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EDITED BY
Lourdes Maria Correa Cabral,
Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

REVIEWED BY
Stuart W. Bunting,
Bunting AAARCS, Glemsford, Suffolk, United Kingdom
Zeljko Vasko,
University of Banja Luka, Bosnia and Herzegovina

*CORRESPONDENCE
Christian-Yves Amato-Ali
christianamatoali@gmail.com

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Food loss in Pacific Island Countries: a scoping review of the literature

Christian-Yves Amato-Ali[1]*, Viliamu Iese[2], Gayathri Mekala[2], Daniela Hidalgo[3] and Hilda Sakiti-Waqa[1]

[1]Pacific Center for Environment and Sustainable Development, The University of the South Pacific, Suva, Fiji, [2]School of Agriculture, Food and Ecosystem Sciences, The University of Melbourne, Dookie Campus, VIC, Australia, [3]Sippy Downs Campus, The University of the Sunshine Coast, Maroochydore, QLD, Australia

Food loss and waste pose significant challenges to global food security, economic development, and environmental sustainability. Pacific Island Countries (PICs), with limited resources, being geographically isolated, and vulnerable to climate change, face unique challenges when it comes to the issue of food loss. This scoping review aims to systematically map the literature on food loss in PICs, addressing knowledge gaps and understanding specific methodological aspects. The review utilizes the PRISMA-ScR process to identify, categorize, and synthesize relevant literature, offering a comprehensive overview of the existing evidence. Studies focusing on food loss in PICs published in English from 2011 to 2023 were included. Exclusion criteria considered studies conducted outside PICs, those lacking food loss reduction interventions, and non-peer-reviewed sources. A comprehensive literature search was conducted using the databases of JSTOR, Scopus, Science Direct and Web of Science. A total of 5,787 studies for food loss interventions were identified and out of these only 49 met the inclusion criteria. A notable increase in publications from 2011, with a significant surge in 2018 and 2019, indicate a growing interest on the topic. The review reveals a limited focus on this issue across individual PICs and underscores the need for more localized expertise in the region. The review also highlights critical inefficiencies in PIC food supply chains and the need for more studies outside the common root crop agricultural system. The scoping review identified three thematic categories addressing food loss in PICs, namely., the lack of infrastructure and need for innovative technology for post-harvest management; increased vulnerability to climate change and postharvest risks of newer convenient markets. The findings underscore the need for holistic and context-specific approaches to create resilient and sustainable food systems in the Pacific, providing valuable insights for researchers, policymakers, and practitioners involved in addressing these challenges.

KEYWORDS

postharvest, food security, circular economy, Pacific Islands, sustainable food systems

1 Introduction

Food loss and waste is a global challenge that affects food security, economic development, and the environment. It diminishes the food systems' overall productivity, increases consumer expenses and decreases producer income (Schuster and Torero, 2016). It is estimated that one third of all food produced globally, which roughly equates to 1 trillion USD or 1.3 billion tons, is wasted or lost at various stages in the supply chain every year, rotting in transportation or in retailer and consumer garbage bins or spoiling during post-harvest processes (Zeineddine et al., 2021). The decision to undertake a scoping review is grounded in the need to address specific methodological, conceptual and knowledge gaps within the current literature on food loss in PICs (Atzori et al., 2024; Loke and Leung, 2015; Thow et al., 2022; Gunasekera et al., 2017). Roughly 40% of food loss occurs at post-harvest and processing levels for developing countries, including the Pacific Island Countries (PICs) (Halavatau, 2016) due to lack of storage facilities (Thow et al., 2022). Studies focusing on food loss in the Pacific focus primarily on post-harvest losses and not on pre-harvest on-farm losses, a key area missed especially for developing countries. In the Pacific, food loss is a particularly pressing issue due to inadequate infrastructure, limited access to markets and market information, and the impacts of climate change (Gunasekera et al., 2017).

In the context of PICs, food loss is defined as any change in the availability, edibility, wholesomeness, or quality of the foo-d that prevents human consumption (Loke and Leung, 2015). Food loss in the Pacific region is significantly exacerbated by the persistent high tropical temperatures, prolonged market storage periods and the resultant increased exposure risking more perishable goods to these challenging environmental factors (Underhill et al., 2017). PICs, which comprise of a diverse set of island nations in the Pacific Ocean, have limited resources, geographically isolated, and vulnerable to climate change (Thomas et al., 2019; Wairiu, 2017).

The aim of this scoping review is to systematically map the literature on food loss in PICs, utilizing the PRISMA-ScR (preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews) methodology to map and understand the knowledge gaps. PRISMA-ScR framework offers a transparent and rigorous approach for conducting scoping reviews, ensuring methodological precision, and enhancing the replicability of the

Full Boolean Search String

Science Direct and JSTOR

ALL=("Food Loss" OR "Horticultural Loss")

AND

ALL=(Literacy OR knowledge OR farming systems OR systems OR food chains OR food systems OR value chains OR food production systems OR production systems OR supply system OR food chain OR agri-food chain)

AND

ALL=(Guam OR {Pacific Island} OR Melanesia* OR Micronesia* OR Polynesia* OR {Cook Island*} OR Fiji* OR Kiribati OR {Mariana Islands} OR {Marshall Islands} OR Nauru OR {New Caledonia} OR Niue* OR Palau OR {Papua New Guinea*} OR Pitcairn OR Samoa* OR {Solomon Island*} OR Tokelau OR Tonga* OR Tuvalu* OR Vanuatu OR {Wallis and Futuna})

Web Of Science

(((TS=((Food Loss OR Horticultural Loss))) AND TS=((Literacy OR knowledge OR farming systems OR systems OR food chains OR food systems OR value chains OR food production systems OR production systems OR supply system OR food chain OR agri-food chain))) AND TS=((Guam OR {Pacific Island} OR Melanesia* OR Micronesia* OR Polynesia* OR {Cook Island*} OR Fiji* OR Kiribati OR {Mariana Islands} OR {Marshall Islands} OR Nauru OR {New Caledonia} OR Niue* OR Palau OR {Papua New Guinea*} OR Pitcairn OR Samoa* OR {Solomon Island*} OR Tokelau OR Tonga* OR Tuvalu* OR Vanuatu OR {Wallis and Futuna}))

Scopus

(TITLE-ABS-KEY ("food loss" OR "horticultural loss") AND ((literacy OR knowledge OR farming AND systems OR systems OR food AND chains OR food AND systems OR value AND chains OR food AND production AND systems OR production AND systems OR supply AND system OR food AND chain OR agri-food AND chain)) AND ((guam OR {Pacific Island} OR melanesia* OR micronesia* OR polynesia* OR {Cook Island*} OR fiji* OR kiribati OR {Mariana Islands} OR {Marshall Islands} OR nauru OR {New Caledonia} OR niue* OR palau OR {Papua New Guinea*} OR pitcairn OR samoa* OR {Solomon Island*} OR tokelau OR tonga* OR tuvalu* OR vanuatu OR {Wallis and Futuna}))

FIGURE 1
Full Boolean search string across Science Direct, JSTOR, Web of Science, and Scopus databases.

study (Tricco et al., 2018). The lack of country-specific data on food loss is a limitation to researchers as it can only be approached instead by estimates from regional organizations (Atzori et al., 2024).

The research question guiding this scoping review is: "What is the nature and extent of food loss in the food systems in Pacific Island Countries?", examining their climate vulnerable and geographically isolated food systems. It examines peer-reviewed literature between the years 2011 and 2023, identifying strategies to reduce food loss. The findings of this scoping review will provide insights for researchers, policy- makers and practitioners involved in addressing food loss in PICs. By identifying key thematic areas, the current knowledge will be synthesized to understand the challenges faced by PICs, the effectiveness of current interventions and strategies, and the critical gaps that need to be addressed to promote the establishment of resilient and sustainable food systems.

2 Methodology

This scoping review followed the first five stages of the six-stage process outlined in the PRISMA-ScR protocol (Page et al., 2021) which provides a systematic and transparent approach to conducting scoping reviews.

1. Identifying the research question: the research question guiding this scoping review is: "What is the nature and extent of food loss in the existing literature on food systems in Pacific Island Countries?" This question focuses on understanding the existing evidence, identifying and assessing the efficacy of current interventions and strategies, uncovering new knowledge that could lead to more research or practical interventions that address food loss within Pacific food systems.
2. Conducting a comprehensive literature search: a comprehensive search strategy was developed in collaboration with a qualified research librarian. The search strategy was developed in December 2022 and was used to search electronic databases JSTOR, Scopus, Science Direct, Web of Science using relevant keywords such as "food loss", "Pacific Island Countries," and related terms. This search strategy focused on primary research studies that examined any aspect of food loss in the Pacific region. The search was limited to studies published in English from years 2011 till 2023. Search strings were based off the Full Boolean Search String (Figure 1).

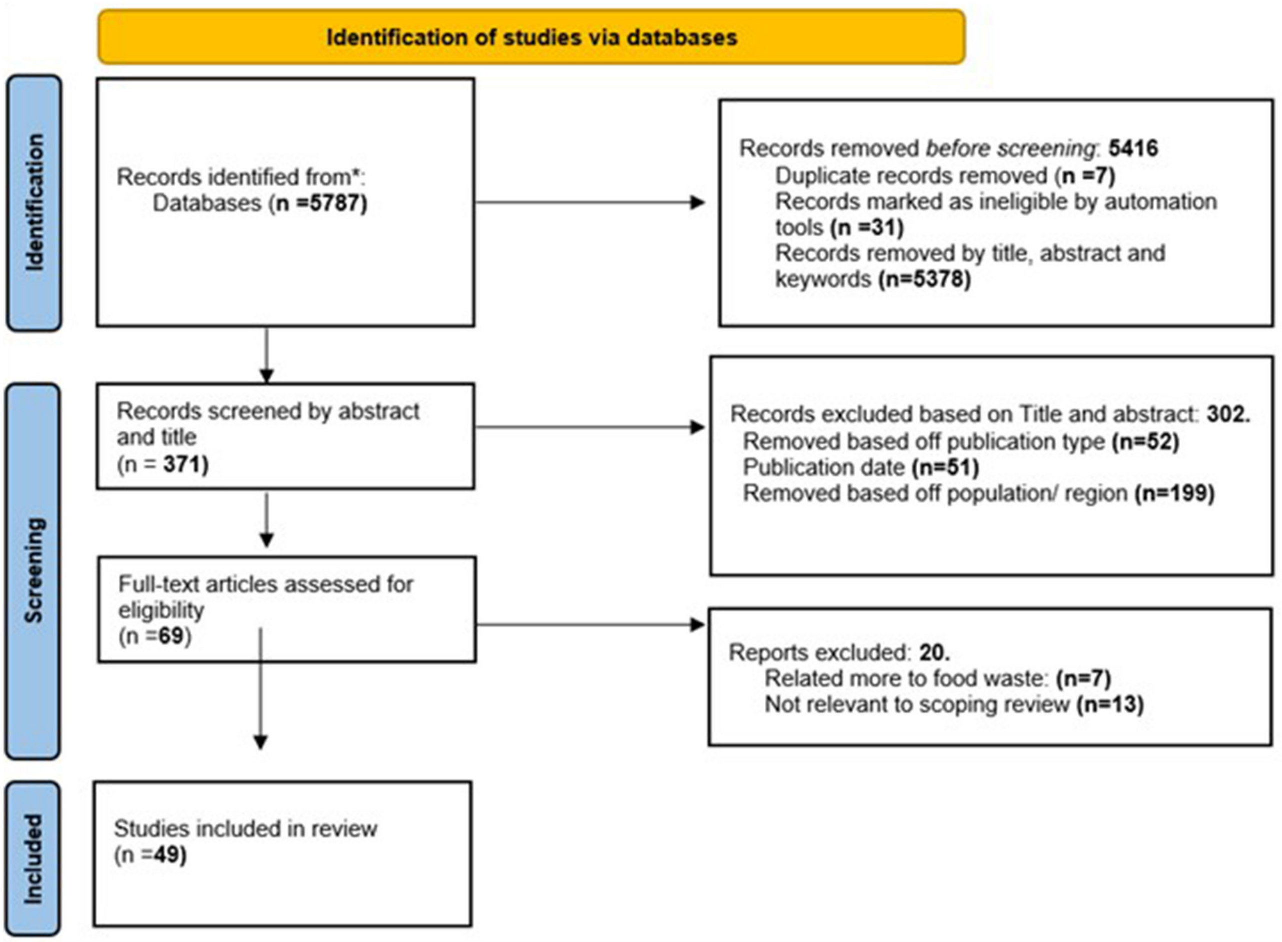

FIGURE 2
PRISMA-ScR flow diagram, 5,787 journals were identified, out of which forty-nine journal articles were selected for review.

3. Screening and selecting relevant studies: the search results were imported into the reference management software endnote for deduplication and screening. The screening process was conducted in two stages: title and abstract screening followed by full-text screening. During the stage of screening titles and abstracts, a total of 371 studies were carefully reviewed to assess their suitability for inclusion. Inclusion criteria were established to ensure the selection of studies that focused on food loss and PICs.

The exclusion criteria used to exclude studies were (Figure 2):

- Studies conducted in regions or countries outside of the PICs.
- Studies did not include a food loss reduction intervention.
- Studies published in language other than English.
- Studies published outside the years 2011–2023.
- Non-peer-reviewed papers as conference abstracts, opinion pieces, editorials, and letters to the editor.
- Studies for which full-text articles are not available or accessible for review.

4. Extracting and data synthesis: a standardized data extraction form was developed tto capture relevant information from the selected studies. The form included data elements such as year of publication, country, type of food system, thematic focus, postharvest activity stage and key findings. The data were manually extracted from the 49 studies that were finally selected for this review.
5. Collating, summarizing, and reporting the results: A comprehensive review of food loss journals was undertaken, focusing on identifying recurring concepts, patterns, and issues within the literature. This process involved systematically reading and analyzing the content to discern key insights related to the primary research question: "What is the nature and extent of the relationship between food loss and the food systems in Pacific Island Countries?" Codes were then assigned to relevant segments of the data, using NVivo to organize and manage these codes effectively. NVivo facilitated the categorization of data, ensuring consistency in the coding process and linking specific data segments to illustrative examples for clarity. Following the coding process, the identified codes were thoroughly reviewed and refined to ensure their relevance and accuracy. These codes were then grouped into broader categories to identify potential themes, which were crucial in uncovering the significant patterns and relationships within the data. The final themes were labeled and discussed in the paper's discussion section. The findings were summarized and presented narratively, supplemented with tables and figures to enhance clarity, and facilitate data visualization.

3 Results and discussion

3.1 Geographical distribution of publications

Out of 5,787 studies, only 49 met the inclusion criteria for food loss interventions in the PICs and the broader Oceania region. Figure 3 provides insight into the distribution of food loss publications across different geographic scales, including

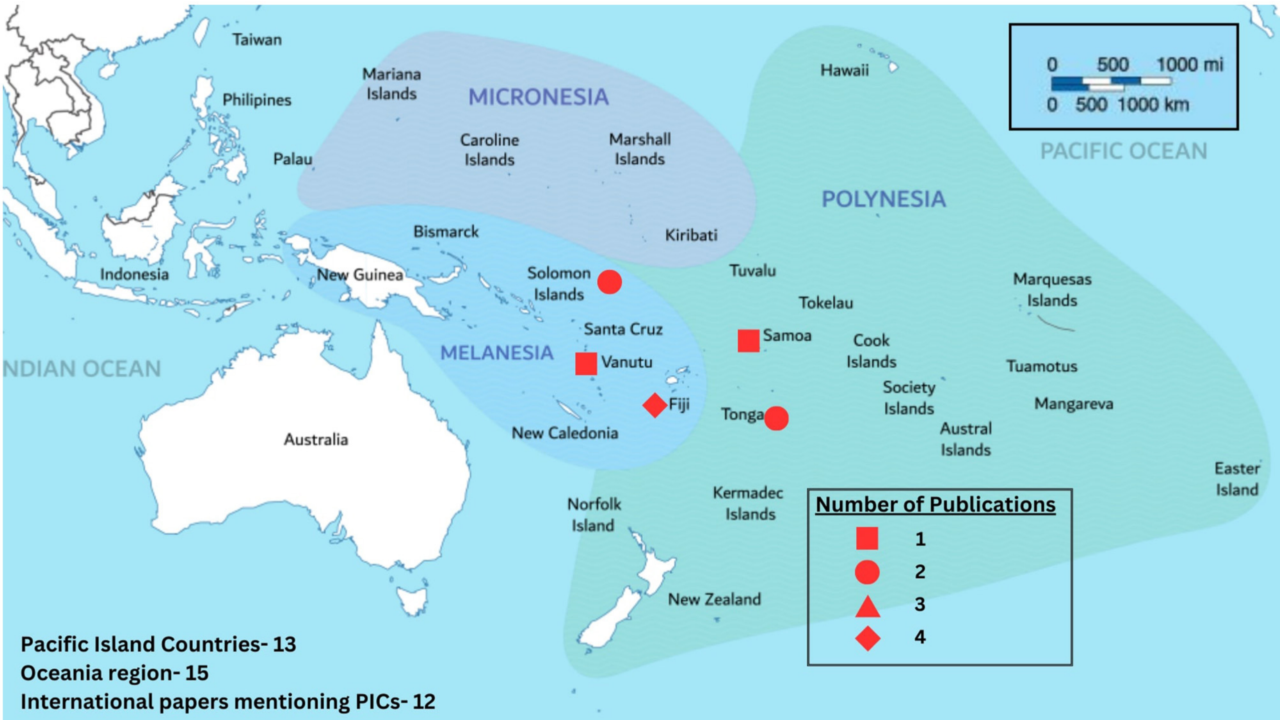

FIGURE 3
Map demonstrating the spread of publications across the Pacific source: cormesis.

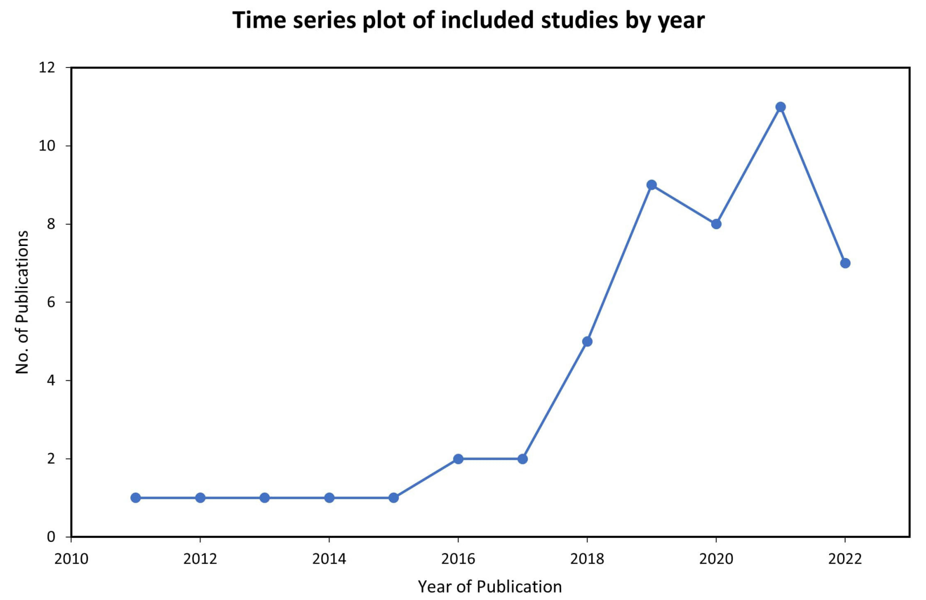

FIGURE 4
Time series plot of included food loss studies in the Pacific, highlighting a spike from the year 2017 to the year 2022.

international, regional, and specific Pacific Island countries. A geographical breakdown of publications showed that Samoa and Vanuatu each had one publication, Tonga and Solomon Islands each had two, and Fiji had the highest number with four publications. Thirteen publications were categorized under the Pacific Island countries, which included studies mentioning food loss interventions across multiple PICs. Fifteen publications were classified under the Oceania region, which was the highest of all categories, encompassing studies from the broader Oceania region (including New Zealand and Australia) that referenced food loss interventions in PICs. Additionally, twelve international publications discussed food loss interventions in PICs, as depicted in Figure 3.

3.2 Distribution of publications across the databases

Of the 49 included studies five were from JSTOR, seventeen from Scopus, ten from Science Direct, and seventeen from the Web of Science. The number of publications increased gradually from 2011, with a notable spike in 2018, averaging eight publications per year over the subsequent 5 years. This spike in the number of publications from the year 2018 highlighted in Figure 4 is linked to the escalating frequency and severity of climate change shocks and the growing emphasis on sustainable development in the Pacific. This includes sustainable development goal 12, target 12.3, that aims to reduce food losses along production and supply chains, for example at harvest, storage, transportation and market stage (Underhill et al., 2019). These factors have driven increased attention and research in the area of food loss in the Pacific.

The substantial increase also highlights the role of regional NGOs and institutions such as CSIRO, SPREP and ACIAR. ACIAR's food loss research program supported food loss and waste publications and research activity in the Pacific during these years with other regional institutions following suit. Regional development departments across the Pacific also contribute to the list of food loss publications, highlighting the heightened awareness and importance of understanding and addressing issues related to food loss over the last few years. This remarkable surge in not only researcher attention but broader academic, governmental and NGO attention toward the topic underscores the growing urgency and relevance of addressing food loss in the Pacific, emphasizing the need for up-to-date insights and solutions to meet the evolving challenges.

3.3 Overview of postharvest interventions studied

3.3.1 Distribution of publications across food supply chain components and food source types

Food loss studies are examined against food supply chain components, different food sectors and policy frameworks on food quality and safety (Figure 5). Location categories are arranged according to individual countries; Fiji, Vanuatu, Solomon Islands, Samoa and Tonga with grouped categories labeled PICs, regional (Asia) and international. The PICs category highlights publications on food loss interventions in two or more Pacific Island countries. The regional category highlights publications within the Asia region that mention PICs whereas the international category highlights international publications that discuss food loss interventions within PICs.

The policy category included papers that studied support framework for ensuring food safety, quality, and sustainable agricultural practices. Production category included papers on

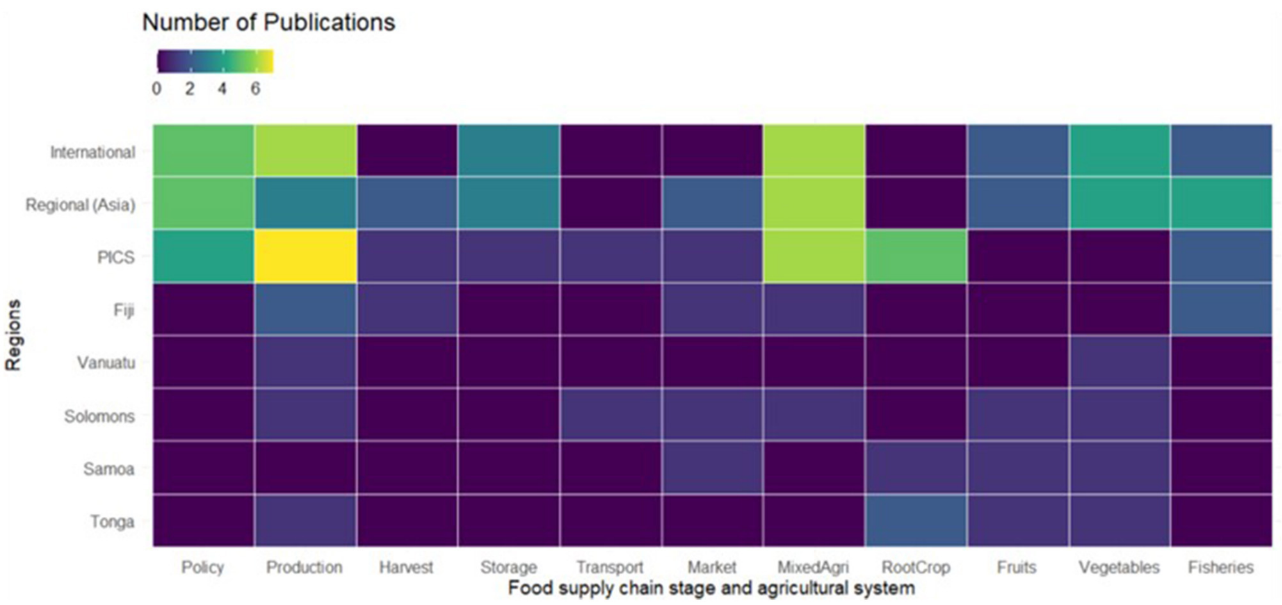

FIGURE 5
Heat map of publications by location and food supply chain stage and agricultural system. PICs represent publications that covers more than one Pacific Island Country. International and Regional (Asia) represent publications with mention of Pacific Islands within the publication.

food loss occurring during the growing of crops and raising of livestock; policy and production categories both come under pre-harvest on-farm losses. The harvesting category looked at food loss post-harvest during the gathering and handling of crops; the storage category includes papers that look at appropriate conditions that maintain quality of food and prevent spoilage; the transport category involves the carting of food products from farms to processing facilities, markets, and consumers; and finally, the market category includes papers on distribution and retailing of food products to consumers. Among the studies investigating various stages of food loss, production had the highest number with 25 studies, indicating a significant focus on on-farm processes. Policy was the second highest with 16 studies, followed by marketing with 11 studies, while the harvest, storage, and transportation stages each averaged seven studies, highlighting the importance of understanding food loss across the entire supply chain.

Studies arranged according to agricultural sectors were grouped into root crops, fruits, vegetables, a mixed agricultural systems sector which contained a mixture of the other systems and a fisheries category that included papers on food loss occurring along the fisheries value chain. The highest number of studies across various agricultural sectors was 25 journal articles under the mixed agricultural systems sector. The vegetables category recorded the second highest with 13 publications, followed by root crops with 11 publications, and fisheries and fruits with 10 and nine publications, respectively.

The heatmap in Figure 6 mainly indicates the strongest association between food loss found in the production stage and the mixed agricultural system category, indicating the high relative importance of food loss reduction at this point of the supply chain. There is also a strong association between the policy stage and mixed agricultural system category; however, there is no association between root crops and harvest and policy as well as policy and vegetables.

The heat map highlights the varying importance of different categories within each stage of the value chain. Understanding these relative intensities can help inform decision-making and resource allocation efforts to address specific areas of the value chain that require attention or improvement.

3.3.2 Distribution of publications across different stages of food supply chain

An analysis of studies illustrated in Figure 3 highlights the distribution of food loss research across individual PICs. Specifically, four studies were conducted in Fiji, one in Samoa, two in the Solomon Islands, two in Tonga, and one in Vanuatu. This distribution underscores the varying levels of food loss each country has received in this field and the need for more to be done. A total of four of these studies were carried out by the regional expert on food loss, Professor Steven Underhill, highlighting the need for more local experts in the field (Underhill et al., 2019, 2020, 2017).

These studies provide insights into the stages of the food supply chain where losses are most prevalent. Four studies identified significant food loss occurring at the production stage (Buckwell et al., 2020; Iese et al., 2018, 2021; McGuigan et al., 2022), indicating critical inefficiencies in the initial phases of food supply due to the failure to maximize land resources, lack of irrigation at the start of the production process and pest problems especially in perishable crops like tomatoes in Fiji. Meanwhile, three studies pointed to the market stage as a significant point of food loss (Mangubhai et al., 2021; Underhill et al., 2019, 2017), due to the exposure of produce to heat, during the sale processes and the poor shelf life associated with produce. Additionally, one study

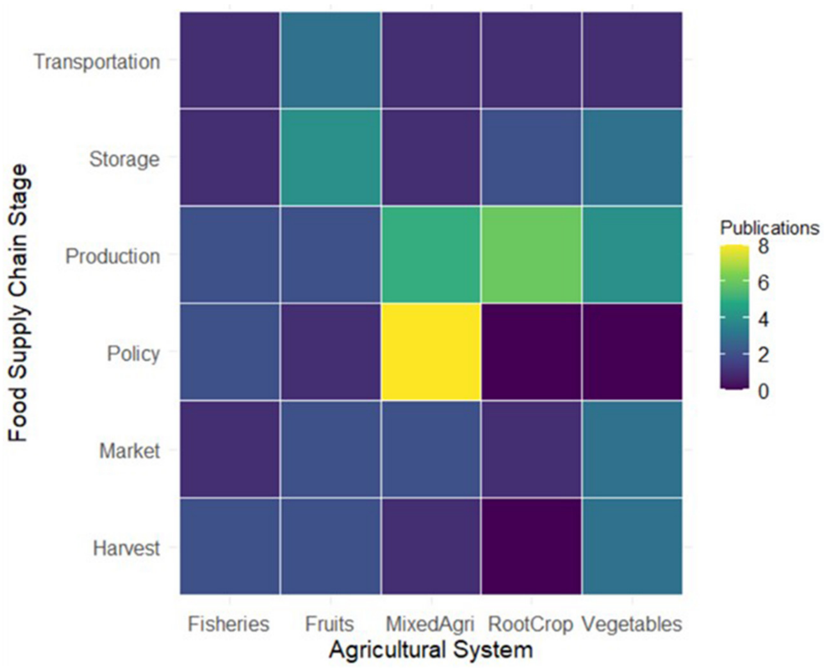

FIGURE 6
Heatmap of food loss publications categorized by stages of the food supply chain (policy, production, transportation, storage, harvest, and market) and agricultural systems (fruits, root crops, vegetables, mixed agricultural systems, and fisheries).

each highlighted food loss during the harvesting (Thomas et al., 2019) and transportation (Underhill et al., 2020) stages, further diversifying the understanding of where food losses occur.

The agricultural systems examined in these studies were varied; fruits, vegetables, root crops, mixed agricultural systems and fisheries, reflecting the diverse agricultural practices within the Pacific Islands. Root crops emerged as a notable area of focus, being the subject of four distinct journal articles (Iese et al., 2018; McGuigan et al., 2022; Underhill et al., 2020, 2017). This emphasis on root crops highlights the Pacific's agricultural landscape, the importance taro, yam and cassava have and the critical need to address food loss within the root crop category.

The findings from the reviewed studies as shown in Table 1 provide a comprehensive understanding of food loss in PICs food systems. The studies collectively highlight the vulnerability of these food systems to climate change (Buckwell et al., 2020) and other external pressures arising from complex interactions across various stages of the food supply chain (Parajuli et al., 2019), from production to harvesting, storage, transportation, market access, and policy frameworks.

3.3.2.1 *Production stage*

Interventions targeting food loss at the production stage of the value chain, as detailed in Table 1, emphasized training and skill development for farmers (Lazar-Baker et al., 2011), increased planting of famine food crops and new starch crop cultivars post-cyclone (McGuigan et al., 2022) as well as adjusting planting and harvesting schedules in their crop calendars (Parajuli et al., 2019).

3.3.2.2 *Harvesting stage*

Key interventions at the harvesting stage included nutrient and pest management strategies to adapt to changes in nutrient needs and pest pressures (Parajuli et al., 2019) brought about by climate change and worsening environmental conditions along with developing quality management plans (Shewfelt and Prussia, 2021) that ensure consistent harvesting practices that ensure the best quality produce from farm to markets.

3.3.2.3 *Storage stage*

At the storage stage, interventions focused on technological innovation and infrastructure for developing cold chain logistics of vegetables and fruit (Han et al., 2021). Additionally, food safety training was emphasized to address new risks from climate change and higher spoilage potential (Misiou and Koutsoumanis, 2022).

3.3.2.4 *Transport stage*

Transportation stage interventions include examining the suitability of transport types for various produce and the hygiene involved with specific fruits, vegetables and crops (Underhill et al., 2019) along with exploring packaging involved in transportation e.g., the use of plastic crates in helping reduce food loss (Khatun and Rahman, 2018).

3.3.2.5 *Market stage*

In the market stage, interventions encouraged the exploration of new markets with producers tapping into the use of digital technologies (Sinha and Swain, 2022) like the internet to sell produce online, ensure farmers harvested just the right amounts as well as bypass the transportation stage as consumers would buy

TABLE 1 Summary of findings of food supply chain stages.

Food loss stage	Countries	Key findings	Reference
Production	PICs in General with exception Vanuatu, Fiji, Solomon Islands, Hawaii	• The identification of challenges in quantitative data aggregation when examining complex and multi-dimensional concepts like resilience.	Beauchamp et al., 2019
		• Tree nurseries • Extension officers for guidance and support, • Community radio/rangers • Demonstration garden plots. • Increasing garden productivity through targeted ecosystem-based adaptations provides significant social benefits and helps mitigate natural resource threats. Additionally, balancing formal conservation efforts with customary management can yield important complementary benefits for the community	Buckwell et al., 2020
		• Encouraging the use of indigenous food species and locally adapted varieties to reduce malnutrition.	Burlingame et al., 2019
		• While strengthening regional production and trade could enhance food security and provide health benefits, significant challenges in production, processing, and storage must be overcome to reduce reliance on imported shelf-stable foods.	Farrell et al., 2020
		• Cultivation of sweet potato as a strategy of CC adaptation • Increasing food production from home gardens, particularly of root crops, vegetables, and fruits • Changing aspects in seasonal cultivation • While sweet potato has historically been a resilient crop, its resilience is not guaranteed as climate change intensifies. The need for ongoing research and regional collaboration is emphasized to ensure that staple crops like sweet potato continue to contribute to food security in the face of increasing climate risks	Iese et al., 2018
		• COVID-19 mitigation measures led to reduced agricultural production, food availability, and incomes due to the decline in local and international markets. Despite these efforts, the limited diversity of agricultural production and decreased household incomes negatively impacted dietary diversity, which was already low before the pandemic	Iese et al., 2021
		• Training and skill development for farmers, technical personnel, transporters, and retailers to improve postharvest management and reduce losses. • The key findings highlight that postharvest management is a priority research area in the South Pacific region. Current stakeholders are often poorly trained in postharvest management, leading to significant losses and reduced quality of fresh produce. There is limited research on postharvest pathogens and their effects on crops in the region	Lazar-Baker et al., 2011
		• Increasing fruit and vegetable production to meet recommended consumption levels. • Historically, fruit and vegetable availability has often been below recommended consumption levels. Economic growth will improve availability but may not be sufficient alone to meet recommended consumption levels in many countries. Significant food waste could further reduce the availability of fruits and vegetables, potentially increasing the number of people living in countries with insufficient supply by 1.5 billion by 2050.	Mason-D'Croz et al., 2019
		• Increased planting of famine food crops and new starch crop cultivars post-cyclone. • Frequent crop substitutions and the introduction of new cultivars, which, while improving resilience, also led to a decline in the total number of cultivars over time. • Resilience in Fijian agroforestry systems demonstrated high reactivity to cyclone disturbances, with an increase in crop species richness immediately after the cyclone and continued higher levels 3 years later. Increased presence of famine food crops and new starch crop cultivars contributed to system robustness, redundancy, and resourcefulness.	McGuigan et al., 2022
		• Changes in crop calendar: Adjusting planting and harvesting schedules. • Risks to current practices: Increased risks include failures in crop protection strategies, pest infestations, and stresses related to water and nutrients.	Parajuli et al., 2019

(Continued)

TABLE 1 (Continued)

Food loss stage	Countries	Key findings	Reference
		• Need for motivation and action: There is a need to better motivate and act on implementing food loss reduction measures across the value chain.	Parmar, 2019
		• Mention of challenges to food production capacity before the pandemic, including climate-related issues, declining arable land, freshwater resources, and persistent pests and diseases and how COVID-19 exacerbated them	Teng et al., 2021
		• Sustainable land management practices: These are aimed at addressing land degradation, which can indirectly affect food systems by improving soil health and productivity • Scientifically guided biological control: This approach involves managing invasive pests through biological means, which has led to significant yield-loss recoveries in non-rice crops.	Wairiu, 2017
Harvesting	PICs in general with exception Fiji	• Anticipating crises: Emphasizes the importance of assessing risks and vulnerabilities through early warning systems to anticipate and prepare for potential crises.	Ashley, 2016
		• Key drivers influencing seafood supply and consumption as ecosystem changes, ocean regulation, corporate influence, consumer demand, and nutritional needs.	Farmery et al., 2022
		• Nutrient and pest management strategies: Adapting to changes in pest pressures and nutrient needs. • Adjusting crop calendars • Several risks posed by climate change to the productivity and quality of fruit and vegetables, including issues with texture, color, maturity, and nutrients, as well as increased pest infestations and crop-water and nutrient stresses. adaptation and management strategies, such as changes in raw material inputs, resource flows, and farming practices, are crucial for reducing the environmental impacts and ensuring sustainability in the face of climate change	Parajuli et al., 2019
		• Developing quality management plans	Shewfelt and Prussia, 2021
		• Controlling pests and diseases (identified as the highest strategic priority) • Improving worker skills in the picking process • Managing competing wild plants • Optimizing pesticide use	Suryaningrat et al., 2021
Storage	PICs and regional	• Cold chain logistics that indirectly contribute to reducing food loss such as technological innovation and infrastructure and equipment Improvement • Future trends in cold chain logistics involve adopting low-carbon strategies and intelligent innovations to address environmental concerns and market demands.	Han et al., 2021
		• Potential risks associated with climate change that could lead to increased food spoilage such as disease and microbial spoilage • There is a potential increased risk of microbial spoilage for certain types of food, particularly bulk dried foods and non-refrigerated processed foods, which could be highly susceptible to climate change.	Misiou and Koutsoumanis, 2022
		• Ensuring food safety handling practices • Use of simulation models can improve postharvest handling and ultimately reduce food loss.	Shewfelt and Prussia, 2021
		• Solar crop drying as an intervention to improve the drying process of agricultural products. • Traditional drying methods: Traditional methods like burning wood or fossil fuels and open-air drying have environmental and efficiency issues vs. solar crop drying: solar drying provides a more efficient and less expensive alternative, utilizing both solar energy and fuel burning.	VijayaVenkataRaman et al., 2012
Transportation	PICs and regional	• While strengthening regional production and trade could enhance food security and provide health benefits, significant challenges in production, processing, and storage must be overcome to reduce reliance on imported shelf-stable foods.	Farrell et al., 2020

(Continued)

TABLE 1 (Continued)

Food loss stage	Countries	Key findings	Reference
		• Farmers use plastic crates for packaging and transportation, which is a key intervention to reduce postharvest losses. • Highlights the importance on type of transport and hygienic state • The primary causes of postharvest losses are physical damage, disease, and insect infestation (key determinants: total harvested amount, family labor, training, and selling price are identified as the main determinants of postharvest loss).	Khatun and Rahman, 2018
		• Systems-thinking practices: The paper suggests that adopting systems-thinking practices, including the use of simulation models, can improve postharvest handling and ultimately reduce food loss	Shewfelt and Prussia, 2021
Market	PICs in general with exception of Fiji, Solomon Islands, Tonga and Samoa	• Rural food systems in the Pacific were relatively resilient to early global food systems shocks. Despite the disruptions caused by the COVID-19 pandemic and response, region-wide, most respondents reported no change in food availability or fishing pressure in their communities.	Farrell et al., 2020
		• Cultural safety networks like barter systems to support food access and community resilience (Fiji-Samoa).	Iese et al., 2021
		• Research and innovation in postharvest disease management to enhance the effectiveness of marketing systems and maintain the quality of horticultural produce	Lazar-Baker et al., 2011
		• Exploration of new markets: Due to global lockdowns and logistic restrictions, producers and consumers had to explore new markets to mitigate the impact of the pandemic. • Digital technologies: mentions the rapid reaction of digital technologies in mitigating the impacts of COVID-19 on the agriculture and food system value chain	Sinha and Swain, 2022
		• Food waste stemming from modern supermarkets' practices and the decline of traditional food infrastructures. • Modern supermarkets contribute to food waste by discarding imperfect food and encouraging bulk purchases through promotions like "buy one get one free."	Tammara, 2018
		• Consumer purchasing activity and the ratio of commercial vendors to transient farmer-traders may influence postharvest loss levels and market variability	Underhill et al., 2017
		• Comparison of market systems: Honiara's road-side market system is more effective in managing postharvest loss compared to the municipal market.	Underhill et al., 2019
		• Strategies used by vendors to mitigate postharvest loss, including regulating market supply volume and price discounting. • Vendor vulnerability: Road-side vendors were more vulnerable to postharvest loss compared to municipal vendors.	Underhill et al., 2020
Policy	PICs in general with exception of Papua New Guinea, Cook Islands, Solomon Islands, Fiji and Tonga	• Focuses on improving access to nutritious food through employment opportunities and social protection policies.	Ashley, 2016
		• The influences of drivers like decentralization, climate change, and demographic transition are poorly documented and understood.	Béné et al., 2016
		• Recognizing and promoting the nutritional superiority of local and neglected species and incorporating them into diets through cultivation in small farms and gardens.	Burlingame et al., 2019
		• Communities with lower socioeconomic status are more likely to experience significant impacts from climate change in both fisheries and agriculture sectors	Cinner et al., 2022
		• While strengthening regional production and trade could enhance food security and provide health benefits, significant challenges in production, processing, and storage must be overcome to reduce reliance on imported shelf-stable foods.	Farrell et al., 2020
		• Establishing clear guiding principles for resilience, tailored to specific contexts, could improve the effectiveness and coordination of resilience efforts in food systems within the Indo-Pacific region	Friedman et al., 2022b

(Continued)

TABLE 1 (Continued)

Food loss stage	Countries	Key findings	Reference
		• Government campaigns and education to raise awareness and promote sustainable seafood consumption.	Iue et al., 2022
		• More effective adaptation strategies could be developed by addressing complex societal factors and implementing supportive policies.	Leal et al., 2021
		• The paper introduces research methodologies used in existing FLW studies and encourages the application of diverse methodologies to discuss FLW issues. This aims to provide a more comprehensive view of FLW and stimulate further research in the field.	Luo et al., 2021
		• Many small scale farmers lack access to social security or safety nets, which exacerbates their vulnerability to economic shocks from COVID-19 and Cyclone Harold.	Mangubhai et al., 2021
		• Systematic public policy targeting constraints in production and consumption to address food availability issues. • Communities reliant on agriculture-based livelihood systems have been identified as particularly at risk from climate change, due to likely increases in crop failure, new patterns of pests and diseases, lack of appropriate seed and plant material, and loss of livestock • Significant food waste could further reduce the availability of fruits and vegetables, potentially increasing the number of people living in countries with insufficient supply by 1.5 billion by 2050.	Mason-D'Croz et al., 2019
		• Impact of modernization: The shift from traditional food practices to modern, industrial agriculture and supermarket-driven food systems has led to increased food waste. Large convenience stores and corporate food systems have replaced smaller, traditional markets, often resulting in higher levels of food loss in long production chains and increased waste by consumers	McDermott, 2015
		• Need for mitigation and adaptation: Reducing vulnerability to climate impacts requires immediate mitigation efforts from major CO2 emitters and strategic adaptation measures both within and across agricultural and marine sectors.	Thiault et al., 2019

straight from residence. Cultural safety networks and community-driven support, like barter systems, were highlighted for their role in bolstering food access and resilience in communities, especially in Fiji and Samoa (Iese et al., 2021).

3.3.2.6 *Policy stage*

At the policy level, a key intervention involved promoting the nutritional benefits of local and underutilized crops, fruits, and vegetables by incorporating them into local diets through small-scale farming and gardening (Burlingame et al., 2019).

3.4 Thematic distribution of the studies

The scoping review identified three thematic categories addressing food loss in PICs, namely, the lack of infrastructure and need for innovative technology for post-harvest management, increased vulnerability to climate change and postharvest risks of newer convenient markets.

3.4.1 Lack of infrastructure and need for innovative technology for post-harvest management

Lack of appropriate infrastructure is a significant challenge to minimizing post-harvest losses in PICs. Fragmented value chains that include inefficient harvesting processes, limited storage facilities, and inadequate transportation networks, hinder the efficient handling and preservation of agricultural produce. Farmers in these regions struggle with suboptimal storage conditions and difficulties in transporting perishable goods to markets (Friedman et al., 2022a).

Pacific horticultural value chains are predominantly structured around smallholder and semi-subsistence farmers who utilize low-intensity production systems (Underhill et al., 2020). These farmers often lack the resources to implement advanced agricultural techniques, which can limit their productivity and efficiency. Additionally, the infrastructure for postharvest handling is typically inadequate, reflecting a broader trend of insufficient investment in the sector (Underhill et al., 2022). Farmers and market vendors frequently face significant constraints due to limited postharvest capacity and knowledge e.g., with tomato farmers in Fiji (Underhill and Kumar, 2015). This lack of infrastructure and expertise means that they are unable to adequately process, store, and transport their produce, leading to significant inefficiencies and losses.

Given these challenges, it is expected that postharvest loss is excessively high. A recent study by Underhill and Kumar (2015) in the South Pacific region highlighted this issue by examining municipal markets in Fiji, where postharvest losses were found to range between 2.5 and 10%. These losses represent a substantial economic burden for farmers, who rely on maximizing their yields to sustain their livelihoods. The high rate of postharvest loss not only impacts individual farmers but also affects the overall food security and economic stability of the Pacific region (Gunasekera et al., 2017). Addressing these issues requires targeted interventions to improve postharvest handling infrastructure and enhance the knowledge and capacity of farmers and vendors, thereby reducing losses and improving the efficiency and sustainability of the horticultural value chains in the Pacific (Underhill et al., 2020).

Emerging and innovative technology play a key role in minimizing both on-farm and post-harvest losses within PICs. There is a plethora of tools, information, and practices within such technology that farmers who are at the brunt of climate change can find useful such as agriculture management practices and advances in horticulture and climate projections. Traditional agriculture management practices that look at soil health such as crop rotation and water management techniques such as rainwater harvesting (Fenemor et al., 2010), coupled with the inclusion of solutions such as satellite remote sensing, ground images and solar powered cold storage units pave the way forward in addressing the challenges that come with post-harvest losses (Friedman et al., 2022b). Such innovations address post-harvest losses, by strengthening the efficiency of the entire food system, providing an outlook into conditions of crops, storage facilities, and transportation logistics all in real time.

By utilizing satellite remote sensing and ground images, stakeholders acquire a better understanding of the causes and extent of these losses. This enables targeted interventions at critical stages of the supply chain, from continuously monitoring crop conditions at early stages, measuring the variability in conditions of the farm to the monitoring of storage facilities and optimizing logistics and transport. Studies highlighted that post-harvest losses were not always directly linked to transport distance, as seen in the case of high-perishable crops in inter-island and remote intra-island chains. Spatial maps using data from ground images and satellite remote sensing highlighted the intensity and distribution of post-harvest losses across the villages within the island, which then directly correlated to factors like market operations, packaging type, and mode of transport (Underhill et al., 2019).

Innovations used to address postharvest losses in cold chain and dry chain processes can be adapted to suit smallholder farms and communities. Looking into transformative solutions such as the deployment of solar-powered cold storage units for extending perishable produce shelf life not only reduces postharvest losses but offer energy-efficient and sustainable backup options for areas with power supply issues (Batalofo et al., 2024). The implementation of such innovations come with challenges such as need for specialized expertise and capital costs, preventing the widespread adoption and effective use across the PICs. Nevertheless, by addressing these challenges and delving into the potential benefits in the long run, these innovative technologies offer a pathway toward minimizing post-harvest losses, improving storage conditions, and ultimately bolstering the overall resilience and efficiency of food systems across PICs.

3.4.2 Increased food losses from changing climate and weather

The impact of changing climate and weather patterns on PICs is profound and poses significant challenges to their communities. Given that many of these countries are in areas highly exposed to climate hazards, they are particularly vulnerable to the effects of climate change. The consequences of climate change include sea-level rise, alterations in rainfall patterns, heightened frequency and severity of extreme weather events, ocean acidification, and coral bleaching (Johnson et al., 2020). Among these, the accelerated rise in sea levels has attracted considerable attention due to its observable impacts (Storlazzi et al., 2015). This rise leads to coastal erosion, land and property degradation, increased frequency of flooding, saltwater intrusion, and various ecological shifts. Research underscores the urgent need to prioritize understanding and addressing the impacts of climate change on coastal areas within PICS. The vulnerability of low-lying PICs is further exacerbated by their limited natural resources and constrained options for adaptation, making them particularly susceptible to the challenges posed by climate change (Leal et al., 2021).

Due to the inherent vulnerability of PICs to climate hazards, the impact on Pacific food systems has been significantly intensified, with increased food losses (Iese et al., 2021). Climate shocks damage crops causing pre-harvest losses on-farm and as a result reducing their yield, for example, droughts can lead to water stress, causing wilting and reduced crop growth (Farooq et al., 2009); floods destroy crops through waterlogging and erosion and tropical cyclones physically damage plants and crops, stripping them of leaves and fruits (Bal and Minhas, 2017). These climate-induced stresses disrupt the normal physiological processes of crops, leading to significant yield reductions which can be identified as crop loss, a form of food loss that takes place on-farm greatly threatening food security (Beauchamp et al., 2019).

This scoping review sheds light on these pre-harvest production stage inefficiencies, which are a critical yet overlooked aspect of food loss in PICs. It introduces fresh perspective by integrating these inefficiencies at the production stage into the broader conversation on food loss. This provides a deeper understanding of how food systems in PICs function under challenges such as climate change and limited resources. Addressing these inefficiencies on-farm not only contributes to improving food security, but also strengthens the resilience of Pacific Island food systems to climate shocks. Identifying these pre-harvest, on-farm losses, creates a pathway for enhancing both climate adaptation and food security in the Pacific region (Iese et al., 2018).

Climate shocks adversely affects food systems in PICs, from the supply of food in the agriculture and fisheries sectors to the systems for the distribution of food, the supply chains involved, and ultimately the ability of households to purchase and utilize food (Iese et al., 2018). Climate shocks can disrupt transportation and infrastructure, making it difficult to harvest, transport, and store crops effectively. This disruption leads to postharvest losses as harvested crops may spoil or deteriorate before reaching markets or storage facilities. Preserving genetic diversity in crops and livestock through well-managed seed banks and equitable sharing of benefits from genetic resources is essential for maintaining food security and resilience in the face of evolving environmental conditions and ensuring access to nutritious food for Pacific Island communities (Ashley, 2016). Highlighting production-stage losses as a key dimension of food loss, this research encourages a shift in PIC food systems analysis and management, calling for strategies that integrate both pre-harvest and post-harvest stages, promoting more resilient and sustainable food systems.

Additionally, reinforcing supply chains and transportation networks is essential to ensure that food can be effectively harvested, stored, and transported even in the face of severe tropical cyclones (Thomas et al., 2019). The introduction of insurance policies that cover farmers during tropical cyclones and by integrating climate resilience into agricultural planning and investing in adaptive infrastructure, PICs can better safeguard their food systems against the growing threats posed by climate change, ultimately ensuring food security for the region (Iese et al., 2021).

3.4.3 Postharvest risks of newer convenient markets

The risks associated with postharvest processes in emerging pop-up, convenient roadside markets have not yet been thoroughly examined. Although household expenditure census data offers some insights, it highlights a growing dependence among Pacific Island consumers on commercial value chains for their fresh produce (Sherzad, 2020). The rapid rise in private vehicle imports and ownership within PICs signify a shift in how and where local consumers access fresh food commercially (Underhill et al., 2020). While large central fruit and vegetable markets in PICs have historically dominated the horticultural fresh food system, they are now being complemented by an expanding network of roadside vendors (Underhill and Singh-Peterson, 2017). However, amidst this apparent transition in the local horticultural fresh food system, there has been minimal attention directed toward understanding the horticultural value chains that support these markets.

Crucial risk factors within these value chains, such as postharvest handling practices, transportation logistics, market storage conditions, and knowledge and capacity, remain unclear. Furthermore, there has been no reporting on the extent of horticultural postharvest loss in Tonga, which could serve as a potential indicator of market efficiency (Underhill et al., 2020). This dearth of fundamental information regarding the structure and operation of horticultural market and distribution systems in PICs poses a significant obstacle to the development of targeted interventions aimed at enhancing the enabling environment for horticultural fresh food.

4 Conclusion

The persistent challenges of inadequate infrastructure and fragmented value chains in PICs continue to contribute significantly to post-harvest losses, which impose a considerable economic burden on farmers and threaten the region's food security. Farmers face difficulties with suboptimal storage conditions and unreliable transportation networks, leading to inefficiencies in handling and preserving agricultural produce. To address these issues, it is crucial to invest in improved storage facilities, such as cold storage units, and upgrade transportation systems to ensure the timely and safe delivery of produce to markets.

In addition to infrastructure improvements, the adoption of innovative technologies such as satellite remote sensing, real-time monitoring of crop conditions and climate-controlled storage facilities, allow targeted interventions to reduce food losses. The introduction of affordable, accessible technologies like solar-powered cold storage can further extend the shelf life of perishable produce, enhancing market opportunities for smallholder farmers. By integrating these technological advancements into existing practices, PICs can significantly boost the efficiency and sustainability of their horticultural value chains. Escalating impacts of climate change on PICs' food systems require urgent attention. Climate shocks, including droughts, floods, and cyclones, increasingly damage crops, leading to substantial on-farm losses and further endangering food security. To mitigate these risks, PICs must adopt climate-resilient agricultural practices, such as drought-resistant crop varieties and improved water management systems. Strengthening supply chains and infrastructure to withstand severe weather conditions is also essential. By prioritizing these adaptive strategies, PICs can better protect their food systems and ensure their resilience in the face of growing climate challenges.

This scoping review has shed light on the complex and multifaceted nature of food loss in PICs. The analysis of food loss studies highlights the limited focus on food loss across individual countries and the need for more localized expertise in the Pacific region. The studies highlight critical inefficiencies in the food supply chain, particularly at the production stage, where issues like inefficient land use, lack of irrigation, and pest impacts are prevalent. The market stage also emerges as a significant point of food loss due to factors such as crop exposure to environmental elements and limited shelf life. Additionally, the research spans diverse agricultural systems, with a notable focus on root crops like taro, yam, and cassava, underscoring their importance in the Pacific's agricultural landscape and the need to address food loss in this category.

The global challenge of food loss and waste has significant implications for the food systems in PICs, affecting not only food security but also economic development and environmental sustainability. Ensuring sustainable food systems in PICs requires a multifaceted approach that addresses both production and postharvest stages while adapting to the challenges posed by climate change and extreme weather events. This entails implementing resilient agricultural practices to enhance productivity and sustainability, maintain ecosystem health, and build adaptive capacity. These efforts are crucial for combating food loss and waste, aligning with SDG 12, which targets reducing postharvest losses and promoting sustainable consumption patterns.

Overall, this scoping review highlights the need for comprehensive and context-specific approaches to tackle food loss in PICs. By synthesizing existing knowledge and identifying gaps, this review provides valuable insights for researchers, policymakers, and practitioners involved in addressing these challenges. The findings emphasize the importance of holistic strategies that integrate innovative technologies that create resilient and sustainable food systems in the Pacific.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

C-YA-A: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. VI: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. DH: Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. GM: Supervision, Writing – original draft, Writing – review & editing. HS-W: Funding acquisition, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Gen AI was used in the creation of this manuscript.

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