial Engineering,
Vol.17, Issue 2, Summer & Autumn 2024, 105-123
DOI:10.22094/QJIE.2024.1127687

Research Article

DPSIR framework of global food loss and waste: Recommended sustainable intervention for indonesia

Imam Djati Widodo [a,*], Qurtubi [b], Elisa Kusrini [c], Feris Firdaus [d], Roaida Yanti [e]

[a, b, c, d, e] *Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Islam Indonesia, Yogyakarta 55584, Indonesia*

Received 30 July 2024 ; Revised 15 September 2024 ; Accepted 20 September 2024

Abstract

Global population growth is the main driver of an unsustainable food system with the increased problem of Food Loss and Waste (FLW) as the most severe consequence. Based on data from Indonesia Statistics (BPS), in 2024, Indonesia's population reached more than 281 people. The pile of FLW in Indonesia reaches 48 million tons/year and efforts to overcome it are still challenging. This research aims to determine the drivers, pressures, impacts, and responses of FLW globally as a sustainable intervention model for FLW mitigation in Indonesia. Economic, political, cultural, and socio-demographic drivers of FLW are explained, highlighting global variations. The method used in this research is a systematic literature review of 54 FLW studies at the global level. Pareto is used to analyze the components of findings that need to be prioritized based on 80 percent cumulative contribution. The literature is in English, taken from reputable journals on the Scopus database within the last 5 years, distributed from 2019-2024. The research results reveal 12 drivers, 12 pressures, 10 impacts, and 11 global FLW responses based on sustainable aspects, namely environmental, social, and economic. Moreover, it was found that all 18 FLW drivers in Indonesia were recorded in the global FLW drivers and pressures findings in this study. So, the response findings in this study can be considered for adoption in Indonesia. This approach may be very useful for scientists, local governments, and policymakers to identify global variations and focus on their future implications.

Keywords: FLW; Mitigation model***;*** *Sustainable Intervention; Environment*

1. Introduction

FLW has become a global issue that has caught much attention in recent decades (Popat et al., 2022); (Dora et al., 2021). The Food and Agriculture Organization of the United Nations (FAO) reported that approximately 1.3 billion metrics or about a third of all food produced for human consumption worldwide is wasted each year or lost along the food supply chain. (Wohner et al., 2019); (Quevedo et al., 2023); (Ishangulyyev et al, 2019); (Li, et al., 2022); (Coudard et al., 2021).

The amount of food produced in the world can feed 10 billion people, while almost 10% of the world's population, or one out of nine people suffers from malnutrition (FAO, 2019); (Popat et al., 2022) (Spang, et al., 2019); and one out of three people suffers from a lack of adequate access to food in some regions (Popat et al., 2022). It has resulted in serious problems with food security that threaten around 828 million people with malnutrition (Mokrane et al., 2023), and about 236 million of them live in Sub-Saharan Africa (SSA) (Popat et al., 2022), around 118 million people in the world suffer from famine due to limited access to food.

At the same time, the volume of food loss and waste in the world is enough to feed 940 million adults (Abbess, 2020), which delineates this problem as a major factor in the fight against hunger (Kotykova et al., 2021). This has been a measurable global food waste statistic for the last 10 years.

FAO (2019) outlines "Food Loss" as a reduction in quantity (weight) or quality (nutritional value) produced for human consumption. "Food Loss" refers to commodities as well as livestock and crops that are completely thrown away, burned, or damaged so that they are unable to be reused in other productive usages. It usually occurs at farms and suppliers during transportation, storage, and processing in the food chain before reaching the retail level (Spang, et al., 2019), (Aburime, 2023). "Food Waste" refers to the reduction in quantity or quality of food that occurs at the end of the supply chain due to the decisions and actions of retailers, food service providers, and consumers. Food loss and waste are interrelated and cut across all levels of the food chain (Kotykova et al., 2021).

In a recent report published by WWF-UK in 2021, it was estimated that 2.5 billion tonnes of food go uneaten every year, including 1.2 billion tonnes that never leave the farm. It reveals that around 40% of all food grown is wasted. Another report from the United Nations Environment Program (UNEP) on the 2021 Food Waste Index estimates that approximately 931 million tons of food waste was generated in 2019 by distribution: in households (61%), food services (26%), and retail outlets (13%) (Aburime, 2023). This suggests that 17% of total global food production may be wasted.

The number of FLW varies between countries, influenced by income levels, urbanization, and economic growth (Chalak et al., 2016). In China, total FLW in 2019 reached

* Corresponding author Email address: imamdjati@uii.ac.id

422.56 million tons, which is around 22.37% of total food production (1889.12 million tons). Meanwhile the FLW percentage in the EU is 20.22%, Spain is 20%, Saudi Arabia is 33.1%, Switzerland is 34%, and Peru is 47.76%. (Jia et al., 2023). In Lebanon, food waste reaches 0.2 kg per capita per day (Chalak et al., 2019). Developed countries, including European countries, North America, Oceania, as well as industrialized countries such as Japan, South Korea and China, produce 56% of the world's total FLW. Of this amount, 40% of FLW in developed countries occurs at the distribution stage (Aburime, 2023) and consumption (Chalak et al., 2016), which is largely influenced by consumer behavior, values and attitudes. The amount of Food Waste (FW) in developed countries, around 222 million tons, is almost the same as the total clean production in countries in Sub-Saharan Africa (230 million tons) (Ishangulyyev et al., 2019).

While, in developing and low-income countries such as Nigeria (Aburime, 2023), Mozambique (Popat et al., 2022), Philippines (Spang, et al., 2019), food losses happen at the production and post-harvest levels, it was reported for approximately 44% of total global FLW. In the Philippines, commodity losses from harvest to distribution have been reported to reach up to 50% (Priest, 2016). This is due to poor practices, technical and technological limitations, manpower and financial constraints, and lack of adequate infrastructure for transportation and storage (Gustavsson et al., 2011). Moreover, this also happens in Turkey, as the seventh largest agricultural producer in the world, the amount of loss and waste at the agricultural stage is also high. Salihoglu et al. (2018) revealed that nearly 9 million tons of fruit and vegetables are lost during production, while 4 million tons are wasted during post-harvest handling and storage. This loss of fruit and vegetables accounts for 53% of total food loss in Türkiye (Surucu-Balci & Tuna, 2022). In Ukraine, most agricultural producers still prefer extensive and intensive management practices that create additional environmental stress on the soil, resulting in wastage in fruits by 42% and vegetables by 31% (Kotykova & Babych, 2019).

Indonesia, a developing country with a population of more than 280 million people, has pile of FLW reaching 48 million tons/year or 44% in 2018. Based on the report from Ministry of National Development Planning (BAPPENAS) in 2021, it is stated that the percentage of food loss generation reached 45%. Meanwhile, the percentage of food waste in 2019, has reached 55%, and the largest group occurred at the consumption stage. In terms of sectors and types of food, the largest occurrence happens in food crops, the rice category. Meanwhile, the most inefficient food sector is horticultural crops, specifically in the vegetable category (BAPPENAS, 2021). These data, in general, underline the indication that food loss and waste is a major problem that the world needs to address, and that food waste itself raises several social, economic, and environmental concerns. (Spang, et al., 2019). This paves the way for several bodies to accurately provide estimates of the extent of food loss and waste and its social, environmental and economic impact.

The significant impact of FLW has increased the interest and awareness of policymakers, academics, and even the private sector to examine the problem exponentially and shape prevention programs worldwide (Mokrane et al., 2023); (Ishangulyyev et al., 2019). In 2015, 193 United Nations members adopted the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development which stand on three dimension of sustainability proportioally such as economic, social and environmental. SDGs 2 aims to end hunger, achieve food security and improve nutrition, and promote sustainable agriculture by 2030 (Popat et al., 2022), while SDGs target 12.3 stated that "By 2030, reducing by half of food waste per capita at retail and consumer levels and decreasing food losses along production and supply chains, including post-harvest losses" (Couard et al., 2021).

The FLW problem has been investigated expansively by many scientists around the world. Several studies explored the causal factors of FLW (Barrion et al., 2023); (Donato & Óscar, 2021); (Wohner et al., 2019); (Chalak et al., 2019); (Gatto & Chepeliev, 2024); as well as ways to mitigate and reduce it (Yan et al., 2021); (Benyam et al., 2021); (Surucu-Balci & Tuna, 2022); (Ishangulyyev et al., 2019); (Domingo-Morcillo et al., 2024); (Sagi & Gokarn, 2023); (March et al., 2019); (Medveľová, Kapsdorferová, Švikruhová, & Zábojníková, 2022); while others identify FLW's impact on the environment (Read, et al., 2020); (Xue, et al., 2021); (Goossens, et al., 2019); (Coudard et al., 2021); (Stathers & Lamboll, 2022); (Kotykova et al., 2021); (Jia et al., 2023); (Cattaneo et al., 2021); (Munesue & Masui, 2019); (Xue et al., 2024); social (Aburime, 2023); and economics (Popat et al., 2022); (Li, et al., 2022); (Kotykova & Babych, 2019). Additionally, other studies proposed a unified methodology to calculate FLW (Spang, et al., 2019); (Bartelings & Philippidis, 2024); (Xue et al., 2024). Some studies have also focused on FLW along stages of the food supply chain to measure the true extent of the problem (Spang, et al., 2019); (Boz & Sand, 2020); (Luo et al., 2021); (Dora et al., 2021); (Read, et al., 2020); (Pastolero & Sassi, 2022).

In addition, O'Connor et al. (2023) implied a critical review of FLW by identifying the causes of FLW and management options in farmland. O'Connor et al. (2023) suggested performing deeper observations on the systemic causes of FLW and the entire drivers, such as risk. This study bridges the implication gap on the research performed by O'Connor et al.'s (2023) by investigating the causes and drivers expansively towards global FLW.

Donato and Carpintero (2021) identified losses, waste, and environmental pressures of food consumption at the regional level in Spain. However, this approach has several limitations. One is related to the lack of quality data on FLW, which is partly based on consumption at global and national levels. Donato and Carpintero (2021) also pointed out that further research should address these and other shortcomings, as well as investigate the social and economic drivers of food consumption patterns, to

support effective policies in addressing environmental issues related to the food system.

Mokrane et al. (2023) explored the global literature on FLW. They used social network analysis and bibliometrics to identify FLW problems related to environmental impacts and food security. They realize that environmental implications are insufficient, so the results of their study show the need to develop interdisciplinary approaches and methodologies that can provide a comprehensive understanding of FLW issues with social, economic, and environmental implications.

Domingo-Morcillo et al. (2024) investigated which FLW prevention measures are most beneficial in terms of environmental sustainability. However, in their findings, it is revealed that improvements in terms of reducing environmental impacts can also lead to new impacts from an economic and social perspective, thus emphasizing the need to be active in the process of continuous improvement in these three domains.

From these three studies, it was found that several research on FLW only focuses on environmental aspects and ignores social and economic aspects. While other studies raise the FLW issue from a social or economic perspective. So, the created intervention variables significantly complicate the decision-making process because hotspots detected during one aspect's assessment can conflict or provide a new impact from the perspective of another aspect. Thus, the integration of environmental, social, and economic assessments in a framework to overcome these difficulties and clarify the decision-making process in FLW is one of the novelties of this study. Therefore, the integration of environmental, social, and economic assessments within a framework to address these difficulties and clarify the decision-making process in FLW becomes one of the novelties of this study.

Moreover, efforts to reduce food waste in Indonesia are less managed. Efforts for food availability or security usually only focus on how to maximize agricultural production while ignoring how to prevent food loss and waste (Munir & Fadhilah, 2023). Apart from that, a crucial problem in Indonesia at the national level is concluded as no comprehensive and holistic intervention model related to the FLW phenomenon. The study of FLW in Indonesia is the first chapter in analyzing the FLW phenomenon in the food industry sector from upstream to downstream (farm to fork) to support low-carbon development and ensure sustainable consumption and production patterns in accordance with the 2030 SDGs mandate. Hence, this research contributes to FLW study extensiveness in Indonesia.

Therefore, this research aims to design a Sustainability Intervention Model for FLW Mitigation efforts in the Food Industry Sector using the DPSIR (Drivers, Pressures, State, Impact, and Response) Scenario in Indonesia. This research explores the drivers, pressures, impacts, and global responses of FLW from literature that has been published throughout the world. DPSIR analysis is used to describe the pattern of causal relationships between the components involved, namely driving factors, pressures, existing conditions, impacts, and responses to the most appropriate intervention models recommended for mitigating FLW in the food industry sector in the world.

2. Research Methodology

2.1. Research Strategy

This study uses a systematic literature review (SLR) as the primary research strategy to identify, categorize, and examine Drivers, Pressures, Impacts, and Responses of FLW worldwide. SLR can identify, select, critically appraise research, and interpret findings from various studies to respond to clearly formulated questions (Yanti et al., 2023). It helps researchers to precisely analyze the current status of the topic of interest. Additionally, SLR followed a search strategy to select relevant literature associated with the research question (Moher et al., 2010). This SLR method has been used in several studies examining FLW (Driver) affect factors. (Quevedo, Lukman, Ulumuddin, Uchiyama, & Kohsaka, 2023); FLW mitigation (Dora et al., 2021); Quantity, impact, and mediator of FLW (Li, et al., 2022). Therefore, this study uses the SLR method to map the Driver, Pressure, Impact, and Response of global FLW based on three elements of sustainability, namely environmental, social, and economic, by strictly following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, to minimize the risk of bias and increase the scientific validity of the findings. The PRISMA protocol for SLR includes research question formulation, keyword selection, database selection, literature search and retrieval, filtering, inclusion/exclusion, metadata extraction, and data analysis. This stage is classified into data collection and data analysis (Wuni I. Y., 2022).

2.2. Data collection

Data collection in this study was carried out twice. The first data collection was carried out using Mendeley tools using the keywords "drivers" OR "pressures" OR "impact" OR "responses" OR "strategies" OR "intervention" AND "food loss and waste", and 70 articles were found. The articles were carefully separated against predetermined inclusion and exclusion criteria, as in Table 1. Document types were limited to articles as these document types undergo rigorous peer review and are considered certified knowledge. Conference papers and other types of documents are widely criticized for their limited amount of peer review and are generally excluded from strict SLRs (Wuni, Shen, & Osei-Kyei, 2019).

Table 1
Inclusion and exclusion criteria

No	Inclusion	Exclusion
1	Articles that specifically discuss FLW and/or DPSIR models	Articles without full text
2	Articles with full text are easily available	Articles written in languages other than English
3	Research journal articles	Non-journal literature or articles
4	Articles published in reputable international journals	Article not indexed by Scopus

After filtering, from 70 articles only 13 were suitable and it was confirmed that the selected articles were indexed by Scopus. Furthermore, because the number of selected articles was very small, a second data collection was carried out using Publish or Perish (PoP) software on the Scopus database. The keywords used as a search in the article title were "food loss and waste" while in the keyword field outside the article title, the words "driver" OR "pressure" OR "impact" OR "response" are applied, and 53 articles have resulted. By using the same inclusion and exclusion criteria in the screening process, 42 articles were generated. So, a total of 54 articles met the requirements, which were then reviewed systematically to extract metadata. Figure 1 is a flow chart of the PRISMA diagram for literature retrieval. Table 2 shows the included studies.

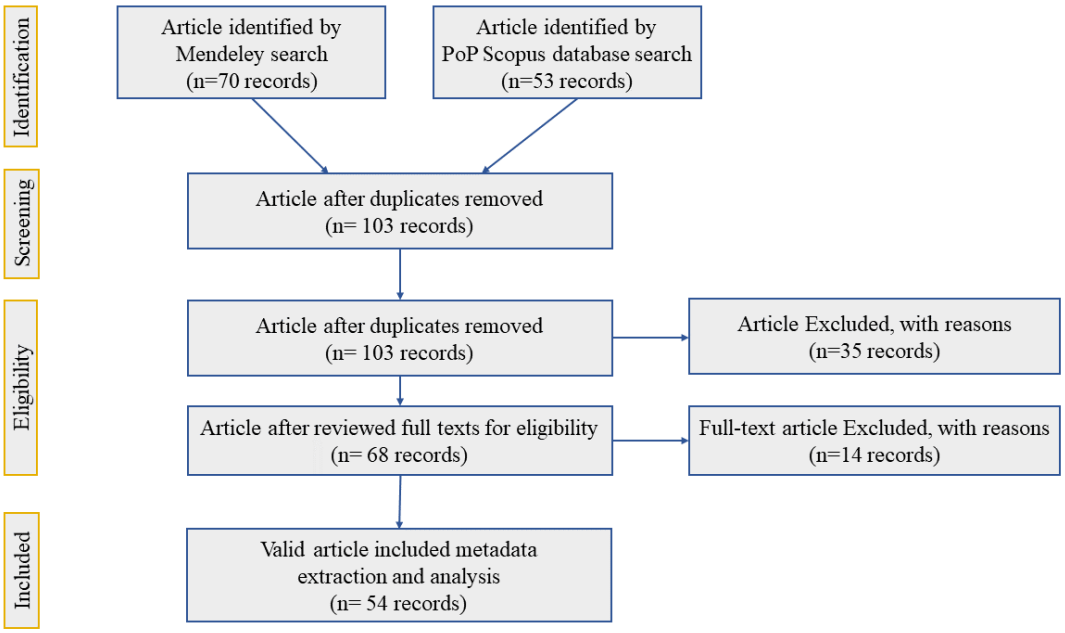

Fig .1. PRISMA flow diagram of the literature sampling process.

2.3. Data analysis

This study extracts relevant metadata from each article, including year of publication, location of study as stated in the DPSIR dimension, sustainability dimension, and drivers, pressure, impact, and response (DPIR). If verified empirically, this study also explains the FLW conditions in several countries in the world and the relationship among DPIR components. A data summary sheet was developed to record each driver, pressure, impact, and response from each literature. Then, this study calculated the frequency of mentions for drivers, pressure, impact, and response from existing literature. Then each DPIR element is ranked based on the highest to lowest number of mentions along with the percentage.

Next, Pareto analysis was delivered to identify elements that are important or have the most contribution to FLW based on mentions in the entire literature. Pareto analysis is a quality control tool that ranks data classifications, in descending order, from highest to lowest frequency of occurrence. The Pareto principle states that for many events, about 80% of the effects come from 20% of the causes, which results in the "80/20 rule" heuristic of the Pareto principle (Wuni I. Y., 2022).

Pareto analysis was employed in this study because the main data is the frequency of mentions, which limits the scope of analysis techniques that can be applied. The Pareto analysis technique is suitable to the study objectives since there is a need to prioritize DPIR elements for analysis in formulating FLW mitigation in Indonesia. It makes this engineering approach appropriate as it has been used to rank and prioritize critical items in existing studies. The total (cumulative) frequency is considered to be 100%, so the “most important” barrier occupies a substantial amount (80%) of the cumulative percentage of citation frequencies and the “most useful” barrier occupies only the remaining 20% of occurrences. This study uses Pareto diagrams (i.e., histograms and curves) to identify the most important DPIR components in each taxonomy.

Table 2
Reference numbers of 54 studies that meet the requirements.

ID	References	ID	References	ID	References
1	Brunhara et al. (2023)	20	Mokrane et al. (2023)	39	Kotykova & Babych (2019)
2	Quevedo et al. (2023)	21	Popat et al. (2022)	40	Kotykova et al. (2021)
3	Hajra et al. (2023)	22	Barrion et al. (2023)	41	Jia et al. (2023)
4	Agramont et al. (2022)	23	Spang, et al. (2019)	42	Cattaneo et al. (2021)
5	Idris et al. (2022)	24	Donato & Óscar (2021)	43	Munesue & Masui (2019)
6	Khan, et al. (2022)	25	Wohner et al. (2019)	44	Aburime (2023)
7	Jorge-García & Estruch-Guitart (2022)	26	Chalak et al. (2019)	45	Xue, et al. (2021)
8	Ladi, Mahmoudpour, & Sharifi (2022)	27	Surucu-Balci & Tuna (2022)	46	Sagi & Gokarn (2023)
9	Vittuari, et al., (2023)	28	Ishangulyyev (2019)	47	Pastolero & Sassi (2022)
10	Khan, et al., (2022)	29	Bartelings & Philippidis (2024)	48	March et al. (2019)
11	Swangjang & Kornpiphat (2021)	30	(Boz & Sand, 2020)	49	Medveďová et al. (2022)
12	Oliveira et al. (2021)	31	Domingo-Morcillo et al. (2024)	50	Luo et al. (2021)
13	Sahani (2021)	32	Rajeh et al. (2020)	51	Dora et al. (2021)
14	Malmir et al. (2021)	33	Gatto & Chepeliev (2024)	52	Cattaneo et al. (2021)
15	Quevedo et al. (2021)	34	Coudard et al. (2021)	53	Reynolds, et al. (2019)
16	O'Connor et al. (2023)	35	Li, et al. (2022)	54	Albalate-Ramírez, et al. (2024)
17	Yan et al. (2021)	36	Read, et al. (2020)		
18	Benyam et al. (2021)	37	Xue (2021)		
19	Stathers & Lamboll (2022)	38	(Goossens, et al., 2019)		

3. Finding

3.1. Data characteristic

There were fifty-four (54) selected studies that were eligible to be published between 2019 and 2024, the distribution is shown in Figure 2. The research only used studies published in the last five years to ensure that the findings are still relevant today, especially when it comes to FLW response and mitigation.

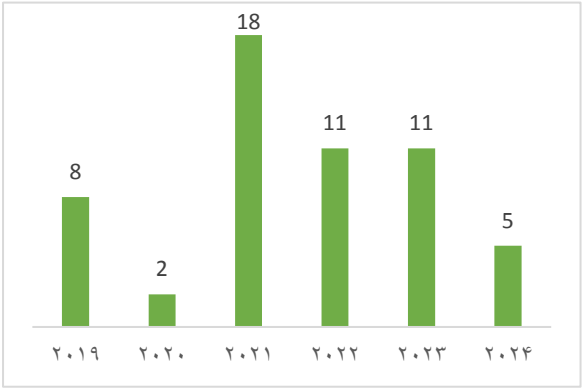

Fig. 2. Year distribution of the studies

Based on Figure 2, it can be seen that the most widely used studies were published in 2021 while the least were published in 2020. However, this distribution cannot represent today's FLW research trends considering the specific and strict data collection process on the FLW global DPIR element. All selected articles represent 28 countries in the world. This number is considered to represent the global condition of FLW in both developed and developing countries. The country that contributed the most studies was Italy. Figure 3 shows the country distribution of these studies.

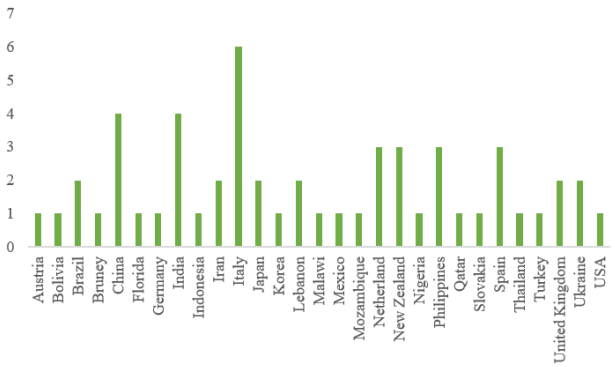

Fig. 3. Countries of distribution for studies

3.2. Drivers

There were 19 drivers identified from the literature review as shown in Table 3. All the drivers found were further investigated related to their contribution to the dimensions

of sustainability, which are environmental, social, or cultural. The results found that 2 drivers are categorized into the "environmental" category, 9 drivers fall into the "social" dimension, and the other 8 are the "economic" dimension of sustainability. Apart from that, based on the percentage contribution of driving components to FLW in Table 4. Drivers that contributed a cumulative contribution of up to 81% by pareto (Figure 4) were further identified in the DPSIR model (Figure 8), namely 12 drivers.

"Population growth" is the most frequently occurring driver, recorded in 19 studies representing 16 different countries and accounting for 16% of the total literature. This finding is also aligned with studies that have been conducted Quevedo et al. (2023) that population growth is the most frequently mentioned driver and is recorded in 16 provinces in Indonesia. This driver is also documented in India as a country with 1.44 billion people. The drivers of "increased consumption and "individual needs" which include this social dimension, are often documented together with "population growth", for example documentation from Japan, Italy, the Philippines, Spain, Korea, Florida and Nigeria. "Increased consumption and individual needs" were mentioned by 13 studies from 12 countries. Additionally, "Population growth" is also documented along with "Number of households" in Iran and Korea.

"Lack of knowledge, awareness and motivation" were the second most common drivers, mentioned by 13 pieces of literature representing 11 countries. Not only identified in developing countries such as Indonesia and the Philippines, but this driving factor has also been identified in the Netherlands, New Zealand, and the UK. "Human behavior" and "Modern dietary preferences and patterns" are mentioned together in Italy and Lebanon. Apart from "population growth", "human behavior", and "low knowledge, awareness, and motivation", Indonesia documents represent many FLW drivers related to the economic dimension including "income growth", "tourism growth", "economic growth, and inequality", and "urbanization". China and Qatar said that increasing GDP also contributed to FLW.

The increasing number of FLW occurrences can also be caused by "Institutional management inefficiencies" and "Regulations and policies" identified by China and Japan. The Philippines identified several drivers caused by the environment such as "climate changes and weather conditions" as well as the arrival of "pests and diseases." "Logistics problems," "price fluctuations," and "infrastructure and technology limitations" are documented FLW drivers in China. Meanwhile, the driver that is least frequently mentioned is "imports and exports".

Table 3
Findings of global FLW drivers

No	Drivers	Sustainability Dimension			Location of Study	ID References (Table 1)
		Env	Soc	Eco		
D1	Population growth		v		China, Florida, India, Indonesia, Iran, Italy, Japan, Korea, Malawi, Mozambique, Nigeria, Philippines, Qatar, Spain, UK, Ukraine	2, 3, 8, 10, 14, 15, 17, 18, 19, 20, 21, 22, 24, 28, 30, 40, 44, 46, 54
D2	Income growth			v	Indonesia, Korea, Netherland, New Zealand, Slovakia	2, 28, 33, 35, 49
D3	Human behavior		v		Indonesia, Italy, Lebanon, Turkey	2, 26, 27, 9
D4	Lack of knowledge, awareness, motivation		v		China, Indonesia, Italy, Korea, Lebanon, Netherland, New Zealand, Nigeria, Turkey, UK, Philippines	2, 16, 19, 26, 27, 28, 29, 34, 35, 41, 44, 46, 54
D5	Modern preferences and diet		v		Italy, Lebanon, New Zealand	9, 20, 26, 35, 51
D6	Pests and diseases	v			Italy, Philippines, UK	19, 20, 23
D7	Institutional management inefficiency		v		Austria, China, Italy, Japan, Philippines, Turkey	9,15, 17, 47, 25, 27
D8	Increased consumption and individual needs		v		China, Florida, Germany, Italy, Japan, Korea, Netherland, Nigeria, Philippines, Spain, Turkey, UK	15, 20, 22, 24, 27, 28, 30, 34, 38, 41, 44, 47, 48
D9	Urbanization		v		Bolivia, Indonesia, Iran, Japan, Netherland	2, 4, 8, 15, 34, 41
D10	Tourism growth			v	Indonesia, India, Japan, Spain, Thailand	2, 7, 11, 13, 15
D11	Number of households		v		Iran, Korea, Lebanon, New Zealand, Philippines, Slovakia	8, 23, 26, 28, 35, 49
D12	Increase in GDP			v	China, Netherland, Philippines, Qatar	10, 22, 29, 34, 41, 54

No	Drivers	Sustainability Dimension			Location of Study	ID References (Table 1)
D13	Regulations and policies		v		China, Italy, Japan, New Zealand	15, 17, 41, 35, 9
D14	Economic growth and inequality			v	Indonesia, Iran, Netherland, Spain	2, 14, 24, 33
D15	Logistics problems			v	China, Italy, Philippines, Lebanon	17, 23, 20, 32
D16	Climate change, weather conditions	v			China, Italy, Malawi, Mozambique, New Zealand, Philippines, Turkey, UK	16, 19, 20, 21, 23, 27, 41
D17	Limited infrastructure and technology			v	China, Italy, Korea, Turkey, Philippines	17, 27, 28, 47, 9
D18	Import and Export			v	Netherland	33
D19	Market price fluctuations			v	Italy, Philippines	20, 23

Table 4
Contribution of driver components

Driver			
Element	**Mentions**	**%**	**cum %**
D1	19	16%	16%
D4	13	11%	27%
D8	13	11%	38%
D16	7	6%	44%
D9	6	5%	49%
D12	6	5%	54%
D7	6	5%	59%
D11	6	5%	64%
D17	5	4%	68%
D2	5	4%	72%
D10	5	4%	76%
D5	5	4%	81%
D13	5	4%	85%
D14	4	3%	88%
D15	4	3%	92%
D3	4	3%	95%
D6	3	3%	97%
D19	2	2%	99%
D18	1	1%	100%

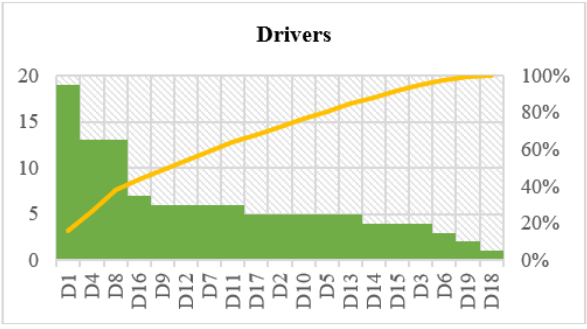

Fig. 4. Pareto diagram of drivers

3.3. Pressures

Based on the literature review that has been carried out, 21 pressures were found, of which 4 are included in the "environmental" field in the sustainability dimension, 6 pressures are included in the "social" dimension, and 11 others are included in the "economic" dimension. These findings are presented in Table 5. If you look at the percentage contribution of pressure components to FLW in Table 6, 12 pressures provide a cumulative contribution of up to 80% using Pareto based literature mentions (Figure 5) so they are used further in the DPSIR model (Figure 8).

"Household activities" is the social dimension that is the most frequently mentioned pressure by 12 pieces of literature originating from 11 countries. This pressure is widely documented along with “Inappropriate operational practices” in documentation from Italy, Korea, Florida, and Nigeria. The pressure with the second highest contribution, "inappropriate operational practices" was recorded in 11 pieces of literature from 10 countries. “Packaging defects and errors” were also mentioned 9 times in Austria, China, Florida, Germany, Italy, Korea, New Zealand, Nigeria, and Turkey.

Not only packaging, “manufacturing activities”, “technical and technological inefficiencies”, “demand uncertainty”, “inefficient transportation, “inaccurate storage”, “errors in labeling”, “inappropriate use of materials” and “inefficiencies cold chain" is a pressure or direct factor in the occurrence of FLW which is included in the economic dimension. Some of these pressures relate to “low product quality” and “short product shelf life”, which are documented simultaneously in Nigeria. Meanwhile, India documents “tourism activities” and “commercial activities” as FLW pressure. Meanwhile, Italy and Bolivia documented 'Industrial Waste' as another direct factor.

"Post-harvest activities" are often cited by developing countries such as Mozambique, Nigeria and the Philippines as a stage of FLW generation that contributes quite significantly. In this case, “Inadequate temperature” also contributes. New Zealand and Nigeria document "Retail distance to storage warehouse" as one of the factors causing FLW. On the consumer side, “Excessive ordering, large portions” and “Consumer selective behavior towards freshness or aesthetic appearance” directly contribute to food loss and waste. It has been widely recorded in developed countries such as Italy, Korea, UK, Netherland, New Zealand and Turkey.

Table 5
Findings of global FLW pressures

No	Pressure	Sustainability Dimension			Location of Study	ID References (Table 1)
		Env	Soc	Eco		
P1	Manufacturing activities			v	Bruney, China, India, Iran, Qatar	5, 6, 8, 10, 36
P2	Household activities		v		Florida, Germany, India, Korea, Lebanon, Netherland, Nigeria, Philippines, Turkey, USA, Slovakia	6, 22, 26, 27, 28, 29, 30, 34, 36, 38, 44, 49
P3	Demand uncertainty			v	China, Italy, Korea, Turkey, UK, USA	17, 19, 20, 36, 41, 27, 28
P4	Technical and technological inefficiencies			v	China, Italy, Nigeria, UK, Ukraine	17, 20, 39, 41, 44, 48
P5	Inefficient transportation			v	China, Florida, Germany, Japan, Korea, Nigeria, Turkey	17, 27, 28, 30, 38, 41, 43, 44
P6	Inappropriate operational practices		v		China, Florida, Japan, Korea, Malawi, Mozambique, New Zealand, Nigeria, Philippines, Turkey,	16, 17, 21, 22, 27, 28, 30, 35, 41, 43, 44
P7	Packaging defects and errors	v			Austria, China, Florida, Germany, Italy, Korea, New Zealand, Nigeria, Turkey	20, 25, 30, 35, 27, 28, 38, 41, 44
P8	Over-ordering, large portions		v		China, Italy, Netherland, New Zealand, Nigeria, Turkey, Ukraine, USA	20, 27, 33, 35, 36, 40, 41, 44
P9	Insufficient temperature	v			China, Italy, Turkey	17, 20, 27, 41
P10	Consumer selective behavior towards freshness or aesthetic appearance		v		Italy, Korea, New Zealand, Turkey, UK	16, 19, 20, 35, 27, 28
P11	Inaccurate storage			v	China, Italy, Nigeria, Philippines, Turkey, Ukraine	17, 20, 22, 27, 39, 41, 44, 47
P12	Cold chain inefficiency			v	China, Nigeria, Turkey	27, 41, 44
P13	Low product quality			v	Korea, New Zealand, Nigeria, Ukraine	16, 28, 39, 40, 44
P14	Short product storage duration			v	Italy, Nigeria, UK	19, 20, 44
P15	Tourism activities		v		India, Thailand	11, 13
P16	Commercial activities			v	India	6
P17	Industrial waste	v			Bolivia, Italy	4, 20
P18	Error in labeling		v		Austria, Italy, Turkey	20, 25, 27
P19	Post-harvest activities			v	China, Korea, Malawi, Mozambique, Nigeria, Philippines, Turkey, UK, Ukraine	19, 37, 28, 27, 39, 21, 23, 44
P20	Use of inappropriate materials	v			Austria, China, Italy	17, 20, 25
P21	Distance between retail and storage warehouse			v	New Zealand, Nigeria	35, 44

Table 6
Pressures component contribution

	Pressures		
Element	**Mentions**	**%**	**Cum %**
P2	12	10%	10%
P6	11	9%	20%
P7	9	8%	28%
P5	8	7%	34%
P8	8	7%	41%
P11	8	7%	48%
P19	8	7%	55%
P3	7	6%	61%
P4	6	5%	66%
P10	6	5%	72%
P1	5	4%	76%
P13	5	4%	80%
P9	4	3%	84%
P12	3	3%	86%
P14	3	3%	89%
P18	3	3%	91%
P20	3	3%	94%
P15	2	2%	96%
P17	2	2%	97%
P21	2	2%	99%
P16	1	1%	100%

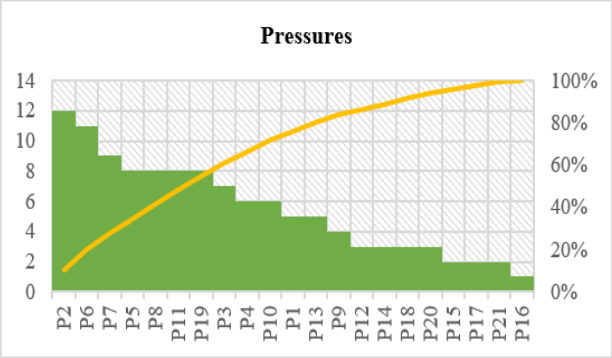

Fig. 5. Pareto diagram of pressures

3.4. Impacts

Many impacts found by many researchers in their studies related to FLW, then grouped into 20 impacts consisting of nine environmental, seven social and four economic impacts (Table 7). Out of the 20 impacts found, there were 11 impacts which provided a cumulative contribution of up to 80% based literature mentions (Table 8) and filtered the priority impacts using pareto (Figure 5), so it is used further on the DPSIR model (Figure 8).

"Decreased availability of clean water" was the environmental impact of FLW most frequently mentioned by 15 studies from 11 countries including Austria, China, Florida, Italy, Japan, Netherland, Philippines, Spain, USA, UK, Ukraine, followed by increased emissions of the greenhouse gas methane (GHG emissions) recorded in 14 literatures from seven countries. Apart from that, other environmental impacts caused by FLW include "land loss" and "water and soil pollution" which are recorded simultaneously in documents from China, Florida, Italy, Nigeria and Ukraine.

China and several other countries state the environmental impacts caused by FLW including "contributing to climate change", "waste of non-renewable energy", and "habitat and environmental degradation". "Using up natural resources" is also recorded as an environmental impact due to food waste in various countries such as Japan, Korea, the Philippines and the Netherlands.

Additionally, the social impacts found from existing literature include "increased pollution", "decreased quality of human health", and "hunger or malnutrition", and "poverty". Meanwhile China and New Zealand documented "reputation damage to logistics service providers". Then FLW can also "reduce the productivity of logistics service providers" as recorded in documents from China and Spain. The least frequently mentioned impact is the "dust generation" recorded in Brazil.

Apart from environmental and social losses, FLW also causes economic losses. New Zealand and Turkey document that one of the economic impacts of FLW is "monetary loss and waste". FLW can "reduce profits", this impact was recorded in five countries, namely China, New Zealand, Nigeria, Philippines and Ukraine. Furthermore, the document from Italy alludes to "waste management fees". Directly or indirectly, FLW has an impact on the "global, regional and national economy".

Table 7
Findings of global FLW impacts

No	**Impact**	**Sustainability Dimension**			**Location of Study**	**ID References (Table 1)**
		Env	**Soc**	**Eco**		
I1	Increased pollution		v		Brazil, Italy, Philippines, Qatar, UK	1, 10, 19, 20, 22
I2	Loss of land	v			Austria, China, Florida, Italy, Japan, Nigeria, Qatar, UK, Ukraine, USA	10, 18, 19, 25, 30, 36, 39, 40, 41, 43, 44
I3	Water and soil pollution	v			Brazil, China, Florida, Italy, Nigeria, Ukraine	1, 18, 30, 37, 40, 41, 42, 44, 58

No	Impact	Sustainability Dimension			Location of Study	ID References (Table 1)
I4	Decreased quality of human health		v		Austria, China, Italy, Philippines, Spain, UK, Ukraine	17, 20, 22, 23, 25, 31, 37, 39, 41, 48
I5	Reducing profits			v	China, New Zealand, Nigeria, Philippines, Ukraine	16, 17, 23, 39, 44
I6	Increased emissions of the greenhouse gas methane	v			China, Italy, Japan New Zealand, Nigeria, UK, USA	16, 17, 18, 19, 20, 36, 37, 38, 41, 42, 43, 44, 48, 54
I7	Contributing to climate change	v			Austria, China, Italy, Netherland, New Zealand, Nigeria, Spain, Ukraine,	16, 18, 19, 24, 26, 33, 34, 39, 41, 44, 54
I8	Waste of non-renewable energy	v			China, Florida, Japan, Netherland, UK, Ukraine, USA	12, 17, 19, 30, 34, 36, 40, 43
I9	Habitat degradation	v			China, Indonesia, India, Italy, Qatar, UK, Spain,	2, 10, 18, 19, 20, 26, 31, 39, 43
I10	Environmental degradation	v			China, Japan, Lebanon, Philippines, Spain, UK, Ukraine	19, 22, 24, 26, 32, 37, 40, 43, 45
I11	Decreased availability of clean water	v			Austria, China, Florida, Italy, Japan, Netherland, Philippines, Spain, USA, UK, Ukraine	9, 12,19, 20, 23, 24, 25, 30, 34, 36, 39, 40, 41, 42, 43
I12	Hunger/lack of nutrition, nutrition		v		Florida, Italy, Japan, Korea, Nigeria, Philippines, Turkey, UK	18, 20, 22, 26, 27, 28, 30, 43, 44, 47, 48, 51
I13	Depletes natural resources	v			Italy, Japan, Korea, Lebanon, Netherland, New Zealand, Philippines, Spain	16, 20, 22, 28, 31, 32, 33, 42, 43, 47, 54
I14	Poverty		v		China, Indonesia, Iran, Italy, Korea, Nigeria, Philippines, Ukraine	2, 14, 20, 22, 23, 26, 28, 39, 41, 44
I15	Global, regional and national economy			v	Lebanon, Nigeria, Ukraine	26, 39, 44
I16	Monetary loss and waste			v	New Zealand, Turkey	16, 27
I17	Harm the reputation of the Logistics Service Provider		v		China, New Zealand	17, 50
I18	Reducing labor productivity and wages		v		China, Spain	17, 24
I19	Waste management costs			v	Italy, New Zealand	16, 20
I20	Dust generation		v		Brazil	1

3.5. Responses

From many responses to reduce and overcome FLW, 20 FLW response findings are presented in Table 9. The responses were recorded in at least two studies. It is found 8 responses included in the "environment" dimension, 5 responses in the "social" dimension, and 7 responses in the "economy" dimension. Out of the 20 impacts found, there were 11 responses that provided a cumulative contribution of up to 80% based literature mentions (Table 10) and filtered the priority responses using Pareto (Figure 7), so it is used further on the DPSIR model (Figure 8).

"Establishment or development of sustainable public policies" was the most frequently mentioned response by 18 studies representing 12 countries, followed by "environmental awareness/zero waste campaigns" recorded in 13 studies from 11 countries. Both are mentioned together in Italy and the UK. Brazil and Nigeria alluded to the response of "establishing a regulatory governing body" while China, Indonesia, Italy, London and the Philippines referred to "strict implementation or enforcement of policies". Additionally, "investment in facilities and technology" was recorded in 10 studies from 10 countries. This relates to the "waste and sustainable management" responses documented in China, Lebanon, UK.

In the FLW in Supply Chain Stage, "Improved monitoring, traceability" and Improved supply chain management", and "distribution network optimization" were mentioned as mitigation measures to reduce FLW in SCM, which were renowned in the same documents from Korea and China. Meanwhile "process and resource optimization" was identified in China and Japan and "packaging optimization" was identified in Austria,

Korea, Nigeria, Spain. In association with this economic sector, the Netherlands alludes to how to control FLW by "improving product quality". Meanwhile, Korea, Mozambique, New Zealand and the Philippines documented "market and facility management".
Some responses included in the environmental dimension include "recycling", "recovery", "reduce", "reuse", and "rethink". New Zealand and the Philippines mentioned "using environmentally friendly packaging". Meanwhile, Korea in two different documents recorded social actions to "distribute surplus food to charities and NGOs"

Table 8
Component contribution pressure

	Impacts		
Element	**Mentions**	**%**	**Cum %**
I11	15	10%	10%
I6	14	9%	19%
I12	12	8%	27%
I2	11	7%	34%
I4	11	7%	41%
I7	11	7%	49%
I13	11	7%	56%
I9	10	7%	63%
I14	10	7%	69%
I10	9	6%	75%
I3	8	5%	80%
I8	8	5%	86%
I1	5	3%	89%
I5	5	3%	92%
I15	3	2%	94%
I16	2	1%	95%
I17	2	1%	97%
I18	2	1%	98%
I19	2	1%	99%
I20	1	1%	100%

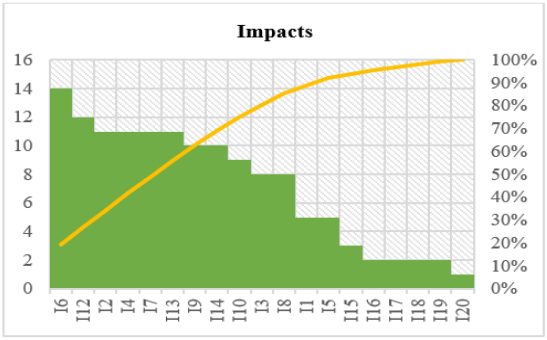

Fig. 6. Pareto diagram of impacts

Table 9
Findings of global FLW responses

No	Responses	Sustainability Dimension			Location of Study	ID pada Table 1.
		Env	Soc	Eco		
R1	Formation or development of sustainable public policy		v		Austria, Brazil, China, Italy, Netherland, New Zealand, Philippines, Spain, Turkey, UK, USA, Mexico	1, 9, 16, 17, 19, 23, 24, 25, 27, 33, 35, 36, 37, 45, 47, 52, 53, 54
R2	Environmental awareness campaign/zero waste	v			Austria, China, Indonesia, Italy, Malawi, Mozambique, New Zealand, Nigeria, Philippines, Qatar, Spain	2, 9, 10, 21, 22, 23, 26, 31, 35, 41, 44, 45, 47
R3	Strict implementation or enforcement of policies		v		China, Indonesia, Italy, Philippines, UK	2, 18, 19, 22, 41, 42, 45
R4	Recycling	v			Austria, India, New Zealand, Philippines	6, 16, 23, 25
R5	Waste management and sustainability	v			China, Lebanon, UK	17, 51, 32, 45, 12
R6	Investment in facilities and technology			v	China, India, Italy, Korea, Lebanon, New Zealand, Qatar, Spain, Turkey,	10, 16, 18, 27, 28, 31, 32, 45, 46, 9
R7	Recovery	v			New Zealand, Nigeria, Philippines	16, 23, 44
R8	Reduce	v			Italy, Lebanon, Philippines	23, 28, 9
R9	Reuse	v			New Zealand	16, 12
R10	Rethink	v			Austria, Philippines	23, 26
R11	Packaging optimization			v	Austria, Korea, Nigeria, Spain	25, 28, 31, 44
R12	Market and facility management			v	Korea, Malawi, Mozambique, New Zealand, Philippines	16, 21, 22, 28, 35

No	Responses	Sustainability Dimension			Location of Study	ID pada Table 1.
R13	Establishment of a regulatory governing body		v		Brazil, Nigeria	1, 44
R14	Use of environmentally friendly packaging	v			New Zealand, Philippines	23, 35
R15	Improved monitoring, traceability		v		China, Italy, Korea, Malawi, Mozambique	17, 18, 21, 52, 53, 24, 51
R16	Improved supply chain management			v	China, Italy, Korea	17, 28, 42
R17	Distribution network optimization			v	China, Korea	17, 28
R18	Improve product quality			v	Netherland	33, 34
R19	Process and resource optimization			v	China, Japan	43, 45
R20	Redistribution of food surpluses to charities and NGOs		v		Korea	28, 24

Table 10
Component contribution responses

	Responses		
Element	**Mention**	**%**	**Cum %**
R1	18	18%	18%
R2	13	13%	32%
R6	10	10%	42%
R15	7	7%	49%
R3	7	7%	56%
R12	5	5%	61%
R5	5	5%	66%
R4	4	4%	70%
R11	4	4%	74%
R7	3	3%	78%
R16	3	3%	81%
R17	3	3%	84%
R8	3	3%	87%
R10	2	2%	89%
R13	2	2%	91%
R14	2	2%	93%
R18	2	2%	95%
R19	2	2%	97%
R20	2	2%	99%
R9	1	1%	100%

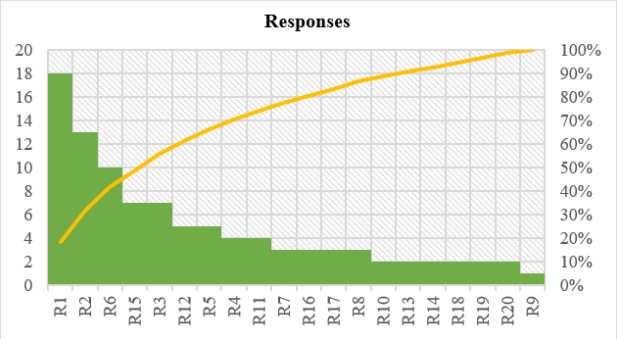

Fig. 7. Pareto diagram of responses

4. Discussion

Based on the results of the FLW study conducted by the Indonesian government, sustainable intervention in FLW is considered essential, by accommodating the three dimensions of sustainability proportionally, which are the social, economic, and environmental dimensions, all stakeholders can be exposed to benefits. If these three dimensions are not accommodated proportionally, there will be disparities between interests so the FLW problem cannot be resolved optimally (Bappenas, 2021). Paired with the findings from studies at the global level in Table 9, it is identified that the response or intervention in FLW interventions tends to be partial, namely only one social, economic, or environmental dimension, leaving unsettled and less optimal homework. In order to optimize the intervention model, it is necessary to integrate these three dimensions into one to design FLW mitigation responses or interventions, especially in Indonesia. So, this research recognizes several drivers and pressures that cause the emergence of FLW in many countries, which have negative impacts on the environment, social and economy, thus encouraging different actions (responses).

A growing global population and modern dietary patterns are the main drivers of today's unsustainable food system (Mokrane et al., 2023). Dealing with a growing population challenges the global food system not only in terms of productivity, but also through associated environmental pressures (Donato et al. 2021). Projections of growth in human population and income suggest that the environmental impact of the food system could be 50-90 percent greater in 2050 compared to 2010, taking us beyond the planetary boundaries that have been defined as a safe operating space for humanity, just to reach supply activities and meeting demand (Springmann, et al., 2018); (Bartelings & Philippidis, 2024).

The high knowledge capacity of consumers can increase awareness, motivation and community involvement in managing FLW and efforts to reduce it. Veselá et al. (2023) and Casonato et al. (2023) identified many drivers of food waste behavior by consumers other than the price of the food itself, so that social awareness is needed to reduce this waste. According to (Stathers & Lamboll, 2022) current knowledge gaps, placing greater emphasis on the importance of coordinated learning, especially in assessing investments in FLW reduction technologies. In agriculture, this lack of knowledge prompted a paper on post-harvest farming in a changing climate (O'Connor et al. 2023). Farmers who only employ outdated growing techniques and harvesting methods and have limited knowledge about the latest technological developments result in poor production results and losses (Surucu-Balci & Tuna, 2022).

In addition, household size also contributes to household food waste as well as household income indicating that the richer a household, the greater the food waste. (Barrion et al. 2023), because the food prepared or purchased is often more than is needed by smaller households. This is also related to human attitudes and behavior, especially consumers who often throw away food to the detriment of the environment (Porat et al., 2018).

The modern world is experiencing significant changes due to economic development, increased purchasing power, eating habits, and increased patterns of food production and consumption (Spang, et al., 2019). According to (Mokrane et al., 2023) Increased food consumption in high-income countries is causing large amounts of edible food to be wasted, which is detrimental because every input at every stage adds value to the food. (Spang, et al., 2019). According to Fami et al. (2019) some studies show that the amount of food wasted at household level varies between 25% in the UK, 42-50% in some European countries, and even 60% in one US state. In the Philippines, DOST-FNRI (2020) reported a total of 57 g (73.8%) of other food was thrown away in a household (Barrion et al., 2023). The emergence of FLW in households largely stems from poor food preparation practices (Schott & Andersson, 2015). This is related to the pressure of inappropriate operational practices which were found recorded in several countries such as China, Florida, Japan, Korea, Mozambique, New Zealand, Nigeria, Philippines and Turkey.

In the agricultural sector, inaccurate operational practices occur during harvest due to damage (either by machines or humans), lack of skilled labor, and failure of technology/machinery, which is very crucial. Thorsem et al. (2022) found that in greenhouse tomatoes, operational errors caused tomatoes were rejected due to damage during harvest or falling to the floor. That is why post-harvest activities are a pressure recorded in the literature and often occur in developing countries due to lack of knowledge and technological investment. In addition, FLW can also occur at processing stages such as using inappropriate materials; manufacturing processes that result in low product quality; storage errors at inadequate temperatures, short storage duration or inaccurate storage; packaging defects, and quality and aesthetic standards (including customer and retail demands and expectations).

FLW drivers and pressures cause negative impacts on the environment, social and economy. The decreasing availability of clean water is a problem in many countries and is most frequently mentioned by literature from Austria, China, Florida, Italy, Japan, the Netherlands, Philippines, Spain, USA, UK and Ukraine. This is in line with (Muth, et al., 2019), FLW has adverse effects on climate, water, and air as well as those related to land use for food production. Apart from that, FLW emissions make a significant contribution to climate change (O'Connor, Skeaff, Bremer, Lucci, & Mirosa, 2023). In Malawi, Climate change has caused extreme rainfall to become heavier and more likely during consecutive storms and cyclones in early 2022 (Otto, et al., 2022). In Indonesia, the average emissions produced are 2,324.24 kg CO2-ek/1-ton FLW, the total potential impact of global warming resulting from FLW over the last 20 years is estimated at 1,702.9 Mton CO2-ek or equivalent to 7.29 % average of GHG emissions in Indonesia for 20 years (BAPPENAS, 2021).

Besides from having a negative impact on the environment, FLW also has a negative social impact, including increased pollution, decreased human health, hunger, malnutrition, and poverty. This is in line with Barrion et al. (2023) that as a social issue, FLW adds to ongoing concerns about the increasing prevalence of malnutrition worldwide. In Indonesia, the energy content lost due to FLW generation from 2000 to 2019 was 618–989 kcal/capita/day or equivalent to the energy needs of around 61–125 million average Indonesians (29–47% of Indonesia's population) (BAPPENAS, 2021). According to Barrion et al. (2023). Concerns regarding FLW are multifaceted and affect all aspects of the food system. Its reduction will help address many issues related to hunger, malnutrition and food security.

Furthermore, FLW also has a negative impact on the global, regional and national economy because FLW can reduce profits, lead to monetary losses and waste, and increase financing for waste management. According to Kotykova & Babych (2019) The economic consequences of food loss and waste are demonstrated by significant economic losses, which equate to wasted losses and inefficient investments, as well as lost income. The number of economic losses in Ukraine in 2016 amounted to approximately EUR 991.9 million, which was 2.8% of Ukraine's budget in 2017, as well as unmet revenues amounting to EUR 2,224.5 million. In Indonesia, losses caused by FLW are 213–551 trillion rupiah/year or equivalent to 4%-5% of Indonesia's GDP/year (BAPPENAS, 2021).

From the many findings related to drivers, pressures, impacts, and responses from the literature review from 29 countries, the components that contributed 80% to FLW

were taken using a Pareto diagram based on the number of mentions in 54 studies. Furthermore, these findings have been identified based on their sustainability dimensions as a framework for FLW mitigation interventions in Indonesia. Two different frameworks were proposed for food loss (Figure 8) and food waste (Figure 9) to make it easier for stakeholders to intervene in mitigating food loss and food waste according to their respective characteristics. In the food industry sector supply chain, food loss mitigation interventions are carried out from the production to distribution stages, while food waste mitigation interventions are carried out from the distribution to consumption stages. Therefore, the characteristics are very different regarding drivers, pressures, impacts, and intervention responses.

Three stakeholders are emphasized in the intervention in this study, which are government, producers, and consumers. Furthermore, the responses are plotted that each stakeholder can make in the DPSIR framework, as depicted in Figure 8 and Figure 9.

Both producers and consumers can benefit from reduced FLW because producers with the same amount of resources can sell more and at the same time have fewer goods to throw away, thereby reducing disposal costs. In addition, market prices can decrease so that consumers gain benefits since they can manage to buy cheaper food products (Carillo, 2021). In addition, both producers and consumers must be aware of the amount of waste generated and the consequences it may have, so that they can take reasonable measures to obtain real benefits for themselves.

According to Stathers and Lamboll (Stathers & Lamboll, 2022) governments are responsible for setting public policy goals and objectives, which significantly influence policy design and implementation. The formation or development of FLW policies requires extensive knowledge of synergies, trade-offs, and potential unintended consequences. In some cases, improving sustainability policies requires context-specific information about which value chains to focus on and identifying intervention points along the supply chain (Cattaneo et al.,). Donato & Oscar (2021) states that innovative approaches are needed to support effective policy efforts.

FLW is multi-faceted, so reducing it requires collaborative efforts from various institutions and stakeholders to continue launching awareness campaigns, implementing the concept of using less or no food waste, improving food storage methods, as well as developing FLW measurement protocols where targets are set and FLW is monitored regularly. periodically (Barrion et al., 2023). However, it is important to recognize that these improvements in terms of reducing environmental impacts can, in turn, give rise to new impacts from an economic and social perspective, thus emphasizing the need to be active in the process of continuous improvement in all three domains (Domingo-Morcillo et al., 2024).

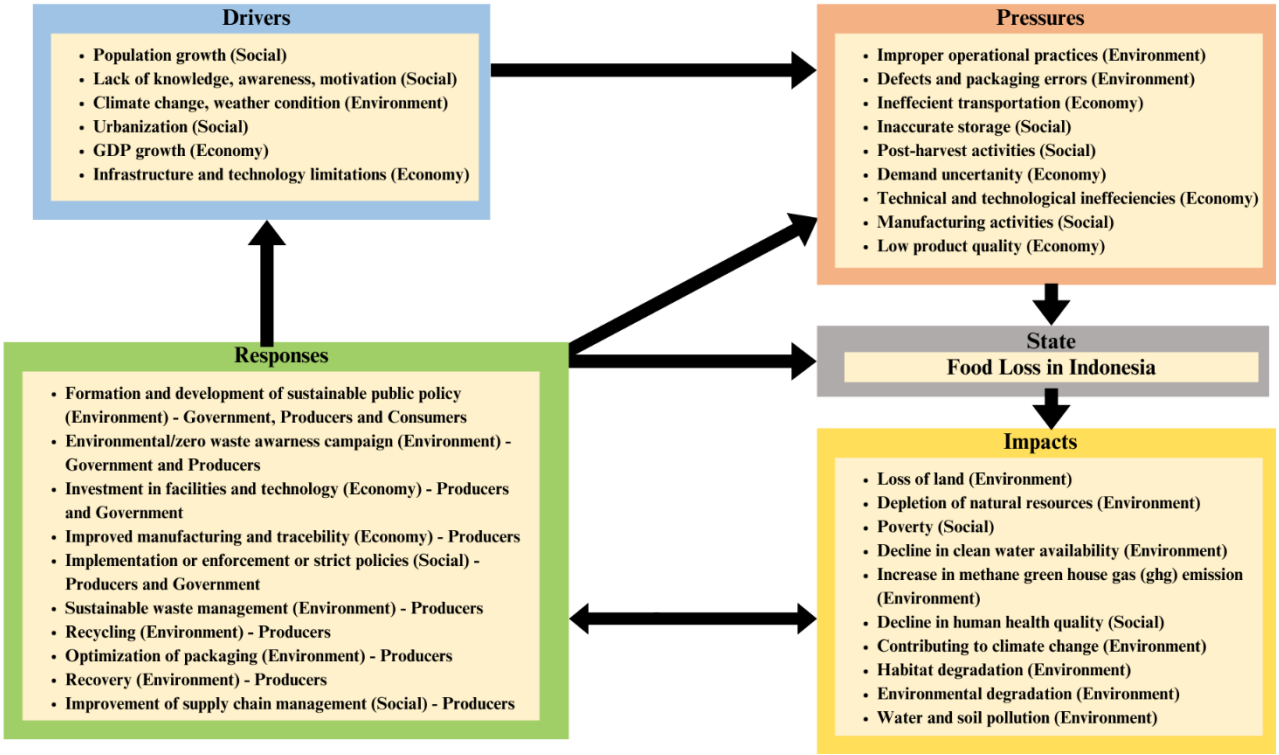

Fig. 8. The DPSIR framework recommendation for Food Loss in Indonesia.

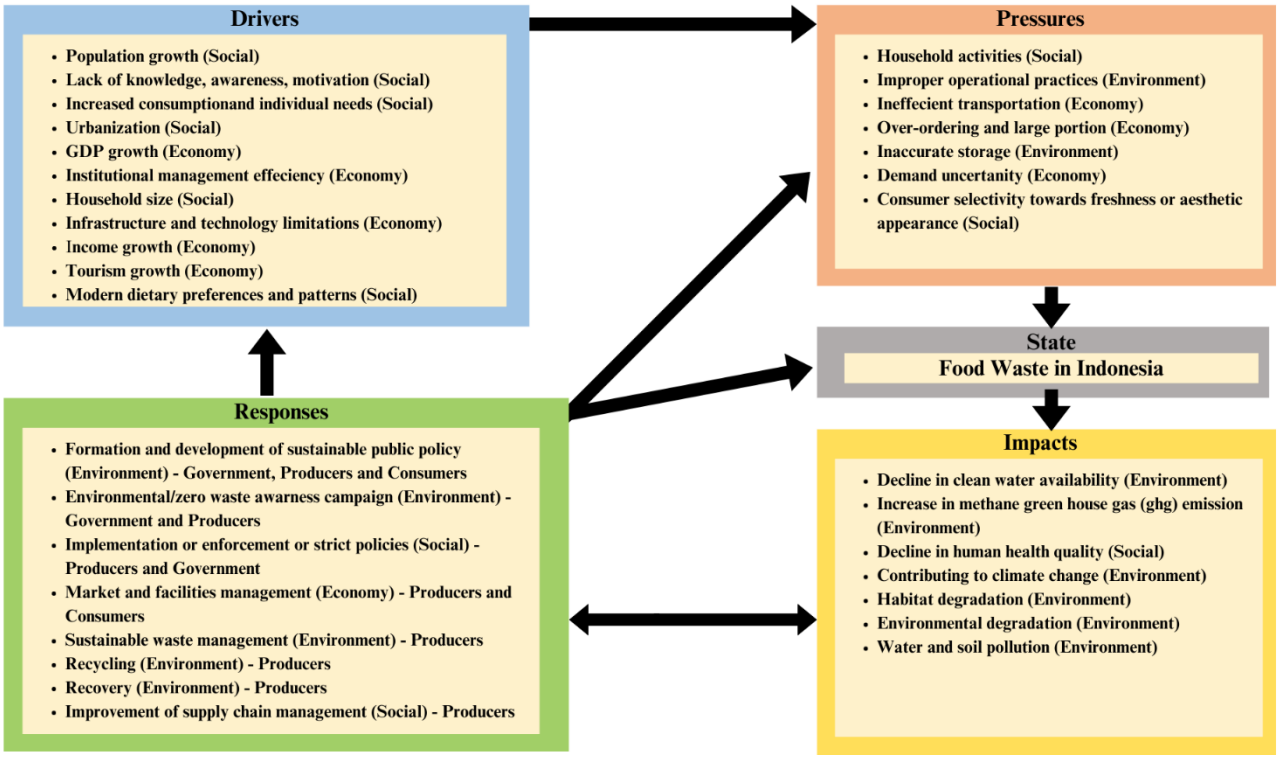

Fig. 9. The DPSIR framework recommendation for Food Waste in Indonesia.

Figure 8 shows the DPSIR framework recommendation for food loss in Indonesia which was designed based on global FLW. These findings are classified into sustainability interventions such as social, economic, and environmental. Especially for responses/interventions, they are also identified according to the stakeholders. The results revealed 6 drivers, 9 pressures, 10 impacts, and 10 responses. These drivers consist of three social dimensions, namely population growth; lack of knowledge, awareness, motivation; and urbanization. The other two emerge from the economic dimension, namely GDP growth, and infrastructure and technology limitations. Another driver is the environmental dimension, namely climate change/weather conditions.

Figure 9 shows the DPSIR framework recommendation for food waste in Indonesia. It comes up with 11 drivers, 7 pressures, 7 impacts, and 8 responses. The drivers include 6 social dimensions, which are population growth; increased consumption and individual needs; household size; modern dietary preferences and patterns; lack of knowledge, awareness, motivation; and urbanization. Then, the other 5 come from the economic dimension, namely GDP growth, institutional management efficiency, income growth, tourism growth, and infrastructure and technology limitation.

In its study, BAPPENAS (2021) identified 18 factors and causes of FLW in Indonesia which are divided into 10 direct causes and 8 indirect drivers. Direct causes include lack of implementation of good handling practices (GHP), less than optimal quality of storage space, excess portions and consumer behavior, technological limitations, poor harvesting techniques, poor packaging/container quality, misinterpretation of expiry time & good before remarks, unoptimized food preparation, inappropriate harvesting time, and excessive production. Meanwhile, indirect causes also recorded include market quality standards and consumer preferences, lack of information/education for food workers and consumers, market competition and limited consumer purchasing power, limited infrastructure, market prices, less efficient supply chains, lack of food waste regulations, and limitations. access to capital. Out of these 18 drivers, all of them emerge as causes that also exist in many countries in the world. It is proven that all the drivers recorded by BAPPENAS are also the drivers and pressures found in the literature review of this study. Moreover, the FLW response found in this study can be considered for adoption in Indonesia.

5. Conclusion

Indonesia is claimed to be the second largest FLW producing country in the world which is 40% of the total other types of waste, estimated at 300 kg per capita per year. However, until now Indonesia does not have comprehensive information and strategies regarding FLW, especially at the national level (BAPPENAS, 2021). This research aims to design a Sustainability Intervention Model as a study for FLW mitigation in

Indonesia. Drivers, Pressures, Impacts and Responses of global FLW were studied from 54 pieces of literature from 29 countries whose contribution was then identified using Pareto analysis based on the number of mentions of each component. The components that have 80 cumulative percentages are then taken. We identified findings based on their sustainability dimensions for a framework to address and improve FLW (Food Loss and

Waste) in Indonesia. Two different frameworks are proposed for food loss and food waste to facilitate stakeholders in intervening in the mitigation of food loss and food waste according to their respective characteristics. So, the findings consist of 6 drivers, 9 pressures, 10 impacts and 10 responses for food loss. Meanwhile, there are 11 drivers, 7 pressures, 7 impacts, and 8 responses for food waste. Ministry of National Development Planning (BAPPENAS) in 2021, conduct study report related FLW in Indonesia and found 18 factors and causes of FLW. Out of these 18 drivers, all of them have become causes that also exist in many countries in the world that became our framework in this study.

This paper also offers managerial implications for stakeholders along the food supply chain. Not all stakeholders have the same level of legitimacy, power, and urgency because their competencies of latent, potencies, and importance are positioned at different levels. The stakeholders are classified into three types, which are governments, producers, and consumers. Producers are responsible for intervention from the production process to distribution before the product reaches the consumer, then the next phase is under the consumer's responsibility. The government is responsible for making regulations and policies that support its intervention process. Producers and consumers must play a more active role in implementing the recommended strategies to reduce losses on both sides. Later, these 2 stakeholders can be proactively connected in participating in FLW mitigation interventions, the government's presence is very urgent in bridging the two parties. The government can channel them through legally binding policies and regulations regarding their respective responsibilities in FLW mitigation interventions in each food supply chain. Lastly, to increase their interest, the government needs to create incentive and reward programs for stakeholder groups who massively carry out FLW mitigation intervention efforts in Indonesia.

Future studies can conduct similar research with the utilization of more general keywords such as "food loss and waste" in the title, so that the literature used can be richer, then analyze all these studies using the DPSIR model, because basically each FLW study discusses at least one element of DPSIR, although it excludes drivers, pressures, impacts, or responses in its study.

Acknowledgment

Many thanks are expressed to the Directorate of Research, Technology and Community Service, Ministry of Education, Culture, Research and Technology of the Republic of Indonesia, who has funded this research under the Regular Fundamental Research scheme (Grant No.: 107/E5/PG.02.00.PL/2024).

References

Abbade, E. B. (2020). Estimating the nutritional loss and the feeding potential derived from food losses worldwide. World Development, 134(October), 105038.

Aburime, L. (2023). The State of Food Loss And Waste in Nigeria: Causes, Impacts, Efforts to Reduce The Menace And Way Forward. Nigerian Journal of Nutritional Sciences, 44(2), 48-54.

Agramont, A., Cauwenbergh, N. v., Griesven, A. v., & Craps, M. (2022). Integrating spatial and social characteristics in the DPSIR framework for the sustainable management of river basins: case study of the Katari River Basin, Bolivia. Water International , 47(1), 8-29.

Albalate-Ramírez, A., Rueda-Avellaneda, J. F., López-Hernández, B. N., Alcalá-Rodríguez, M. M., García-Balandrán, E. E., Evrard, D., & Rivas-García, P. (2024). Geographic life cycle assessment of food loss and waste management in Mexico: The reality of distribution and retail centers. Sustainable Production and Consumption, 48(July), 289-300.

BAPPENAS. (2021). Studi Report Food Loss and Waste in Indonesia to Supporting the Implemention of Circular Economy and Low Carbon Development.

Barrion, A. S., Calayag, J. A., Nguyen-Orca, M. F., & Melo-Rijik, M. N. (2023). Food loss and waste in the Philippines: a literature review. Food Research, 7(6), 278-289.

Bartelings, H., & Philippidis, G. (2024). A novel macroeconomic modelling assessment of food loss and waste in the EU: An application to the sustainable development goal of halving household food waste. Sustainable Production and Consumption, 45(March), 567-581.

Benyam, A. (., Soma, T., & Fraser, E. (2021). Digital agricultural technologies for food loss and waste prevention and reduction: Global trends, adoption opportunities and barriers. Journal of Cleaner Production, 323(November), 129099.

Boz, Z., & Sand, C. K. (2020). A systematic analysis of the overall nutritional contribution of food loss and waste in tomatoes, spinach, and kidney beans as a function of processing. Journal of Food Process Engineering, 43(11).

Brunhara, J. P., Macedo, K. G., Das, T. K., & Innocentini, M. D. (2023). A Driving Force-Pressure-State-Impact-Response (DPSIR) tool to help waste pickers ' cooperatives self-evaluate their environmental and economic performance. Hygiene and Environmental Health Advances, 6(June), 100054.

Casonato, C., García-Herrero, L., Caldeira, C., & Sala, S. (2023). What a waste! Evidence of consumer food waste prevention and its effectiveness. Sustainable Production and Consumption, 41(October), 305-319.

Cattaneo, A., Federighi, G., & Vaz, S. (2021). The environmental impact of reducing food loss and waste: A critical assessment. Food Policy, 98, 101890.

Cattaneo, A., Sánchez, M. V., Torero, M., & Vos, R. (2021). Reducing food loss and waste: Five challenges for policy and research. Food Policy, 98(January), 101974.

Chalak, A., Abiad, M. G., Diab, M., & Nasreddine, L. (2019). The determinants of household food waste generation and its associated caloric and nutrient losses: The case of Lebanon. PLoS ONE, 14(12).

Chalak, A., Abou-Daher, C., Chaaban, J., & Abiad, M. G. (2016). The global economic and regulatory determinants of household food waste generation: A cross-country analysis. Waste Management, 48(February), 418-422.

Coudard, A., Corbin, E., Koning, J. d., Tukker, A., & Mogollón, J. M. (2021). Global water and energy losses from consumer avoidable food waste. Journal of Cleaner Production, 326(December), 129342.

Domingo-Morcillo, E., Escrig-Olmedo, E., Rivera-Lirio, J. M., & Muñoz-Torres, M. J. (2024). Analyzing the suitability of LCIA methods to foster the most beneficial food loss and waste prevention action in terms of environmental sustainability. Environmental Impact Assessment Review, 107.

Donato, M. D., & Óscar, Ó. C. (2021). Household food metabolism: Losses, waste and environmental pressures of food consumption at the regional level in spain. Foods, 10(6), 1166.

Dora, M., Biswas, S., Choudhary, S., Nayak, R., & Irani, Z. (2021). A system-wide interdisciplinary conceptual framework for food loss and waste mitigation strategies in the supply chain. Industrial Marketing Management, 93(February), 492-508.

DOST-FNRI. (2020). Expanded National Nutrition Survey: 2019 Food Consumption Survey: Household Level.

Fami, H. S., Aramyan, L. H., Sijtsema, S. J., & Alambaigi, A. (2019). Determinants of household food waste behavior in Tehran city: A structural model. Resources, Conservation and Recycling, 143(April), 154-166.

FAO. (2019). The State of Food and Agriculture. Moving Forward on Food Loss and Waste Reduction. Retrieved from www.fao.org/3/ca6030en/ca6030en.pdf

Gatto, A., & Chepeliev, M. (2024). Global food loss and waste estimates show increasing nutritional and environmental pressures. Nature Food, 5(2), 136-147.

Goossens, Y., Berrens, P., Custers, K., Hemelryck, S. V., Kellens, K., & Geeraerd, A. (2019). How origin, packaging and seasonality determine the environmental impact of apples, magnified by food waste and losses. International Journal of Life Cycle Assessment, 24(4), 688-693.

Gustavsson, J., Cederberg, C., & Sonesson, U. (2011). Global Food Losses and Food Waste. Save Food Congress, pp. SIK – The Swedish Institute for Food and Biotechnology.

Hajra, R., Mitra, R., & Ghosh, T. (2023). Sustainability assessment of Indian Sundarban delta islands using DPSIR framework in the context of natural hazards. Natural Hazards Research, 76-88.

Idris, P. S., Musa, S. F., & Sumardi, W. H. (2022). Halal-Tayyiban and Sustainable Development Goals: A SWOT Analysis. International Journal of Asian Business and Information Management (IJABIM), 16.

Ishangulyyev, R., Kim, S., & Lee, L. S. (2019). Understanding food loss and waste-why are we losing and wasting food? Foods, 8(8), 297.

Jia, L., Zhang, J., & Qiao, G. (2023). Scale and Environmental Impacts of Food Loss and Waste in China—A Material Flow Analysis. International Journal of Environmental Research and Public Health, 20(1), 460.

Jorge-García, D., & Estruch-Guitart, V. (2022). Comparative analysis between AHP and ANP in prioritization of ecosystem services - A case study in a rice field area raised in the Guadalquivir marshes (Spain). Ecological Informatics, 70(September), 101739.

Khan, A. H., Sharholy, M., Alam, P., Al-Mansour, A. I., Kamal, K. A., Alam, S., . . . Naddeo, V. (2022). Evaluation of cost benefit analysis of municipal solid waste management systems. Journal of King Saud University - Science, 34(4), 101997.

Khan, M., & Al-Ghouti, M. A. (2021). DPSIR framework and sustainable approaches of brine management from seawater desalination plants in Qatar. Journal of Cleaner Production, 319(October), 128485.

Kotykova, O., & Babych, M. (2019). Economic impact of food loss and waste. Agris On-line Papers in Economics and Informatics, 11(3), 55-71.

Kotykova, O., Babych, M., & O. K. (2021). Environmental Impacts of Food Loss and Waste: Land Degradation. Future of Food: Journal on Food, Agriculture and Society, 9(1), 1-17.

Kristianto, A. H., & Nadapdap, J. P. (2021). Dinamika Sistem Ekonomi Sirkular Berbasis Masyarakat Metode Causal Loop Diagram Kota Bengkayang. Sebatik, 25(1), 59-67.

Ladi, T., Mahmoudpour, A., & Sharifi, A. (2022). Assessing environmental impacts of transportation sector by integrating DPSIR framework and X-Matrix. Case Studies on Transport Policy, 10(1), 434-443.

Li Xue, X. L., Lu, S., Cheng, G., Hu, Y., Liu, J., Dou, Z., . . . Liu, G. (2021). China's food loss and waste embodies increasing environmental impacts. Nature Food, 2(7), 519-528.

Li, C., Bremer, P., Harder, M. K., Lee, M. S., Parker, K., Gaugler, E. C., & Mirosa, M. (2022). A systematic review of food loss and waste in China: Quantity, impacts and mediators. Journal of Environmental Management, 303(February), 114092.

Luo, N., Olsen, T. L., & Liu, Y. (2021). A Conceptual Framework to Analyze Food Loss and Waste within Food Supply Chains:An Operations Management Perspective. Sustainability, 13(2), 927.

Malmir, M., Javadi, S., Moridi, A., Neshat, A., & Razdar, B. (2021). A new combined framework for sustainable development using the DPSIR approach and numerical modeling. Geoscience Frontiers, 12(4), 101169.

March, M. D., Toma, L., Thompson, B., & Haskell, M. J. (2019). Food Waste in Primary Production: Milk Loss With Mitigation Potentials. Frontiers in Nutrition, 6.

Medveďová, M., Kapsdorferová, Z., Švikruhová, P., & Zábojníková, V. (2022). Social responsibility in reducing food losses and waste in the Slovak Republic: the role of policies - the responsibility of all. Slovak Journal of Food Sciences, 16, 219.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRIsMa statement. International Journal of Surgery, 8(5), 336-341.

Mokrane, S., Buonocore, E., Capone, R., & Franzese, P. P. (2023). Exploring the Global Scientific Literature on Food Waste and Loss. Sustainability, 15(6), 4757.

Mopera, L. E. (2016). Food loss in the food value chain: T he Philippine agriculture scenario. Journal of Developments in Sustainable Agriculture, 11(1), 8-16.

Munesue, Y., & Masui, T. (2019). The impacts of Japanese food losses and food waste on global natural resources and greenhouse gas emissions. Journal of Industrial Ecology, 23(5), 1196-1210.

Munir, A., & Fadhilah. (2023). Climate Change and Food Insecurities: The Importance of Food Loss and Waste Reduction in Indonesia. The 4th International Conference on Global Issues for Infrastructure, Environment and Socio-Economic Development, 1134, p. 012040.

Muth, M. K., Birney, C., Cuéllar, A., Finn, S. M., Freeman, M., Galloway, J. N., . . . Zoubek, S. (2019). A systems approach to assessing environmental and economic effects of food loss and waste interventions in the United States. Science of The Total Environment, 685(October), 1240-1254.

O'Connor, J., Skeaff, S., Bremer, P., Lucci, G., & Mirosa, M. (2023). A critical review of on-farm food loss and waste: future research and policy recommendations. Renewable Agriculture and Food Systems, 38.

Oliveira, M. M., Lago, A., & Magro, G. P. (2021). Food loss and waste in the context of the circular economy: a systematic review. Journal of Cleaner Production, 294(April), 126284.

Otto, F. E., Zachariah, M., Wolski, P., Pinto, I., Barimalala, R., Nhamtumbo, B., . . . Arrighi, J. (2022). Climate change increased rainfall associated with tropical cyclones hitting highly vulnerable communities in Madagascar, Mozambique & Malawi. Retrieved from https://www.worldweatherattribution.org/wp-content/uploads/WWA-MMM-TS-scientific-report.pdf

Pastolero, A., & Sassi, M. (2022). Food loss and waste accounting: the case of the Philippine food supply chain. Bio-Based and Applied Economics, 11(3), 207-218.

Pastolero, A., & Sassi, M. (2023). Food loss and waste in the Philippines: a literature review. Food Research, 7(6), 278-289.

Popat, M., Cachoa, O., Griffitha, G., & Mountera, S. (2022). Food loss and waste in maize in Mozambique and its economic impacts: a system dynamics assessment approach. Agrekon, 61(3), 339-359.

Porat, R., Lichter, A., Terry, L. A., Harker, R., & Buzby, J. (2018). Postharvest losses of fruit and vegetables during retail and in consumers' homes: Quantifications, causes, and means of prevention. Postharvest Biology and Technology, 139(May), 135-149.

Quevedo, J. M., Lukman, K. M., Ulumuddin, Y. I., Uchiyama, Y., & Kohsaka, R. (2023). Applying the DPSIR framework to qualitatively assess the globally important mangrove ecosystems of Indonesia: A review towards evidence-based policymaking approaches. Marine Policy, 147(January), 105354.

Quevedo, J. M., Uchiyama, Y., & Kohsaka, R. (2021). A blue carbon ecosystems qualitative assessment applying the DPSIR framework: Local perspective of global benefits and contributions. Marine Policy, 128, 104462.

Rajeh, C., Imad P. Saoud, S. K., Naalbandian, S., & Abiad, M. G. (2020). Food loss and food waste recovery as animal feed: a systematic review. Journal of Material Cycles and Waste Management, 23, 1-17.

Read, Q. D., Brown, S., Cuéllar, A. D., Finn, S. M., Gephart, J. A., Marston, L. T., . . . Muth, M. K. (2020). Assessing the environmental impacts of halving food loss and waste along the food supply chain. Science of The Total Environment, 712(April), 136255.

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V. K., . . . Jackson, P. (2019). Review: Consumption-stage food waste reduction interventions – What works and how to design better interventions. Food Policy, 83(February), 7-27.

Sagi, V., & Gokarn, S. (2023). Determinants of reduction of food loss and waste in Indian agri-food supply chains for ensuring food security: A multi-stakeholder perspective. Waste Management & Research, 41(3), 575-584.

Sahani, N. (2021). Application of hybrid SWOT-AHP-FuzzyAHP model for formulation and prioritization of ecotourism strategies in Western Himalaya, India. International Journal of Geoheritage and Parks, 9(3), 349-362.

Salihoglu, G., Salihoglu, N. K., Ucaroglu, S., & Banar, M. (2018). Food loss and waste management in Turkey. Bioresource Technology, 248(Part A), 88-99.

Schott, A. B., & Andersson, T. (2015). Food waste minimization from a life-cycle perspective. Journal of Environmental Management, 147(January), 219-226.

Soesanto, Q. M., Utomo, L. R., Rachman, I., & Matsumoto, T. (2021). Life Cycle Assessment and

Cost Benefit Analysis of Municipal Waste Management Strategies. Journal of Environmental Science and Sustainable Developmen, 4(1), 69-96.

Spang, E. S., Moreno, L. C., Pace, S. A., Achmon, Y., Donis-Gonzalez, I., Gosliner, W. A., . . . Tomich, T. P. (2019). Food Loss and Waste: Measurement, Drivers, and Solutions. Annual Review of Environment and Resources, 44, 117-156.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., . . . Zur. (2018). Options for keeping the food system within environmental limits. Nature, 562, 519-52.

Stathers, T., & Lamboll, R. (2022). Exploring the complex relationships between food loss and waste, climate change, and the environment to support informed sustainable food system transformation decisions with a focus on sub-Saharan Africa. Enterprise Development & Microfinance, 33(4).

Surucu-Balci, E., & Tuna, O. (2022). The role of collaboration in tackling food loss and waste: Salient stakeholder perspective. Journal of Cleaner Production, 367(September), 133126.

Swangjang, K., & Kornpiphat, P. (2021). Does ecotourism in a Mangrove area at Klong Kone, Thailand, conform to sustainable tourism? A case study using SWOT and DPSIR. Environment, Development and Sustainability, 23, 15960–15985.

Thorsen, M., Mirosa, M., & Skeaff, S. (2022). A Quantitative and Qualitative Study of Food Loss in Glasshouse-Grown Tomatoes. Horticulturae, 8(1), 39.

Veselá, L., Králiková, A., & Kubíčková, L. (2023). From the shopping basket to the landfill: Drivers of consumer food waste behaviour. Waste Management, 169(September), 157-166.

Vittuari, M., Herrero, L. G., Masotti, M., Iori, E., Caldeira, C., Qian, Z., . . . Nohlen, H. (2023). How to reduce consumer food waste at household level: A literature review on drivers and levers for behavioural change. Sustainable Production and Consumption, 38(June), 104-114.

Wohner, B., Pauer, E., Heinrich, V., & Tacker, M. (2019). Packaging-related food losses and waste: An overview of drivers and issues. Sustainability (Switzerland), 11(1), 264.

Wuni, I. Y. (2022). Mapping the barriers to circular economy adoption in the construction industry: A systematic review, Pareto analysis, and mitigation strategy map. Building and Environment, 223(September), 109453.

Wuni, I. Y., Shen, G. Q., & Osei-Kyei, R. (2019). Scientometric review of global research trends on green buildings in construction journals from 1992 to 2018. Energy and Buildings, 190(May), 69-85.

Xue, L., Liu, X., Lu, S., Cheng, G., Hu, Y., Liu, J., . . . Liu, G. (2021). China's food loss and waste embodies increasing environmental impacts. Nature Food, 2, 519-528.

Xue, L., Song, G., & Liu, G. (2024). Wasted Food, Wasted Resources? A Critical Review of Environmental Impact Analysis of Food Loss and Waste Generation and Treatment. Environmental Science & Technology, 58(17), 7240–7255.

Yan, H., Song, M.-J., & Lee, H.-Y. (2021). A Systematic Review of Factors Affecting Food Loss and Waste and Sustainable Mitigation Strategies: A Logistics Service Providers' Perspective. Sustainability, 13(20), 11374.

Yanti, R., Qurtubi, Kusrini, E., & Helia, V. N. (2023). The quality of performance as an impact by the implementation of e-procurement: A systematic literature review. 2680, p. 020191. AIP Conference Proceedings.