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Quantitative analysis of food waste from wholesale to households in Colombo, Sri Lanka

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Water, Land and Ecosystems

Quantitative analysis of food waste from wholesale to households in Colombo, Sri Lanka

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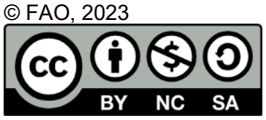

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Abbreviations and acronyms

CMC	Colombo municipal council
FAO	Food and Agriculture Organization of the United Nations
FLW	fool loss and waste
FW	food waste
GHGEs	Green House Gas Emissions
IWMI	International Water Management Institute
LAs	local authorities
MC	municipal council
MSW	municipal solid waste
PS	pradeshiya sabha
SDG	Sustainable Development Goal
SW	solid waste
UC	urban council
SWM	solid waste management

Executive summary

The objective of this study was to assess the scale of urban food waste (FW) in Sri Lanka. The selected steps in the food supply chain were wholesale, retail, food services, and households. FW quantification is of paramount importance in creating a robust evidence base for developing strategies, action plans, and policies towards FW prevention and reduction. The report presents empirical data on FW volumes and current FW management practices. The study covers the service area of three main Solid waste (SW) disposal sites (i.e. Karadiyana, Kerawalapitiya, and Kaduwela) that cover 20 Local authorities (LAs) located in the Western province. The total SW collected in the study area was about 1 317 tonnes in a day, out of which about 55 percent (i.e. 724 tonnes) was estimated to be FW. Considering the total daily SW in Sri Lanka, which is about 7 000 tonnes, the FW proportion appears significant (about 4 000 tonnes). The findings revealed that 42 percent of the total FW in the study area was collected within Colombo municipal council (CMC). This data could be attributed to the high level of urbanization in CMC. Assessing the sectoral contribution of FW is essential not only to identify quantities but also to appropriately select prevention and reduction strategies. However, under the current operational setup and waste management practices, LAs do not maintain disaggregated data on FW. Hence, the data related to FW across the sectors were not available in the respective LAs.

The food-use-not-loss-or-waste hierarchy prioritizes prevention, then recovery and redistribution of safe and nutritious food for people in need. These solutions are followed by redirecting former foodstuffs and co- and by-products (e.g. for bio-active compounds, feed), use for bio-materials sourcing and, finally, energy generation, composting or other extraction purpose and disposal to the landfill. The findings in this report reveal that the current level of FW prevention at source, recovery and redistribution for direct human consumption, as well as directing former foodstuffs for feed are very low. Moreover, currently, only five percent of the collected FW is composted, and one percent is processed through anaerobic digestion in the study area. Consequently, 94 percent of the FW is diverted to landfills.

Food redistribution for direct human consumption is practiced at micro-level in the study area, through different models. These interventions are currently led by volunteer-based organizations. Several challenges could be addressed such as a lack of legal and operational guidance from the public sector, gaps in awareness for the food business operators, and absence of cold storage facilities access to allow redistribution over several days. Diverting former foodstuffs to piggeries for feed is a common practice in the study area. Currently, this activity is informal. Former foodstuffs from the food service sector is directly collected by pig farmers. The results of a survey conducted under this project revealed that there is a high demand for former foodstuffs as feed. However, there are challenges such as poor quality of feed and linkages between supply and demand. Mechanisms to formalize and scale up these initiatives should be explored in collaboration with the public and private sector that could formulate legal and operational guidelines towards facilitating sustainable FW prevention strategies. Well-coordinated and coherent state and non-state interventions are needed in moving up the food use-not-waste hierarchy towards FW prevention and reduction.

The report was produced for the project “Innovative approaches to reduce, recycle and reuse FW in urban Sri Lanka.” The project was implemented under the oversight of the Ministry of Urban Development and Housing, in collaboration with the Food and Agriculture Organization (FAO) and the International Water Management Institute (IWMI) from June 2019 to August 2021. The knowledge from the report supported the drafting of the *National Roadmap on Urban Food Waste Prevention and Reduction for Households, Food services, Retailers and Wholesalers* that was launched on 17 August 20.

1. Introduction: global definitions, data, and policy setting

The Project "Innovative approaches to reduce, recycle and reuse food waste in urban Sri Lanka" (see **Figure 1**) was implemented from June 2019 to January 2021 under the oversight of the Ministry of Urban Development and Housing and in collaboration with the Food and Agriculture Organization (FAO) and the International Water Management Institute (IWMI).

Figure 1 *Innovative approaches to reduce, recycle, and reuse food waste in urban Sri Lanka (2019 - 2021) project structure*

The main objective of the project was to facilitate, through a collaborative effort, the drafting of an *Urban Roadmap and Action Plan on Food Waste Prevention, Reduction, Management in Sri Lanka* that identifies concrete steps to implement towards achieving Sustainable Development Goal (SDG) 12.3.

In 2015, the 2030 Agenda launched Sustainable Development Goal 12 on ensuring "sustainable consumption and production patterns" that includes target 12.3 "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses." The 2020 FAO Conference highlighted that "improving data collection on food losses and FW is a priority for monitoring progress towards achieving the SDGs" (FAO, 2020).

Achieving SDG 12.3 may reduce the food systems' environmental impacts by up to one-sixth. (World Bank, 2020). In 2020, global FLW was estimated to cause between eight and ten percent of the emissions of the gases responsible for global warming in the period 2010–2016 (the intergovernmental panel on climate change (IPCC) report on "climate change and land"). SDG 12.3 and the Paris Agreement, amongst other instruments, provide the framework to develop mutually reinforcing targets and reporting systems at the national level. Specifically, there are opportunities for countries to leverage SDG 12.3 as contributor to SDG 6 (sustainable water management), SDG 11 (sustainable cities and communities), SDG 13 (climate change), SDG 14 (marine resources); SDG 15 (terrestrial ecosystems, forestry, biodiversity) (FAO, 2019).

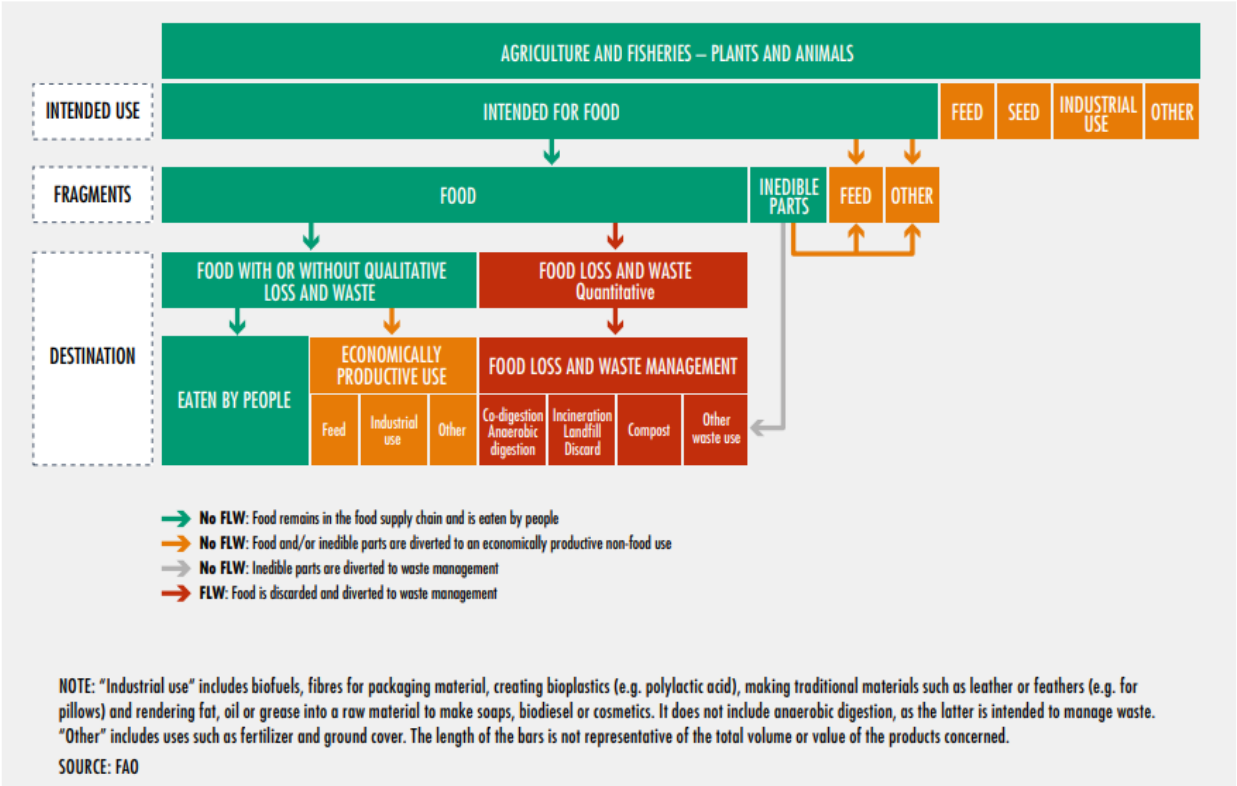
Definitions are at the basis of measurement that allows tracking progress towards a target. SDG 12.3 has two components: food loss and food waste. Each component is measured by a separate indicator.

Food loss is defined as 'the percentage of food quantities removed from the supply chain'. The Food Loss Index sub-indicator 12.3.1.a, that is tracking food losses (i.e. supply-driven), estimated that 13.8 percent of all food produced in 2016 was lost – estimates in physical quantities for different commodities and aggregated by an economic weight – from the farm up to, but excluding, the segment from retail to households. Asia and the Pacific regional estimates range from 5–6 percent in Australia and New Zealand to 20–21 percent in Central and Southern Asia. (SOFA, 2019)

The food waste Index (i.e. sub-indicator 12.3.1.b), tracking progress on FW reduction from retail to consumer level (i.e. demand-driven), is technically supported by the FAO and led by the United Nations Environment Programme (UNEP). It measures tonnes of wasted food per capita, considering a mixed stream of products from processing to consumption. The operational definition of FW is food and associated inedible parts removed from the human food supply chain at the following stages of the food chain: manufacturing of food products; food retail and wholesale; out-of-home consumption and in-home consumption. (UN Environment, 2019)

The overall conceptual framework for food loss and waste (FLW) is presented in **Figure 2.**

Figure 2 *The conceptual framework for food loss and waste (SOFA, 2019)*



Source: FAO. 2019. *The state of Food and Agriculture. Moving Forward on Food Loss and Waste Reduction*. Rome. 168 pp. (also available at https://doi.org/10.1002/9780470172506.ch60).

There are three main aspects to the growing concern over FW, which are food security, monetary losses, and negative externalities such as air and water pollution, soil erosion, salinization, and nutrient depletion (Elimelech, Ayalon and Ert, 2018). Reducing FW prevents the waste of land, water, energy and other resources embedded in food and is therefore not only essential to improving the sustainability of food systems but can also generate a triple win: for the economy, for food security and the environment (Muth *et al.*, 2019).

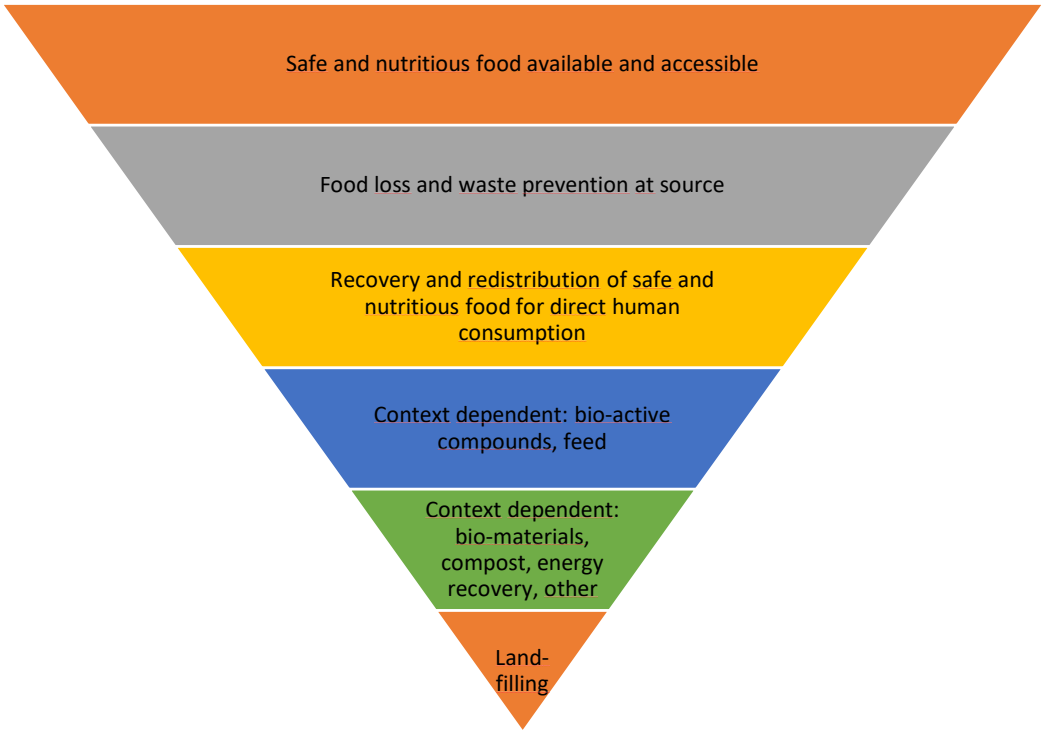
An important aspect to note is that the environmental and socio-economic impacts of FW at the latter part of the food supply chain are higher given that they cumulate. On the contrary, the potential benefits of reducing FW are higher in later stages of the value chain. This study focuses on the FW that occurs at the latter part of the supply chain: wholesale, retail, food services and households.

Sri Lanka was ranked 66th amongst 113 countries in the global food security index in 2019 indicating that food security needs urgent attention at national level. In 2018, Sri Lanka was identified as the second highest ranking country in South Asia for malnutrition (FAO, IWMI and RUAF, 2018). FW prevention is one of the key areas to be considered in terms of contributors to increasing food and nutrition security.

Sri Lanka is facing many challenges due to the significant amount of municipal solid waste (MSW) generated annually. Local authorities (LAs) in Sri Lanka are under tremendous pressure to bring solutions to the MSW issue. Although, historically, authorities opted for open dumping as a common disposal method, this is no longer considered as a solution. Given the fact that FW represents a major part of MSW, FW prevention needs to be prioritized also in view of expanding the lifetime of existing landfills and minimizing their associated GHG emissions.

Appropriate waste management frameworks and concepts, such as the food-use-not-loss-or-waste hierarchy (see **Figure 3** on p. 4), the '3Rs' (reduce, reuse and recycle), extended producer responsibility, polluters pay principle, lifecycle assessment and sustainable consumption and production should be considered in FW prevention and reduction. The High-Level Panel of Experts on Food Security and Nutrition (HLPE) (2014) recommended the food-use-not-loss-or-waste hierarchy for the overall approach to FLW prevention and reduction. The priority is prevention, then recovery and redistribution of safe and nutritious food for people in need (see **BOX 1** on P. 5 for a definition), followed by redirecting for some related use (e.g. bio-active compounds, feed), use for bio-materials sourcing, energy generation, composting or other extraction purpose and disposal to landfill as the last option.

Figure 3 *A food-use-not-waste hierarchy to minimize FLW (adapted from HPLE 2014)*



Source: Authors' elaboration.

Currently, in Sri Lanka, strategies to address FW prevention and reduction are being considered by different state and non-state stakeholders. However, in the current scenario, solutions for FW are mostly addressing (bio-) waste management.

Quantifying FW is of paramount importance in understanding the magnitude and socio-economic as well as environmental impacts of the problem. A good understanding of the availability and quality of FW data is a prerequisite for tracking progress on reduction targets, analyzing environmental impacts and exploring mitigation strategies for FLW (Xue *et al.*, 2017). FW quantification aims at creating a robust evidence base for developing strategies, action plans, and policies towards FW prevention, reduction and management as well as guide prioritization of actions, evaluation of solutions and monitoring progress (CEC, 2019).

In addition to the quantification of FW in the selected area, this study focuses also on prevention strategies, such as safe and nutritious food recovery and redistribution for direct human consumption (see **BOX 1** on p. 5 for definition), as the key priority – given that it has the lowest environmental impact and the highest nutritional impact – while also looking at existing reuse and recycling strategies, such as transforming former foodstuffs into feed and other context-specific solutions.

Quantification allows also causes identification and prioritization of interventions for prevention and reduction. FW (i.e. from retail to households) causes may refer to: low-quality purchases; consumers' confusion with "use-by" and "best before" dates; catering services inefficiencies; lack of awareness about FW (i.e. amount generated, monetary loss associated with the FW generated); overwhelmed waste management systems that face challenges for segregation, collection and utilization of FW; lack of proper transportation, cold chains and packaging from production up to wholesale/retail.

Nevertheless, investing in FW prevention and reduction brings interesting returns. The World Resources Institute (WRI) states that - for a data pool of almost 1 200 business sites across 17 countries (with more than 700 companies from food manufacturing, retail, hospitality and food services) - for every USD 1 invested, half of the surveyed sites realized a USD 14 or greater return. Hotels, food service companies and food retailers tended to have ratios between 5:1 and 10:1. Costs consisted of purchasing smart scales or similar measurement technology and training staff. (Hanson and Mitchell, 2017) Better FW data supports better investment decisions for significant returns.

Recovery of safe and nutritious food for human consumption is to receive, with or without payment, food (processed, semi-processed or raw) which would otherwise be discarded or wasted from the agricultural, livestock forestry and fisheries supply chains of the food system.

Redistribution of safe and nutritious food for human consumption is to store or process and then distribute the received food pursuant to appropriate safety, quality, and regulatory frameworks directly or through intermediaries and with or without payment, to those having access to it for food intake.

Box 1 *Definition for recovery and redistribution of safe and nutritious food for direct human consumption*

Source: Technical Platform on the Measurement and Reduction of Food Loss and Waste; http://www.fao.org/platform-food-loss-waste/old-pages/food-waste/food-waste-reduction/country-level-guidance/en/

2. Methodology

Research indicates that the comparison of FW data is difficult because of different methodologies and timeframes applied (Corrado *et al.*, 2019). There are multiple methods to quantify FW, with different resource requirements that often present trade-offs between accuracy and completeness on the one hand and the cost of conducting the quantification on the other hand (Corrado *et al.*, 2019). Direct weighing is the most accurate method for FW quantification, and it can either be done by the FW generators (i.e. households, food business operators) in the form of surveys or by a third party (FLW Protocol, 2016). For instance, to avoid bias for households' measurement and reporting, Langley *et al.* (2010) recommend a third party, as the generators of FW are likely to underreport discarded amounts. In this study, FW quantities were assessed at the final disposal sites, where the disposal authorities - as a third party - measure the quantities. Secondary data, such as waste collection records for the years 2018 and 2019, were obtained from three major disposal facilities namely Kerawalapitiya, Karadiyana and Kaduwela located in the Western province. The data records from the three sites consisted of waste collected from 20 LAs in Western province including municipal councils (MCs), urban councils (UCs) and pradeshiya sabha (PS)[1] that represent the entire urban to rural trajectory.

All three sites are equipped with weighing bridges to record the waste inputs, hence the level of accuracy of data obtained is assumed to be adequate. However, the granularity of data was not sufficient to differentiate FW from the total collected waste. Thus, FW quantification was conducted based on the average of collected biodegradable waste volumes per LA collection area in a given period and the percentage of short-term biodegradable waste of that particular LA.[2]

Short-term biodegradable percentages for each LA in the study area were extracted from a national database for waste management at the LA level by Central Environmental Authority (CEA) in 2012. Subsequently, per capita FW collection was derived for each LA. In addition, current solid waste management (SWM) practices followed by the three selected disposal centers were identified and recorded to characterize the FW management practiced at the regional level. It is relevant to note that no distinction is possible between edible and non-edible parts of the food that was estimated as being wasted (i.e. the study cannot differentiate between an egg and its shell). Thus, the study refers to both edible and non-edible parts of food that are wasted as a whole (i.e. egg and its shell).

The total amount of FW generated within a given LA does not get collected entirely. Waste collection rates of LAs are often less than 100 percent which implies that only a part of the FW generated is being collected (Department of Census and Statistics, 2012). Thus, the assessment also focused on the waste collection rates of each LA, given that it varies vastly across the LAs. Waste collection rates of LAs were obtained from the national databases of the Department of Census and Statistics for the year 2012. Based on the data, geographic information system (GIS) maps were developed (see **Figure 4** on p. 8) to visualize variations in waste collection coverage[3] as well as per capita FW collection of the LAs in the study area - to identify the FW hot spots.

[1] Sri Lankan local authorities (LAs) are divided into three categories: municipal councils, urban councils and pradeshiya sabhas (PS).

[2] Past studies reveal that about 80 percent of biodegradable waste is FW (FAO, IWMI and RUAF, 2018). In this study, FW generation of each LA was estimated based on the short-term biodegradable waste percentage of that LA. It was assumed that percentage of short-term biodegradable waste is equal to FW given that majority of the short-term biodegradable waste is FW.

[3] Waste collected by a local authority as a percentage of the total waste generated within that particular local authority.

The study also aimed at assessing the sectoral contribution of FW in a number of LAs that were selected based on the highest collection of FW which was estimated using the landfill data records. Field visits were subsequently made to those selected LAs[4] to collect primary data on total FW collection in each LA, distribution of properties in LAs and also the contribution to FW from different sectors (i.e. foodservices, markets and other commercial institutions). Wherever possible, waste collection data obtained from landfills for a given LA was validated with the primary data collected from the respective LA.

To obtain a holistic picture, the study proceeded from estimating the total amount of FW to landfill in the study area – from wholesale to households; to the identification and analysis of activities on safe and nutritious food recovery and redistribution for direct human consumption; to estimating the extent of former foodstuffs diverted to livestock feed (i.e. piggeries) and of recycling (i.e. composting and anaerobic digestion).

Although it was planned to collect data also through field surveys and interviews, this was not achievable due to lockdown and other restrictions from the COVID-19 pandemic health emergency. Consequently, three recovery and redistribution organizations and 24 pig farmers were interviewed remotely.

2.1 Study area and system boundaries

The research area of this study is defined by the service area of three main SW disposal sites located in the Western province namely Karadiyana, Kerawalapitiya and Kaduwela. Currently, 20 LAs in Colombo and Gampaha districts in the Western province utilize these sites as their waste disposal facilities.

Table 1 depicts an overview of the three disposal sites. The study area includes the LAs that are served by the disposal sites. The locations of the three disposal sites are shown in **Figure 4,** on P.8 (i.e. SW included FW generated within a LA that is collected and transported either by the LA or private SW collection operators to any of the aforementioned disposal sites).

The total population of the study area is 3 557 817 which is 60.8 percent and 17.5 percent of the population of Western province and Sri Lanka respectively (Department of Census and Statistics, 2012). Among the nine provinces, the amount of SW generation in the Western province is the largest, accounting for 33 percent of the total waste generation in the country (JICA, 2016). Given that a larger proportion of SW is comprised of FW, the Western province is the highest FW generator compared to the other provinces in the country (FAO, IWMI and RUAF, 2018; JICA, 2016).

[4] Sri Jayawardanapura Kotte MC, Dehiwala MT Lavinia MC, Moratuwa MC, Kaduwela MC, Kolonnawa UC, Boralesgamuwa UC, Maharagama UC, Kesbewa UC and Homagama PS.

Table 1 *An overview of Karadiyana, Kerawalapitiya, and Kaduwela disposal sites*

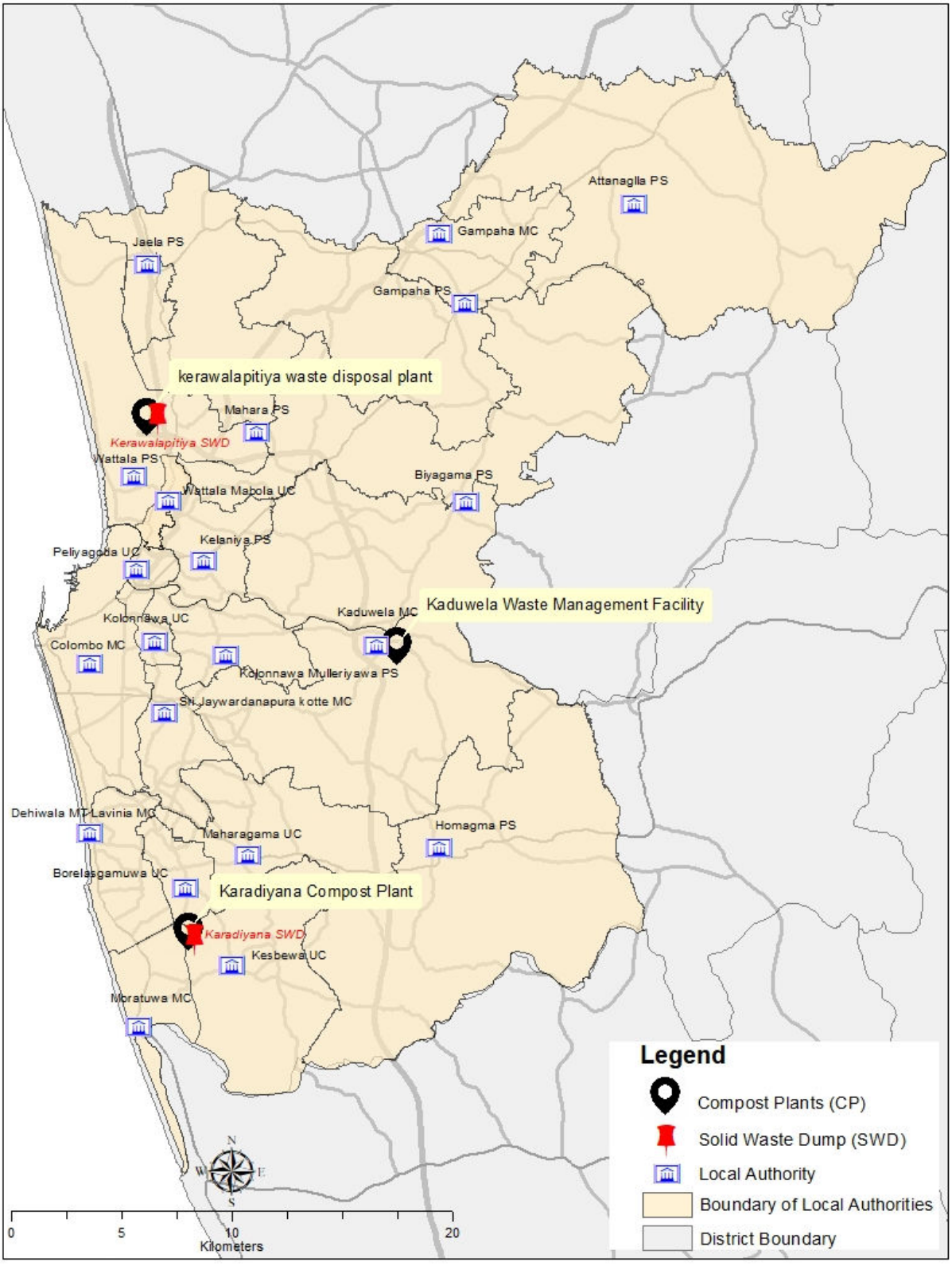
Description	Karadiyana landfill	Kerawelapitiya landfill	Kaduwela waste recycling facility[5]
Land extent	37 acres[6]	20 acres	3.5 acres
Names of the LAs served	Moratuwa MC, Boralesgamuwa UC, Kesbewa UC, Dehiwala - Mount Lavinia MC, Sri Jayewardenepura Kotte MC, Maharagama UC, Homagama PS	Colombo MC. Wattala PS, Kelaniya PS and Kolonnawa UC.	Kaduwela MC
Operated by	Waste Management Authority, Western Province (WMA)	Sri Lanka Land Development Corporation under the Ministry of Urban Development and Housing.	Kaduwela MC
No of employees	35	-	45
Year of establishment	2010	2017	2006

Source: Authors' elaboration.

[5] Kaduwela disposal facility does not operate as a landfill but as a waste recycling facility. SW that is transported to the facility is measured through the weighing bridge and then majority is diverted to a private landfill including both biodegradable and non-biodegradable waste. Hence in the report Kaduwela is not recognized or noted as a landfill.

[6] 1 ha = 2.47 acres.

Figure 4 *Study area based on the three landfill service areas (GIS map)*



Source: United Nations Geospatial. 2022. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors.

3. Food waste (FW) quantification

The total amount of SW generated by Sri Lanka is around 7 000 tonnes per day and it typically consists of a very high percentage of perishable organic material which is about 65–66 percent by weight (Arachchige *et al.*, 2019; FAO, IWMI and RUAF, 2018; Bandara, 2011).

Table 2, on P. 9 depicts the FW volumes generated in major LAs in Sri Lanka. Accordingly, the proportion of FW generated in a LA range from 50-69 percent of the total waste with an average of 56.5 percent. According to this average value, the total FW generated in the country can be estimated as 3 955 tonnes per day.

Table 2 *Food waste quantities generated in selected local authorities in Sri Lanka*

Local authority	Total SW quantity (tonnes/day)	FW quantities (tonnes/day)	FW percentage	References
Colombo municipal council	706	353	50%	FAO, IWMI and RUAF, 2018
Moratuwa municipal council	124.5	65.4	52.5%	JICA,2016
Kandy municipal council	127	73.7–75.2	58.2–59.2 %	Karunaratne *et al.*, 2019; Menikpura *et al.*, 2007; JICA, 2003
Jaffna municipal council	104.9	72.2	68.9%	JICA,2016
Kurunegala municipal council	48	25	52%	JICA, 2016
Batticaloa municipal council	52.5	30	57%	Otoo *et al.*, 2016; Bandara, 2011

Source: Authors' elaboration.

FW generated in the study area was estimated based on the waste amounts transported to the three selected waste disposal facilities. Data was available for the year 2018/19 in the form of weighing bridge records of waste input to the disposal facilities from different LAs and private waste collectors. The total waste delivered to the three sites are given in **Table 3**.

Total waste absorbed by all three disposal facilities on daily basis is about 1 317 tonnes out of which 724 tonnes is estimated to be FW (please see methodology section for details on the approach implemented) that is collected from 20 LAs across the Colombo and Gampaha districts (i.e. based on the data from 2018/19). Subsequently, the proportion of FW in the study area can be estimated as 55 percent of total waste which is comparable to the average percentage of FW (56.5 percent) derived based on the literature, as aforementioned. This is substantial compared to the other types of waste.

Table 3 *Average waste quantities received at three disposal facilities*

	Karadiyana landfill	Kerawalapitiya landfill	Kaduwela waste recycling facility
Daily waste (tonnes/day)	559 ± 149	687 ± 105	71 ± 12
Biodegradable waste (tonnes/day)	259 ± 139	475 ± 79	42 ± 9
FW (tonnes/day)	253 ± 130	433 ± 78	38 ± 7

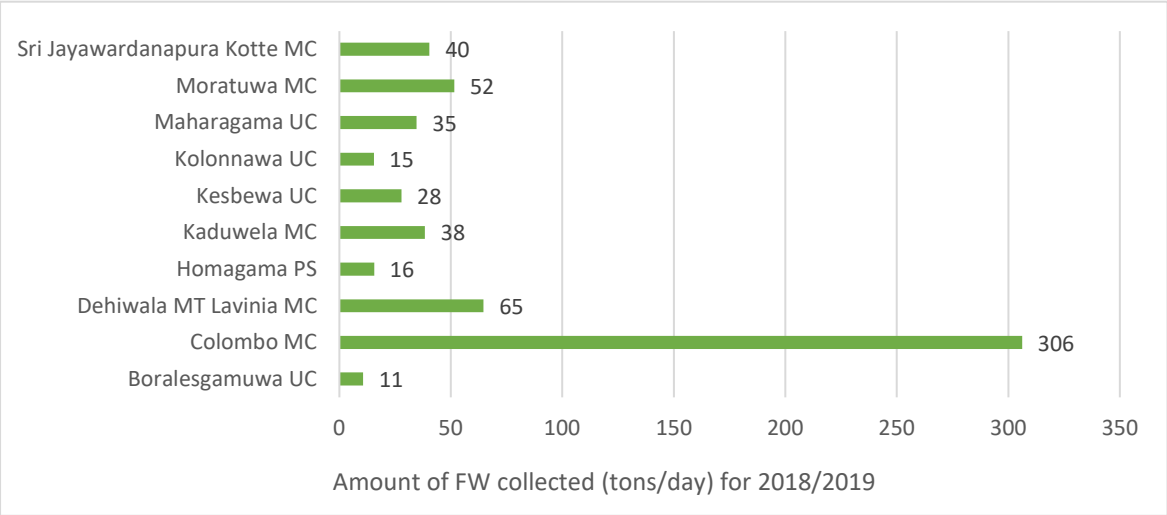
Source: Authors' elaboration.

LAs in Sri Lanka are statutorily responsible for SWM including FW management in a given LA. In addition to LAs, private sector operators are also engaged in SW collection - particularly in the urbanized contexts. Current practice in the study area is such that the SW from residents, government institutions, commercial institutions (i.e. such as foodservices and supermarkets) are collected by the public or private sector and delivered to one of the disposal centers. The waste is measured at the facility and a disposal fee is charged from the waste collectors based on the types and quantities of waste transported.[7]

The quantities of FW collected by each LA were derived based on the methods described in the methodology section.[8] It is estimated that, in total, about 605 tonnes of FW, which is about 83.6 percent of the total FW collected on a day in the study area is from the LAs in Colombo district.

Figure 5 depicts the daily amounts of FW transported to the disposal facilities by LAs in the Colombo district.[9] FW collected by Colombo municipal council (CMC) is remarkably higher (42 percent of total FW) compared to the other LAs. This could be attributed to the high level of urbanization in CMC which has resulted in the highest residential and floating populations and the highest number of commercial institutions, such as foodservices and retail markets.

Figure 5 *Food waste collection in local authorities in Colombo district for the year 2018/19*



Source: Authors' elaboration.

Figure 6, on P. 11 indicates the per capita FW amounts estimated for the entire study area in terms of LAs which was developed using GIS maps and **Figure 7,** on P. 11 gives the per capita FW collection in LAs in Colombo district. This visualizes the FW hotspots in the study area. CMC and suburbs mark the highest per capita FW amounts that range between 0.20–0.55 kg / day. In addition to CMC, Dehiwala - Mt. Lavinia followed by Moratuwa MC indicate the highest per capita FW. WWF (2017) reports

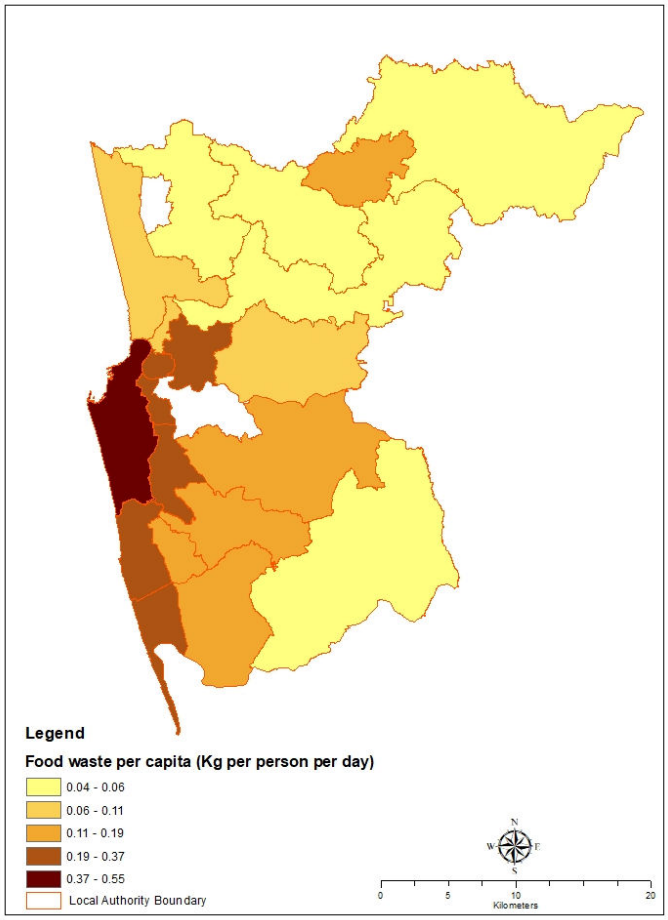
[7] Disposal fee for sorted organic waste which includes FW is LKR 200 (approximately USD 1) / tonne.

[8] An important aspect to note is that these waste amounts does not reflect the total waste generated by the LAs. In reality, total waste generated does not get collected due to various reasons such as lack of resources of the LAs to extend the collection service and self-management at household level. Given different circumstances, waste collection rates across the LAs vary vastly (Annex 1). Actual amount of waste can therefore be higher than the given amounts.

[9] Only the LAs that belong to Colombo district are considered in the figure for further analysis, given the fact that the collected waste amount of the rest of the LAs that belong to Gampaha district are comparatively low (16.4 percent of the total FW).

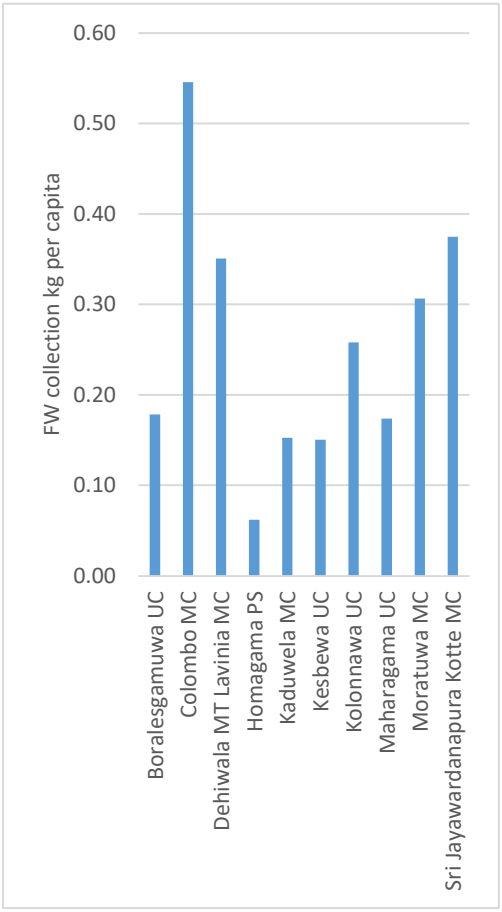
average per capita solid waste generation of around 0.8 kg / day (0.4 kg in low-income households to 1.3 kg in high-income households) which is comparable to the study estimations in a similar context.

Figure 6 *Per capita food waste amounts of LAs in Colombo district*



Source: United Nations Geospatial. 2022. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors.

Figure 7 *Per capita food waste amounts of LAs in the study area*



Source: Authors' elaboration.

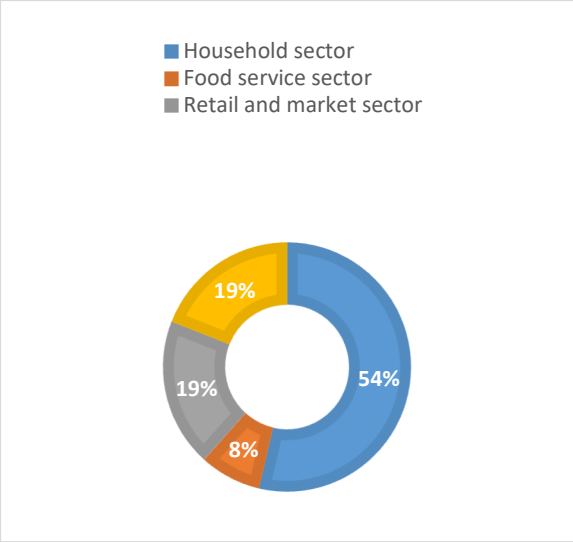
3.1 Overall sectorial contributions to FW

FW generation from different sectors vary significantly based on their operations. It is essential to assess the sectoral contribution of FW to not only identify which sector is responsible for more FW but also to identify appropriate FW prevention and reduction strategies. However, there is a huge gap in data that reflects the contribution of different sectors to the FW generation and the associated economic loss. Most research on FW provides evidence only from developed countries (Papargyropoulou *et al.*, 2019).

Typically, households contribute the largest portion of the total FW generated. A study conducted in the European Union (EU) indicates that up to 53 percent of FW is generated by households (FUSIONS, 2016). Literature for Sri Lanka (see **Figure 8** and **Figure 9** on p. 12) indicates that 54 percent and 64 percent of SW collected from Moratuwa and Negombo MC respectively is household waste (JICA,

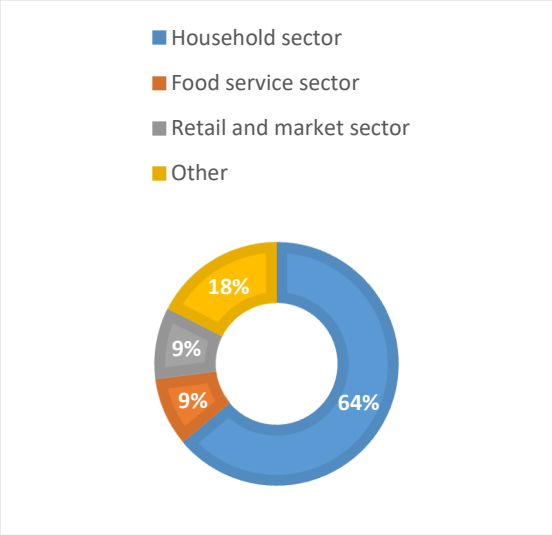
2016; Karunarathna *et al.*, 2019). It is important to note that these illustrations are on SW and further analysis is needed to reflect on FW data estimates (please see the section below on households FW)

Figure 6 *Sectoral contribution of solid waste in Moratuwa MC*



Source: Japan International Cooperation Agency (JICA). 2016. Data collection survey on solid waste management in Democratic Socialist Republic of Sri Lanka-Final Report. JICA, Kokusai Kogyo Co., Ltd.

Figure 7 *Sectoral contribution of solid waste in Negombo MC*

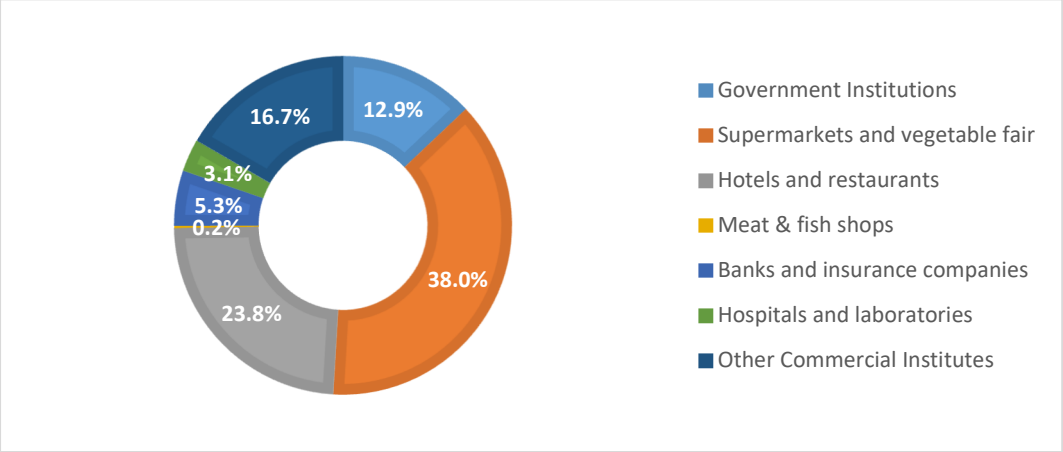


Source : Karunarathna, A. Singh, R.K., Rajapaksha, T., Premakumara, D.G.J. & Onogawa, K. 2019. State of municipal solid waste management in Negombo city, Sri Lanka. United Nations Environment Program.

Apart from households, foodservices and retail markets are among the major contributors to FW. An analysis conducted by FAO/IWMI in 2017 for the segregated waste collected by CMC, consisted of 75 percent of FW from the food services, 17 percent from wholesale and retail markets and 6 percent from slaughterhouses and meat shops (FAO, IWMI and RUAF, 2018). Based on an analysis conducted Kaduwela MC in 2019, Jayathilake *et al*. (2021) report that among different institution categories, supermarkets and vegetable retail shops contribute the most to the biodegradable waste component followed by the food service sector (see **Figure 10**).

Given that most of the biodegradable waste is FW, it can be assumed that the percentage distribution FW from different sectors follows a similar pattern. However, in this case, pig farmers often collect the former foodstuff directly from hotels and restaurants. Thus, this proportion has not been factored into the given FW estimations. Therefore, the actual quantity of FW generated by the hotels and restaurants sector could be relatively higher than the estimated values.

Figure 8 *Distribution of 2019 food waste generation by different sectors in Kaduwela municipal council*

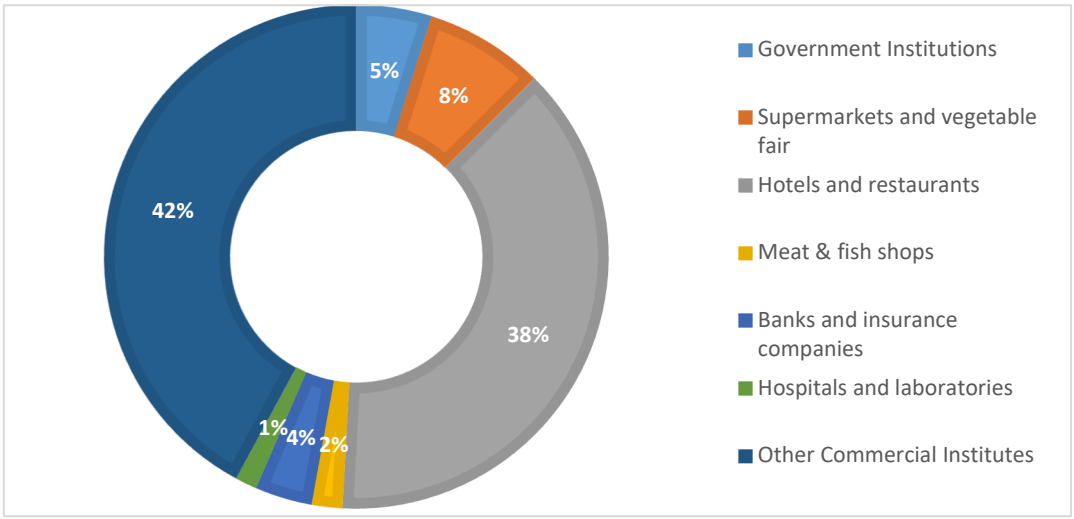


Source: Jayathilake, N., Drechsel, P., Dominish, E. & Carrard, N. 2021. Organic waste system assessment: Kaduwela municipal council. Colombo, International Water Management Institute.

Although it was intended to identify the sectoral contribution of FW in the entire study area, there were limitations such as the unavailability of data records on FW collection from different sectors at the LA level. Moreover, according to the current setup and practices, there was no special requirement for LAs to maintain such data records in the perspective of waste management. However, it was noted that while SW collection is offered as a free service to the households, some institutions - such as commercial properties registered as businesses with the LAs - are required to pay a waste collection fee determined based on the waste volumes to be received by the waste collection services.

The amounts of different components of waste from each institution are estimated to an approximate value by the LA officials to establish the waste collection fees. Likewise, the biodegradable waste component estimated for each organization can be collated and then categorized into different sectors to derive the percentage distribution of biodegradable waste from different sectors.

Figure 9 *Percentage distribution of 2019 food waste collected from different types of institutions in Dehiwala Mt. Lavinia municipal council*



Source: Authors' elaboration, based on waste collection records from Dehiwala Mt. Lavinia MC, 2019.

Figure 11 gives the sectoral contribution of biodegradable waste estimated for Dehiwala Mt. Lavinia MC. Accordingly, the category of other commercial institutions that were not identifiable distinctively indicates the highest proportion followed by the hotel and restaurant sector. It was observed that in Dehiwala Mt. Lavinia MC, the number of unidentified commercial institutions recorded were 790 which is substantially higher than the other institutional categories. For example, 350 hotels and restaurants (**Annex 3,** on P. 29 gives property distribution of some LAs in Colombo district including Dehiwala Mt. Lavinia). This can be a reason for other commercial institutions to report the highest proportion.

However, during the data collection process, it was evidenced that the majority of the LAs do not perform proper analysis in determining the waste produced by each segment/institution. Instead, LAs use ad hoc values to calculate the waste collection fees. It was therefore difficult to differentiate FW generation across the sectors for LAs in the study area. However, it is important to note that assessing the contribution of FW from different sectors is imperative in designing FW prevention and reduction strategies.

3.1.1 Households

Households are a major FW contributor. On average about 87 percent of the properties in Colombo district are residential properties with a range from lowest of 70 percent in CMC to the highest of 95percent in Homagama PS area. Past studies suggest about 80–94 percent of the residential solid waste is FW (Wijerathna *et al*., 2013; Thirumarpan *et al*., 2015; Warunasinghe and Yapa, 2016). A study conducted in Kottawa area in Colombo reports that the majority of households generate more than 1.88 kg of FW / day (Warunasinghe and Yapa, 2016). Considering the average household size of four, FW generation rate per capita can be estimated as 0.47 kg per day. However, it is important to note that waste generation rates (including FW) depend on various factors such as income status, lifestyles, geographic location, attitudes and season of the year.

Existing data indicate that per-capita FW in the household increases with an increase of per-capita GDP (Xue *et al.*, 2019). A preliminary assessment conducted by FAO/IWMI in CMC area in 2017 states that middle to high-income families generates more FW than low-income households. The study also reported that about 48 percent of households generate between 10–20 percent of FW from their total food purchases while 18 percent waste more than 20 percent of their food. Another key finding from the study is that middle to high-income families generates more FW than low-income households (FAO, IWMI and RUAF, 2018). A study in 2012 found that per capita FW generation in high income, middle income and low-income level households in Gampola UC as 0.39 kg, 0.26 kg and 0.24 kg respectively (Wijerathna *et al*., 2013).

3.1.2 Food services

The food service industry encompasses any establishment that serves food to people outside their home including hotels, restaurants, cafeterias, university dining halls, catering companies etc. According to the International Finance Corporation (IFC), the hotel industry in Sri Lanka is among the main producers of solid waste (IFC, 2013).

FW generation is common in the hospitality industry since the supply is mainly focused on demand quality and quantity satisfaction (Sandaruwani and Gnanapala, 2015). When it comes to waste prevention and management, the hotel industry is driven almost entirely by regulatory requirements, except for a few environmentally conscious hotels that take extra measures to reduce, reuse and recycle solid waste. This is because most establishments do not see financial benefits, as they do with energy conservation measures (IFC, 2013). Awareness should be strengthened on the fact that hotels, food service companies and food retailers can reach ratios between 5:1 and 10:1 for their returns on investments for FW prevention actions – with the costs consisted of purchasing smart scales or similar measurement technology and training staff. (Hanson and Mitchell, 2017)

In Sri Lanka, the most adopted strategy for FW management by the hospitality and food services sector is to divert the unused foodstuff to piggeries. This is a transaction that directly occurs between the foodservices and pig farmers. Hence, it is unaccounted in current FW estimations. The Western province has the highest number of hotels, at provincial level, in Sri Lanka. Major hotels in CMC and suburbs have been a key source of former foodstuff for feed to piggeries in the area. Additionally, large scale hotels have adopted anaerobic digestion (i.e. biogas plants) and composting as ways to manage the FW generated within their premises. A survey of registered hotels in the Western province found that comparatively large hotels (with more than 50 rooms) perform better than their smaller counterparts in following good environmental management practices including SWM. Good SWM practices include composting (22 percent), recycling (22 percent) and solid waste segregation (18 percent). (Institute of Policy Studies of Sri Lanka (IPS), 2015)

3.1.3 Wholesale, retail, and markets

FW for wholesale, retail and market sectors is significant. For instance, FAO, IWMI and RUAF (2018) reports that Manning market - which is the largest wholesale market that acts as the main hub of food distribution to Colombo region - produces about 20 tonnes of vegetable waste and 5 tonnes of carcasses / day.

Bakery items, meat, fruits and vegetables are the most wasted foods in supermarkets in most countries (Brancoli, Rousta and Bolton, 2017). A study conducted by Kumara *et al.* (2018) confirms this for Sri Lanka and additionally reports that the monthly average economic loss due to FW is nearly LKR 216 000 / outlet across four major supermarket chains in Colombo.

Certain supermarkets in Sri Lanka are actively engaged in implementing strategies towards FW reduction. In their efforts, food recovery and redistribution for direct human consumption has been identified as one of the most viable solutions. Such innovative models are being explored by the sector to prevent FW as well as embed these measures into the cooperate social responsibility (CSR) initiatives.

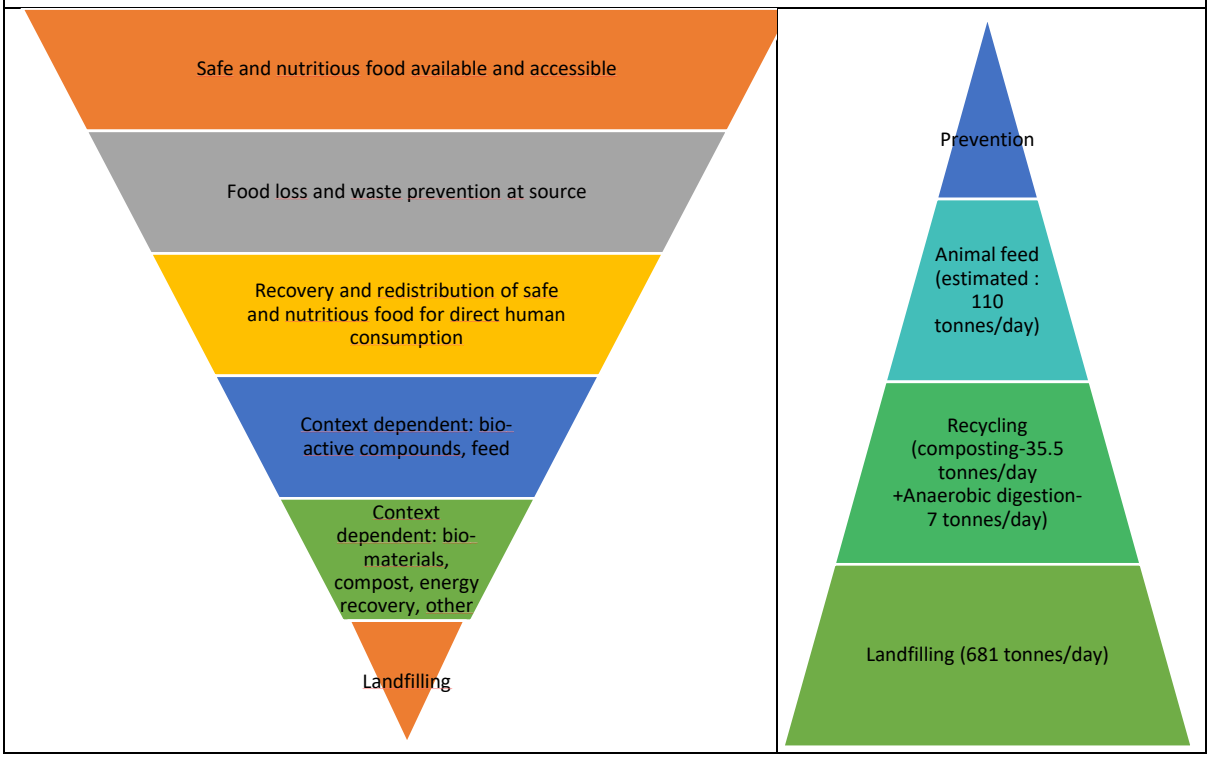
Furthermore, although supermarkets have, in general, the necessary resources to optimize management and minimize FW, other retail markets often lack adequate facilities such as proper storage facilities.

3.2 The food-use-not-waste hierarchy in the study area

In the current Sri Lankan urban context, FW is mostly looked at from the perspective of waste management even if evidence already available from literature and practice (see sections above) demonstrate that prevention and reduction at source are the most socio-economically and environmentally impactful approaches.

There is a significant gap between available evidence and current practice. **Figure 12,** on P. 16 illustrates an overview of the *food-use-not waste hierarchy* compared with current practices in the study area.[10]

Figure 10 *The food-use-not-waste hierarchy compared to the current status in the study area*



Source: Authors' elaboration.

3.2.1 Food recovery and redistribution for direct human consumption

Safe and nutritious food recovery and redistribution for direct human consumption is one of the preferred options in the food-use-not-waste hierarchy (HLPE, 2014). Food rescue programs focus on (non-) perishable food that can be recovered and redistributed, for instance, to needy families, elder care homes, and orphanages. Food redistribution provides an opportunity for utilizing the food at its optimum value for human consumption. Although not yet a common practice in Sri Lanka, food redistribution is practiced to a certain extent in the Colombo region by organizations that operate through different models. These organizations collect prepared food from restaurants and bakeries or fresh vegetables and fruits from supermarkets and redistribute.

[10] The estimations that determined the scale of the options of former foodstuffs for animal feed and recycling are given in section 3.2.2. and 3.2.3. respectively.

Most of these organizations are volunteer-based non-profit organizations. Three such organizations (i.e. Robin Hood Army, the Soup Bowl and the Voice for Voiceless Foundation) were interviewed for this study to understand the nature and scale of their operations. COVID-19 has been a major challenge for the continuation of operations.

Robin Hood Army started its operations in 2018. Safe and nutritious food surplus is collected from restaurants, bakeries. The organization receives support from two leaders, six collaborators and about 200 volunteers. It runs as a zero-fund organization with no acceptance of monetary contributions. The transportation of goods is done with the volunteers' own vehicles and foodstuffs are received from bakeries and restaurants (e.g. Paan Paan and Royal Bakery) around Colombo region mainly from Wattala, Kolonnawa, Dematagoda and Kollupitiya. The types of food accepted exclude dessert, salads, or cooked meals given that those have a very short shelf life. The collection of food is mostly done in the nighttime, after the closure of restaurants. Beneficiaries include homeless families, night shelters, orphanages and elders' homes, low-income people, laborers. The Robin hood Army manages to provide about 100–200 meals daily (personal communication with Mr Aqeeel, co-founder, 14 July 2020). In the month of December 2020, they have been able to feed 7 912 people (The Sunday Morning, 4 January 2021).

The Soup Bowl was launched by a team of three friends in 2014 with the mission to feed the poor. The organization has also a delivery arm WeGiveStuffAway (WGSA) where they drop off food to needy families. WGSA rescues and channels surplus food such as fruits, vegetables, dry rations and canned items to be given to families, children and elder's homes. They also cook hot meals in their drop-in. WGSA evolved by partnering with Keells supermarket that provided surplus vegetables and fruits. The Soup Bowl also donates nonperishables as well as food items from restaurants. Transportation is done through volunteers and they mainly operate in Colombo and suburbs. The organization runs as a charity with support from volunteers. Funds required are raised via social media. The organization has served over 20 000 plates of rice from 2015 to 2020 (personal communication with Ms Rishani, founder, 16 August 2020).

Voice for Voiceless Foundation initiated a project called VDonate in 2019 to collect fresh unsold vegetables and fruits from selected outlets and donate it to needy families with the collaboration of Keells supermarket. The collections are done in the nighttime, followed by segregation and distribution to those in need. About 200 families across the country have been served.

Food redistribution initiatives are currently being practiced at a micro-level in the country. Overall, these models need to be further explored towards implementing sustainable FW prevention strategies. However, challenges such as a lack of legal and operational guidance from the public sector, coupled with a lack of storage facilities limits the extent of operations. Presently, there is also a lack of involvement from the corporate sector. It is worthwhile to explore mechanisms to formalize and scale up these initiatives to prevent and reduce the FW as well as enhance food and nutrition security.

Guidelines exist elsewhere in the world for food redistribution. For example, the European Commission has adopted EU food donation guidelines to facilitate the redistribution of safe, edible food to those in need. The EU guidelines seek to facilitate the compliance of providers and recipients of surplus food with relevant requirements laid down in the EU regulatory framework (e.g. food safety, food hygiene, traceability, liability, VAT, etc.).

3.2.2 Former foodstuffs for animal feed

Using former foodstuffs as animal feed is one of the options for preventing FW, a common practice at global level, often concentrated around metropolitan centers. However, it is relevant to highlight that Sri Lanka currently lacks legal and operational guidelines for former foodstuff to feed operations as well as enforcement mechanisms for sourcing and utilization boundaries as well as feed safety and quality.

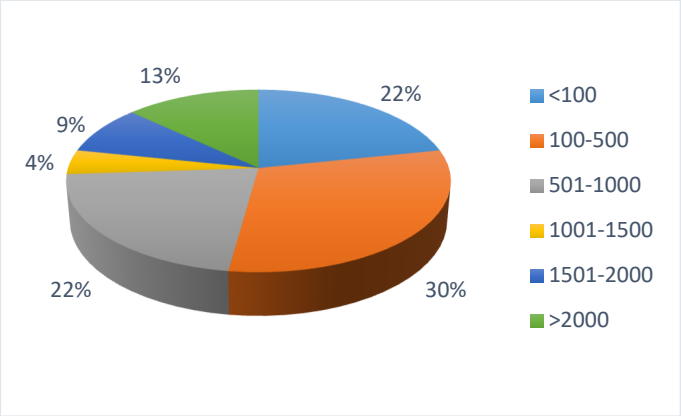
Generally, former foodstuffs from the food service sector is directly collected by pig farmers. Although the former foodstuffs are often given away for free, the foodservice sector can still benefit from this practice by avoiding paying a waste collection fee which would otherwise have to be paid to the waste collector. The small swine operations located near major cities are providing the demand for different sources such as hotels and restaurants, households, etc.

Under this study, 24 pig farmers were remotely interviewed to get an overview of the former foodstuffs' utilization by piggery farmers in the Western Province. Results revealed that the majority of piggeries are scattered in Kaduwela and other areas are Welivita, Hanwella, Kosgma (in Colombo District) and Ja-Ela (in Gampaha District) and Maggona (In Kalutara District). Data indicated that 96 percent of piggery farmers use former foodstuffs as the main feed source to raise their pigs. However, the proportion used appears to be varied based on the purpose and the type of pigs.

The majority of the sample have 100-300 pigs while the entire sample indicated a range of 10 to 5 000 pigs in a farm. Most of the pig farmers collect former foodstuffs from CMC followed by Kaduwela. There were no feed collections reported from Dehiwala - Mt. Lavinia, Jayewardenepura - Kotte and Moratuwa areas. With no indication of diverting the FW to alternative locations such as piggeries, this could be one of the key reasons for these three areas mark the highest FW generation amounts in the region in addition to CMC (see **Figure 7** on p. 11). At the same time, it shows that prevention of food from becoming waste has significant room for improvement in all the study area.

About 26 percent of the farmers usually collect former foodstuffs from hotels while another 26 percent are collecting it from institutional canteens. However, a larger percentage of the farmers (39 percent) collect former foodstuffs from multiple points including hotels, hospitals and institutional canteens, on daily basis, to meet the demand. About 61 percent of the sample make a round trip of less than 50 km to collect the supply whereas 9 percent travel more than 100 km.

Figure 11 *Average amount of 2020 food waste collected by pig farmers (kg per day) in the surveyed areas*



Source: Authors' elaboration based on IWMI survey for this report, 2020.

The average amount of former foodstuffs collected per day by piggery farmers vary with factors such as the size of piggery stock and the availability of feed from other sources. The survey indicated a significant variation between 50 kg to 10 000 kg of former foodstuff usage with the majority using 100–500 kg per day (see **Figure 13**). It was estimated that a piggery farm with 1 000 pigs requires nearly 1.5 tonnes of former foodstuffs daily.[11]

The majority of the pig farmers use former foodstuff as their main feed source in addition to the concentrated feed. Given that the pig farmers mostly receive former foodstuff free of charge, they tend to use it as the major feed source over the concentrated feed. However, the seasonal nature of the supply of former foodstuffs, that is linked with tourism and festive seasons can lead to insufficient supply on some occasions as well as during emergencies such as the COVID-19 pandemic. This has resulted in an increased cost of operations for the farmers. In addition, the collected former foodstuffs need to be sorted to remove the nonfood materials such as plastic, polythene and glass, which creates additional labour cost.

Based on the data gathered during the survey, it was calculated that, in total, 34 tonnes of former foodstuffs from the study area are absorbed daily by the 24 number of piggeries considered. According to the 2019 database from the Department of Census and Statistics,[12] there are 148 and 934 pig farms that operate in the Colombo and Gampaha districts respectively. Assuming that 96 percent[13] of the pig farmers in Colombo district collect former foodstuffs from the study area and given the average number of pigs in a farm is 514,[14] it can be estimated that about 110 tonnes of former foodstuffs are absorbed by this sector on daily basis. If 50 percent of the pig farmers in Gampaha district was also accounted in the calculation, it is estimated that, in total, about 470 tonnes per day of former foodstuffs can be absorbed by this sector.

Currently, the foodservice sector is able to dispose of their former foodstuffs regularly at no cost as well as pig farmers getting their supply, sometimes free of charge. However, there are challenges associated with these operations, such as poor quality of the feed when they are in the mixed form, and poor linkages between farmers, waste generators and collectors. This highlights the need for formalizing this practice. However, the implications of formalizing this practice need to well-assessed prior to implementation.

The results also revealed that 26 percent of the farmers had to pay a price ranging from LKR 2-40 per kilogram when the former foodstuffs were not directly collected from the sources but purchased from intermediaries. A study conducted in 2019 reported that in the Negombo MC area, approximately 1–2 tonnes of former foodstuffs are collected by private traders to sell as animal feed for piggery farmers (Karunarathna *et al.*, 2019). These different operating models need to be further explored to transform such practices into viable business models that ensure: (i) FW prevention is adequately implemented; (ii) what cannot be prevented and becomes former foodstuff, is managed adequately for feed safety and quality.

[11] On average, an adult pig requires 5 Kg of former foodstuffs per day and piglets 1 Kg to fulfill their minimum dietary requirement (personal communication with a veterinary officer). Based on the survey result for this study, on average, farms maintain 1:6 adult to offspring ratio in their farm.

[12] Agriculture and Environment Statistics Division Department of Census and Statistics, Sri Lanka. Number of Livestock Farmers – 2020. Available at: http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubb7 (Consulted on 05 January 2021).

[13] Based on the survey results about 96% of pig farmers use former foodstuff as piggery feed.

[14] According to the results of the survey average number of pigs in a farm is 514.

It is also important to note that this sector has a certain demand and once the supply meets the demand there is no additional former foodstuffs that could be absorbed, except if the industry expands. Therefore, it is important to explore more robust long-term solutions to address FW prevention.

3.2.3 Food waste recycling

In addition to the aforementioned options, currently, there are other FW management practices in the study area, such as composting and anaerobic digestion. These options allow energy or nutrients to be recovered, thus representing a significant advantage over landfill (FAO, 2013).

Table 4, on P. 20 indicates the scale of FW recycling activities in the study area. Accordingly, out of the daily 724 tonnes of FW that is delivered to the three landfill facilities, about 42.5 tonnes is recycled through composting or anaerobic digestion. Consequently, the rest of FW, which is 682 tonnes (94 percent of the total FW), are landfilled.

Table 4 *Food waste management practices at the three surveyed disposal facilities*

Description	Karadiyana landfill	Kerawelapitiya landfill	Kaduwela waste recycling facility	Total (as an average)
FW received (tonnes/day)	253	433	38	724
Amount composted (tonnes/day)	8	15–20	10[15]	35.5
Amount directed to anaerobic digestion (biogas plant) (tonnes/day)	-	-	7	7
Landfilled (tonnes/day)	245	415.5	21	682

Source: Authors' elaboration.

Despite favorable conditions for composting FW (i.e. high organic and moisture content), and widely established composting interventions in the country,[16] the practice is at a very low adoption rate in the Colombo area due to reasons such as space constraints and large volumes of waste. Based on the data from 2018/19 from the three disposal sites, only five percent of the total FW in the study area is composted at the disposal facilities. IWMI communication with CMC officials in 2020 revealed that engaging in recycling operations for the large volume of biodegradable waste collected by the CMC is a great challenge.

While all disposal facilities practice composting, anaerobic digestion is practiced only at the Kaduwela recycling center at a very small scale - which is only one percent of the total FW in the study area (18 percent of FW in the Kaduwela MC).

[15] A private operator engaged in the waste disposal of Kaduwela is also practicing composting in his own premises using the biodegradable waste collected in Kaduwela MC. However, these volumes are unknown (Jayathilake *et al.* 2021).

[16] Pilisaru Project' (the national SWM programme) in 2008 was launched by Central Environmental Authority (CEA) with the main aim of maximizing the re-utilization of waste with the establishment of composting plants essentially at the local authority level. The project has funded over 115 compost plant across the country.

The biogas plant in Kaduwela accepts about 7 tonnes per day of FW and electricity generation of the plant is expected to serve the compost conveyor and screen at the facility (Jayathilake *et al*. 2021). Although currently operated at a very small scale in the study area, anaerobic digestion (i.e. biogas plants) has been in practice in the country for many years. However, most of these plants have not been successful in the long run. One of the major challenges could be the lack of expertise at the local level. Additionally, legal and operational guidelines are necessary to set boundaries and ensure compliance – to minimize the risk of generating demand for FW as a resource, thus, going against the objective of prevention and reduction. Cost-benefit analysis and ex-ante assessment are required.

This study confirms that landfilling is the most practiced FW management strategy in the study area which is, generally, the case for the entire country. Given that the availability of land for disposal is a key challenge, FW has become a huge burden to the authorities that are responsible for waste management in the study area.

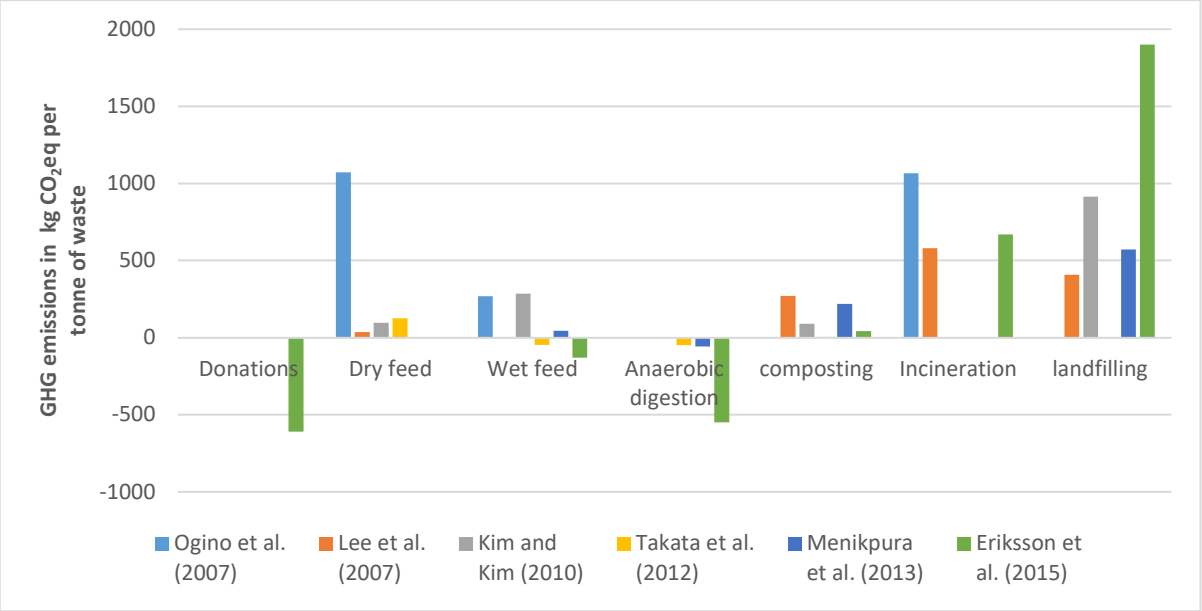
4. Social and environmental impact of FW in the study area

The impacts of FW are linked, for instance, to the natural resources used along the supply chains, from producing to distributing food that is finally not eaten and the effects of disposal on climate change due to Greenhouse gas emissions (GHGEs) (FAO, 2013). The progress made in assessing FW impacts in terms of GHGEs can be measured in two ways:
- FW decomposition at landfills;
- FW embedded emissions associated with food production, transport, retail and after, including waste management, or the 'life-cycle' view of FW.

The most accurate measure to adopt is the life-cycle approach where food commodities are assessed from production to consumption along with waste management. However, this approach may not be feasible in all research or assessment circumstances. Nevertheless, assessing, in addition to one's FW point, a one step forward and one step back in the supply chain can also generate interesting data related to impacts, potential returns on investment and feasibility for scaling-up solutions.

Various studies have been conducted to determine the environmental impacts related to different FW management routes. Examples are shown in **Figure 14** in which a comparison of GHGEs is given for different FW management options based on six studies conducted in different parts of the world. Accordingly, food donations bring the highest GHGEs saving potential followed by wet/dry animal feed and anaerobic digestion, whereas the highest GHGEs are reported for landfilling. It is however important to note that these figures have been estimated for a given context and a defined scope boundary, hence need further scrutinizing before applying to another context.

Figure 12 *GHGEs from different food waste management options – as based on selected literature*



Note: Not all six studies have considered all the given food recovery options. Blank spaces indicate that those options have not been covered under that study.

Source: Hall M. 2016. Techno-environmental analysis of generating animal feed from wasted food products. Thesis. Rochester Institute of Technology. New York. (also available at https://scholarworks.rit.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=10322&context=theses)

This study attempted to investigate the overall environmental and socio-economic impacts from the current food recovery and redistribution practices. When it comes to food redistribution, food donation not only creates benefits in terms of GHG emissions but also brings multiple social and economic benefits.

According to the Household Income and Expenditure Survey (HIES) final report 2016, households in Colombo district spend about 25 percent of their monthly income on their meals, which accounts for LKR 26 066 (Department of Census and Statistics, 2017). However, this can significantly vary across different groups of households, for example from urban residents to rural as well as from low income to high income families. Romeshun and Mayadunne (2011) reports that underserved settlements in Colombo district accounts for approximately 50 percent of the population. A survey conducted in Colombo in 2015 found that households in underserved settlements spend, on average, about 66 percent of the total income on food, accounting for LKR 17 305.69 (Chandrakumara, 2015).

Furthermore, environmental impacts can be analysed for the study area. **Table 5** highlights the GHG emissions with respect to different FW management routes that were extracted from the literature. Based on these figures, it was attempted to identify the environmental impacts in the perspective of current FW management routes practiced in the study area such as animal feed, anaerobic digestion, and composting and subsequently to compare the benefits in terms of GHG emissions. The variations in CO_2eq represent the variations in the waste composition.

Table 5 Food waste disposal routes and related GHGEs in selected countries, as based on literature

Disposal route	GHG emissions in kg CO_2eq per tonne of organic waste	Reference (country)
Landfilling	572	Menikpura *et al*., 2013 (Thailand)[a]
	770	Awanthi and Navaratne, 2010 (Sri Lanka)[b]
	914	Kim and Kim, 2010 (Republic of Korea)[b]
Diverting foodstuffs to animal feed	-236	FAO, 2013
	-104	Kim and Kim, 2010 (Republic of Korea)
Anaerobic digestion	-143	FAO, 2013
	-111	Fusions, 2015[c] (Europe)
Composting	-39	Fusions, 2015 (Europe)

a: estimations were based on household organic waste; b: estimations were based on FW; c: while estimating a credit has been given for avoided fossil fuels in energy recovery and anaerobic digestion.
Source: Author's elaboration.

Based on the estimated shares of FW to different recycling and disposal operations, **Table 6,** on P. 23 gives GHGEs in relation to each disposal route in the study area using an average CO_2eq conversion factor, which is close to the one measured in the Sri Lankan case Awanthi and Navaratne (2010). **Table 6,** on P. 23 shows that the existing transformation of FW to animal feed is, for now, among the most environmentally friendly options in the study area. However, guidelines for legal and operational setting as well as enforcement mechanisms are necessary for scaling up to have a more significant impact on the reduction of GHGEs currently emanating from local landfills.

Table 6 *Total GHGEs in relation to different food waste recovery and disposal routes*

Recovery and disposal operations	Amount FW (tonnes/day)	Conversion factor[a] (kg CO_2 /tonne of waste)	GHG emissions in kg CO_2eq
Landfilling	682	752	512 864
Food stuffs to animal feed	110	-123.5	-13 585
Anaerobic digestion	7	-75	-525
Composting	35	-39	-1 365

a: an average from the range of figures available in the literature (see **Table 4**)

Source: Author's elaboration.

5. Conclusions

FW quantification is of paramount importance in understanding the magnitude of the problem and deciding on what measures should be prioritized for prevention and reduction. One obstacle to effective policymaking is the scarcity of data on how much and where FW occurs in urban Sri Lanka.

FW quantification aims at creating a robust evidence base for developing strategies, action plans, and policies towards FW prevention. To quantify FW in the study area (i.e. Colombo MC and suburbs), waste amounts disposed at three major waste disposal centers in Colombo region (i.e., Kerawalapitiya, Karadiyana and Kaduwela) were gathered and analysed. It was estimated that about 724 tonnes of FW (about 55 percent of total solid waste) is transported to these three centers every day from about 20 LAs, based on the data from 2018/19.

To address this huge challenge various strategies are being considered by the national government and LAs. However, so far, very little or no sufficient attention has been given towards prevention or reduction of FW, which is the most effective approach in the long term. This study focuses on FW prevention strategies, such as food redistribution for direct human consumption, as the key priority – given that it has the lowest environmental impact and the highest nutritional impact - while also looking at existing FW reuse and recycling strategies, such as transforming former foodstuffs into feed.

Food recovery and redistribution for direct human consumption is one of the preferred options in the food use-not-waste hierarchy. Although not yet very common, food redistribution is practiced to a certain extent in Colombo region by organizations that operate through different models. However, these initiatives are currently being practiced at a micro-level by volunteer-based non-profitable organizations. Challenges such as a lack of guidance from the public sector on implementation, lack of involvement from the corporate sector and lack of cold storage facilities currently limit the extent of operation of these organizations. It is worthwhile to explore mechanisms to formalize and scale up these initiatives with the collaborations of public and private sectors towards facilitating sustainable FW prevention strategies.

A mainly informal practice in the study area is to direct former foodstuff to piggeries for feed. Generally, former foodstuffs from the food service sector (i.e. hotels, canteens and restaurants) is directly collected by pig farmers. The results of a survey conducted under this project revealed that there is a significant potential for former foodstuffs to be absorbed by this sector, depending on the demand. The survey also revealed the common challenges related to this practice as poor quality of the feed and poor linkages between the supply and demand.

These challenges could be addressed through: (i) public sector issued guidelines for feed use of food no longer intended for human consumption, i.e. former foodstuffs; (ii) improved source segregation for former foodstuffs; (iii) establishing formal linkages between pig farmers and food business operators. However, the implications of formalizing this practice need to be well-assessed prior to implementation. It is important to note that this sector has a certain demand and once the supply meets the demand beyond that no additional former foodstuffs could be absorbed, except if the industry expands. Therefore, it is important to explore robust long-term solutions to address FW - such as prevention and reduction for all critical points identified (through measurement).

In addition to the aforementioned options, there are other practices such as composting and anaerobic digestion. However, recycling FW via composting and anaerobic digestion is practiced at a very low level in Colombo. Unavailability of land and large volumes are two major challenges.

Anaerobic digestion (i.e. biogas plants) requires technical expertise which is often not available at the local level. Exploring Public-Private Partnerships (PPP) and capacity development of the workforce engaged in waste management at the local level are some of the strategies that could be investigated further in promoting and increasing FW recycling activities.

FW generation from different sectors vary significantly based on the nature of the entities. Waste analysis done in 2017 for the segregated waste collected by the Colombo municipal council (CMC) revealed that 75 percent of the waste was from the restaurants, 17 percent from markets and 6 percent from slaughterhouse and meat shops (FAO, IWMI and RUAF, 2018). An analysis of the sectoral contribution of FW in 2019 in Kaduwela municipal council (MC) showed that supermarkets and vegetable fairs mark the highest FW generation followed by hotels and restaurants. Having an improved understanding of FW data, through this report's estimates, is an opportunity to launch actions of prevention that can be scaled up, such as prevention for each critical point identified from wholesalers to households and food recovery and redistribution for direct human consumption.

This study is accompanied by a report on case studies that were conducted in hotels and restaurants, households, wholesale, retail and supermarkets and institutional canteens in Colombo MC. The primary purpose of the case studies was to review and perform an analysis of FW prevention, reduction and management initiatives and draw lessons and best practices that can enable and facilitate FW prevention and reduction.

This report gives a situational snapshot of the status of FW quantification data in the study area. The findings reveal that the current level of FW prevention at source; recovery and redistribution for direct human consumption; as well as directing former foodstuffs for feed are very low. Urban areas in Sri Lanka need substantially coordinated and coherent state and non-state interventions in moving up the food use-not-waste hierarchy towards FW prevention and reduction to significantly reach toward the target of halving FW (i.e. from wholesale to households) by 2030 (SDG 12.3.1.b). The *National Roadmap and Action plan on Urban Food Waste Prevention and Reduction for Households, Food services, Retailers and Wholesalers* for Sri Lanka that was launched on 17 August 2021, provides the first step towards this goal.

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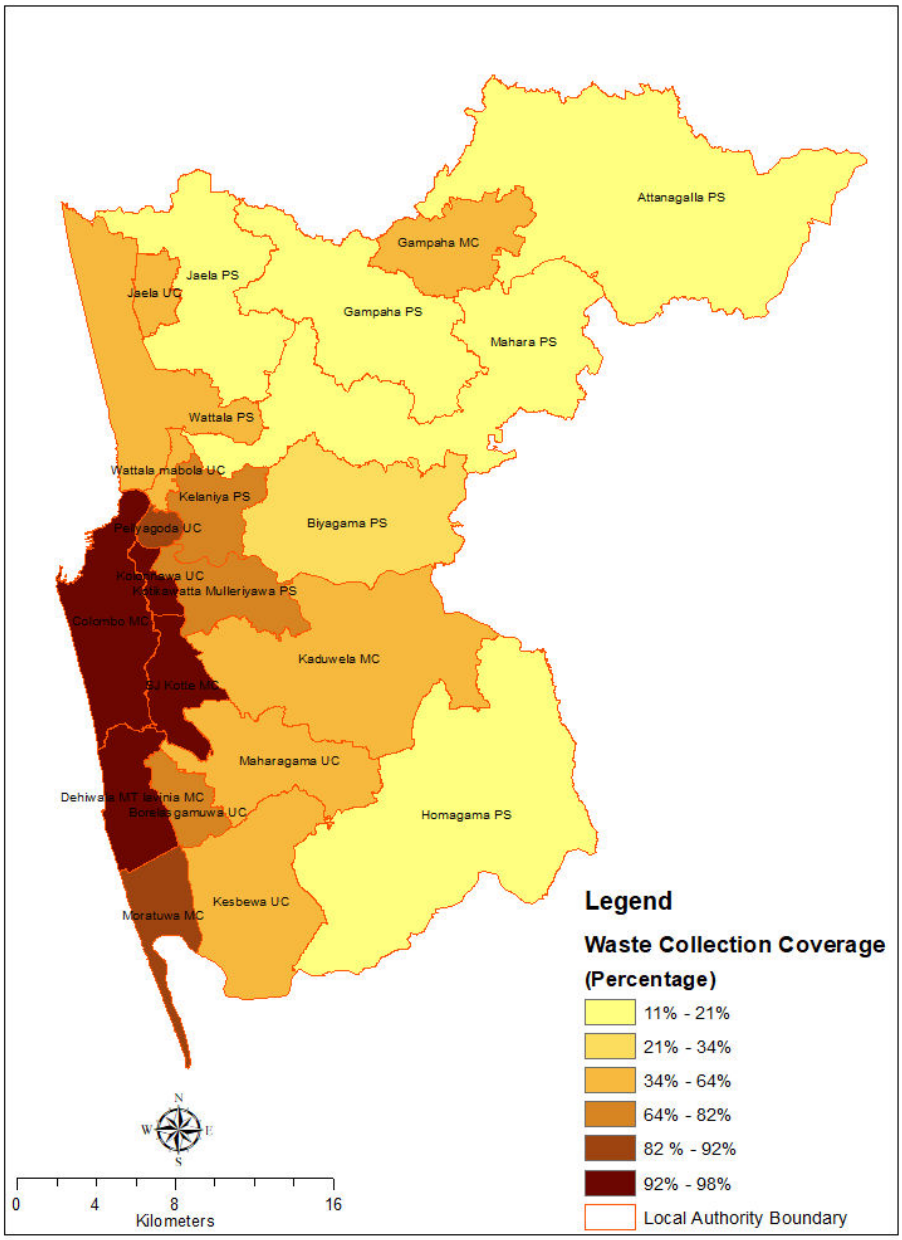
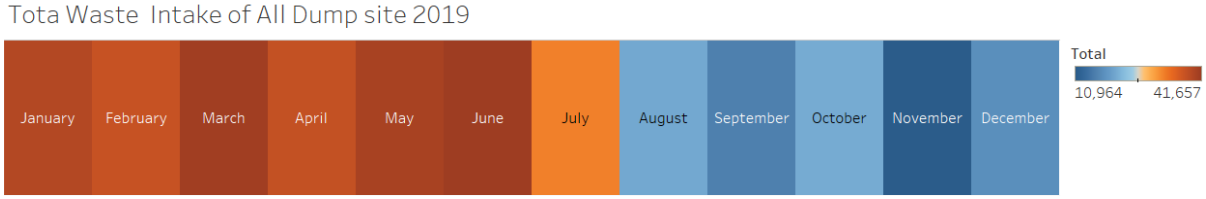
Annexes

Annex 1 Waste collection rates of local authorities in the study area



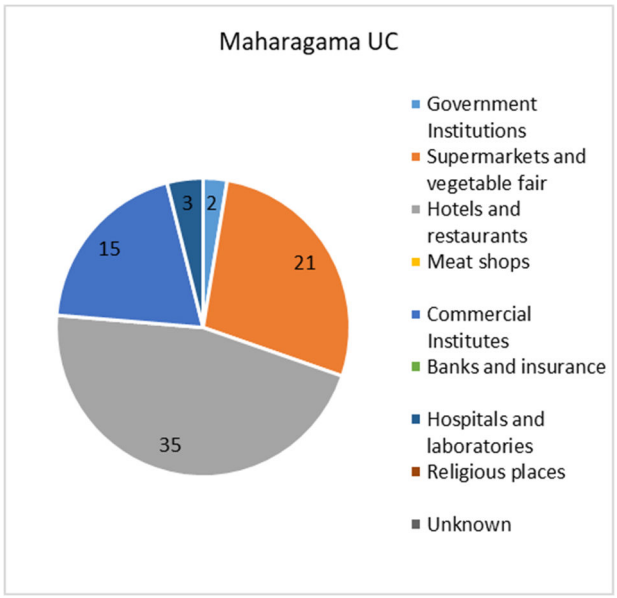
Source: United Nations Geospatial. 2022. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors.

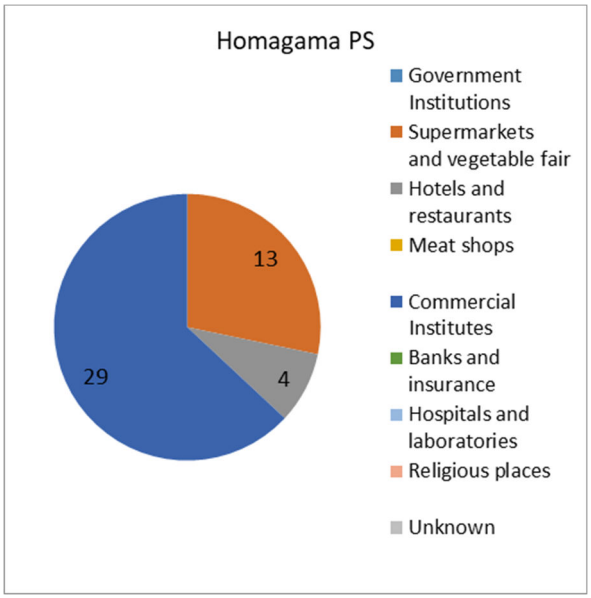
Annex 2 Fluctuations of monthly solid waste intake of Karadiyana, Kerawalapitiya, and Kaduwela disposal sites

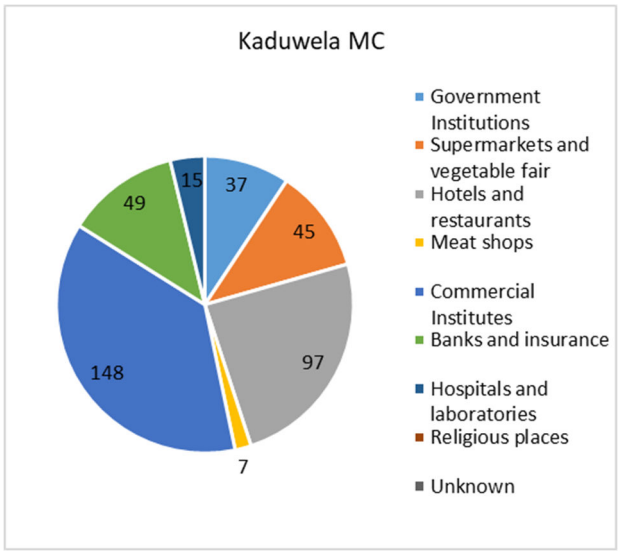


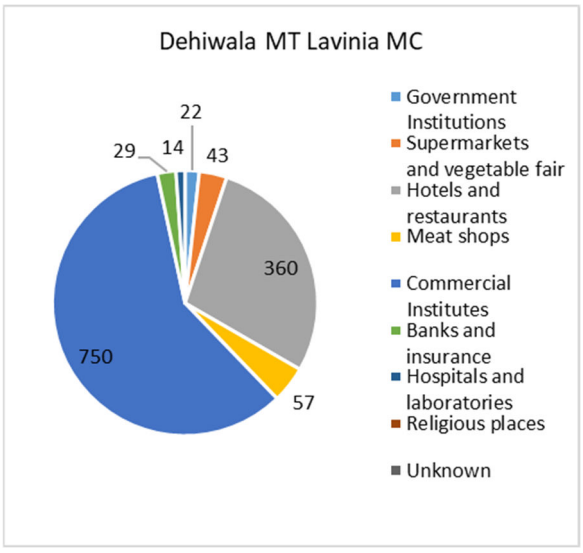
Source: Authors' elaboration.

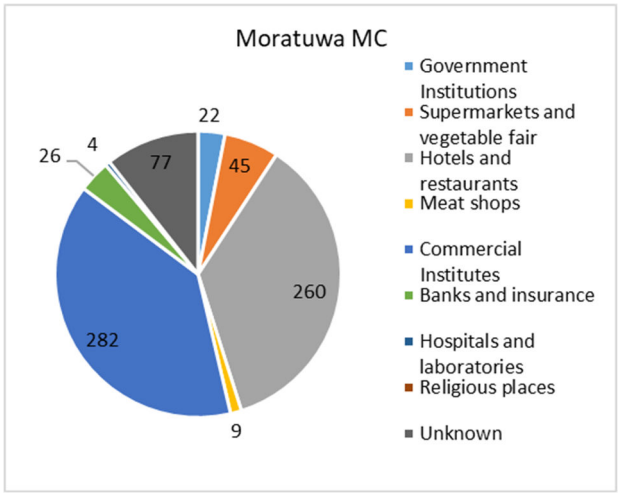
Annex 3 Property distribution of selected LAs in Colombo district

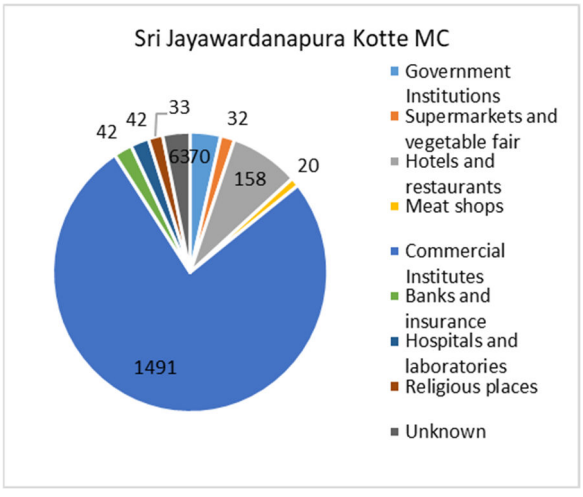


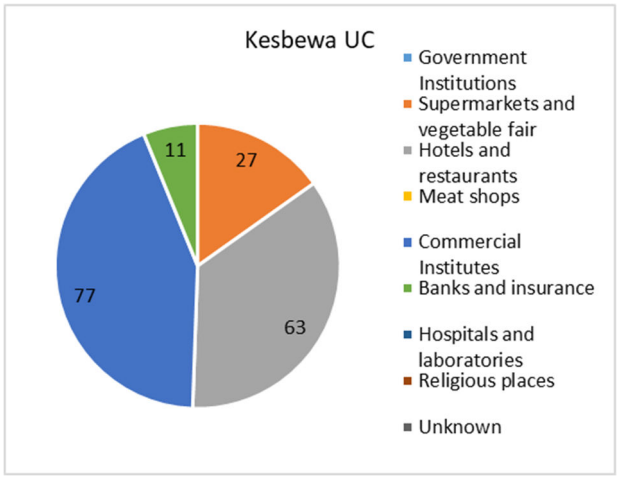












Source: Authors' elaboration.

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