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Limiting food waste via grassroots initiatives as a potential for climate change mitigation: a systematic review

Nikravech Mariam, Kwan Valerie, Dobernig Karin, Wilhelm-Rechmann Angelika, Langen Nina

Abstract

An estimated 30 to 50 % of food produced for human consumption is lost or wasted each year. These global food loss and waste (FLW) annually generate 4.4 Gt CO₂-eq, or about 8 % of total anthropogenic greenhouse gas (GHG) emissions, and thus present a still underestimated driver of climate change. To date, little is known about grassroots initiatives dedicated to reducing and preventing FLW and their actual potential to prevent FLW and thus contribution to mitigate GHG emissions. This paper presents a systematic review that examined the peer-reviewed evidence on grassroots initiatives' potential to limit food waste and GHG emissions. We found 15 relevant studies which represent a small but recent and growing interest in the topic. The findings of the studies are mostly of a qualitative nature, exploring the initiatives' organizational structure, goals and available resources. This systematic review highlights a pressing need for further research and impact measurement to better assess the role of grassroots initiatives in FLW reduction and climate change mitigation. It raises main directions for future research.

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1. Background

Globally about 30 to 50 % of food produced for human consumption is wasted each year (Gustavsson, Cederberg, and Sonesson 2011). For Europe, Stenmarck et al. (2016) estimated that around 20 % of the food produced is wasted whereby individuals in developed countries waste between 10 and 50 % of the food they buy. Apart from the economic, social and ethical concerns, global food loss and waste (FLW) bears high environmental costs, mainly because energy and resources invested in food production are spent in vain. Indeed, global food loss and waste (from food production, land use change, and disposal) generate 4.4Gt CO₂-eq annually, or about 8 % of total anthropogenic GHG emissions (Crippa et al. 2018; EC and JRC/PBL 2012; FAO 2011; 2013; 2014). From the per capita perspective, the average mitigation potential of reducing avoidable FLW is 0.3 t CO₂-eq – considerably higher than the average mitigation potential of managing unavoidable FLW at 0.03 t CO₂-eq/cap (Ivanova et al. 2020). Thus, reducing FLW is indisputably crucial to mitigating climate change and environmental degradation.

Scholarly discussions on measures to reduce and prevent FLW have so far mostly focused on either government-led projects and policies, or on initiatives in the industrial food and third sector (such as the hospitality sector, commercial and collective catering, wholesalers, retailers). Also, a top-down approach has been privileged as a mode of action for cutting the carbon footprint of the food sector (Bows 2012). Regulatory policy is important, yet *“voluntary behavioural change on the individual and household-level is an equally integral part of the transition towards a comprehensive foodprint reduction”* (Kim 2017, p. 367). Bottom-up grassroots initiatives dedicated to reducing and preventing FLW have received less attention, albeit they often follow innovative approaches and strategies and thus might be a powerful actor in FLW reduction and thus climate change mitigation.

Grassroots Initiatives and Food Waste

Forged as a sociological tool to analyse the spread of new forms of collective action, particularly in the context of dictatorships in Latin America (Hirschman 1984), the concept of *grassroots activism* has also been used to reflect on new forms of bottom-up environmental activism in the 1990s and 2000s (Almeida and Brewster Stearns 1998; Cable and Benson 1993; Mihaylov and Perkins 2015). Here, grassroots activism encompassed forms of collective action initiated by communities at the local level as a means of social inclusion. Grassroots initiatives are defined by Grabs et al. (2016, p. 100) as social activism *“including any type of collaborative social undertaking that is organized at the local community level, has a high degree of participatory decision-making and flat hierarchies”*. They are clearly distinguished from profit-oriented organizations as they *“tend to operate in civil society arenas and involve committed activists”* (Seyfang and Smith 2007, p. 585) as well as employ alternative worldviews and system of values (Martin, Upham, and Budd 2015; van Oers, Boon, and Moors 2018). Importantly, *“these groups constitute a nexus between individual motivation and collective action”* (Grabs et al. 2016, p. 100). Often conceptualized as a new social movement, grassroots initiatives aim to promote socio-technological changes to address environmental and social problems (van Oers, Boon, and Moors 2018).

While the impacts and benefits of grassroots initiatives unfold primarily locally (Ornetzeder and Rohrer 2013; Seyfang and Smith 2007; Smith, Fressoli, and Thomas 2014; van Oers, Boon, and Moors 2018), strategies are commonly devised to scale-up these impacts, such as open communication, inclusion of stakeholders, and enrolment of public, private and non-governmental actors (Smith, Fressoli, and Thomas 2014). Grassroots initiatives appear as innovative players to convey the claims of environmental justice activism, which emerged as a form of post-industrial collective action (Mihaylov and Perkins 2015) analysed within the New Social Movement theory (Melucci 1980). Environmental grassroots initiatives differentiate themselves from traditional environmental movements, in shifting the focus away from

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political institutions towards a reshaping of everyday consumption practices (Campos and Zapata 2017; Dobernig and Stagl 2015; Haenfler, Johnson, and Jones 2012; Laamanen, Wahlen, and Campana 2015).

Grassroots initiatives operating in the area of sustainability have embraced food as a key realm for change, along with mobility or energy. They pursue a variety of activities: food growing and sharing (Davies 2014; Rut and Davies 2018), food rescuing (Reynolds, Piantadosi, and Boland 2015), or surplus food redistribution (Midgley 2014). However, little attention has been paid to the effectiveness of sharing practices to reduce food waste (Morone et al. 2018).

This paper addresses this gap by systematically reviewing the existing academic literature on grassroots-level initiatives around food waste and their role in reducing GHG emissions and mitigating climate change. While grassroots initiatives or sustainability transitions literature have been the topic of systematic reviews (Hossain 2016; Sengers, Wiczorek, and Raven 2019), these have not mapped grassroots initiatives according to their potential in tackling climate change via food waste reduction. To date, systematic reviews on food waste have compiled estimates of FLW (van der Werf and Gilliland 2017) and categorized the factors that impede or foster the generation of food waste at the household-level (Schanes, Dobernig, and Goezet 2018; Stangherlin and Barcellos 2018). Other reviews have a specific geographical and/or sectoral focus such as food waste drivers in the Arab world, in Brazilian “Food and Nutrition Units”, or food waste occurring in the national school lunch program in the United Kingdom (Abiad and Meho 2018; Ferigollo and Busato 2018; Shanks, Banna, and Serrano 2017).

The objectives of this systematic review are three-fold: First, it attempts to map grassroots initiatives dedicated to food waste reduction and prevention along their stated objectives, the actors involved, and their broader network. Second, it compiles the outcomes of academic studies which have measured the effectiveness of grassroots initiatives to reduce or recover FLW as well as reduce GHG emissions. Third, it categorizes the key success factors for grassroots initiatives to identify potential “bottom-up” levers for food waste reduction and prevention originating in civil society to complement “top-down” approaches.

2. Methods

We conducted a systematic review of existing academic research on grassroots initiatives dedicated to reducing food waste. To ensure that the review is systematic and replicable, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] quality guidelines (Moher et al. 2009; Moher et al. 2015) which provide an evidence-based minimum set of items for reporting.

Sampling and Search Strategy

Relevant articles were located based on the objective of gathering peer-reviewed evidence of the role of grassroots initiatives in reducing food waste to mitigate climate change. The search focused on peer-reviewed journal articles published between 2000 and 2018 in English, German and French. Grey literature, including master’s theses, conference proceedings and organizational reports, were excluded. For defining the search strategy, we defined inclusion criteria for our study along the PRISMA recommendations (Moher et al. 2015). For this, we used the PICOS criteria (Problem/Intervention/Comparator/Outcomes/Study design) as defined by Methley et al. (2014). We considered FLW as our problem of interest and grassroots initiatives dedicated to food waste prevention or reduction as our intervention. If presented, we conceptualized outcomes as the amount of food waste reduced and/or mitigated GHG emissions, expressed as CO₂-eq. The study design was kept open to include all types of research designs. Finally, due to the low retrieval rate of experimental or quasi-experimental studies, there was no restriction on the comparator (see Table 1).

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Table 1 Sampling strategy

PICOS Criteria	Problem	Intervention	Comparator	Outcome	Study design
	Food waste	Grassroots initiatives for food waste prevention or reduction	open	Reported amount of food waste/ GHG emissions	open
Type of literature	Peer-reviewed literature				
Languages	English, French, German				
Timespan	2000-2018				

To ensure the focus of our review on grassroots initiatives, we excluded literature according to the criteria outlined in Table 2. These criteria were used at screening and at eligibility stages.

In the case that an article described food waste reduction initiatives at the crossroads between the supply-side sector, the public sector, and civil society, a case-by-case approach was used to delimit the intervention as a grassroots initiative or not. The criteria for inclusion as a grassroots initiative were (i) the initiative was started by a civil society actor (ii) the initiative began locally (iii) the initiative was partly or mainly based on the action of volunteers and (iv) the hierarchy of the initiative was flat. Some studies investigated the structural features and impact of food sharing via a pilot approach or meta-analysis. These did not provide sufficient insight into the individual grassroots initiatives.

Table 2 Exclusion Criteria

Exclusion of peer-reviewed studies which:
(a) did not have food loss or waste as main problem
(b) focused on supply-side initiatives driven by retailers, producers or the local government, as well as solely on individual- and household-level initiatives
(c) solely discussed behavioural determinants and attitudes for food waste
(d) only quantified food waste of GHG
(e) investigated grassroots initiatives that did not focus on food waste reduction
(f) did not consider community-based interventions as the main level of analysis, such as meta-analyses or system analyses (used only at eligibility stage)
(g) had a natural science focus (used only at screening stage)

Data Collection

The systematic literature search was conducted via a word search run in the titles, abstracts and text of items in the bibliographic databases Web of Sciences (Social Sciences Indexes only), Science Direct, Scopus and AGRIS. The French-speaking bibliographic databases CAIRN and INRA Sciences Sociales as well as the German-speaking database WiSo were also searched. The first five pages of the web-based database Google Scholar were considered as complementary sources of evidence. Duplicates were removed within databases and between databases (n=135). The initial keyword search string was adapted to fit each database search engine syntax. The search term list was comprised of the three PICOS criteria (i) Problem (ii) Intervention and (iii) Outcome which were respectively "Food waste", "Grassroots" and "Greenhouse Gas" (Appendix A). The search was also run without the third term, to comprehensively appraise all studies which investigated grassroots initiatives for food waste prevention.

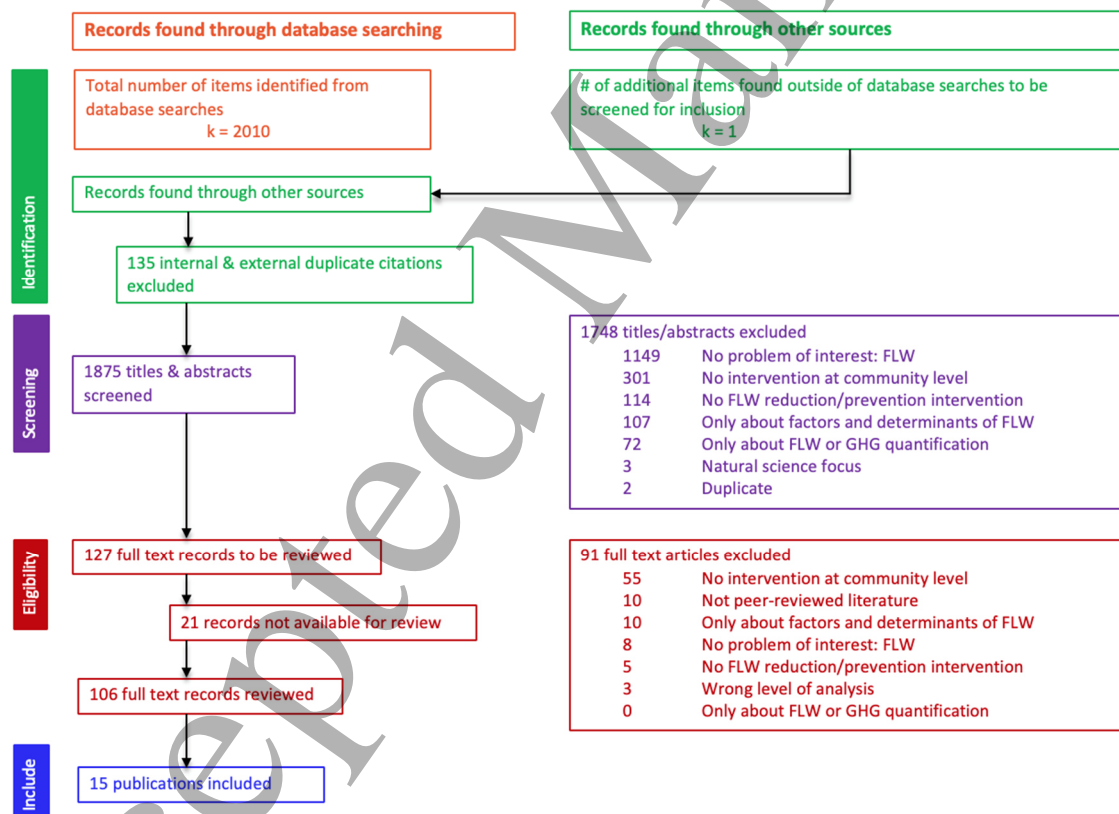
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The systematic search resulted in 1875 articles. All abstracts were screened manually, of which 67 % were screened independently by two reviewers ("Screening" stage in Figure 1). The reviewers decided at that stage to consider the studies for full text reading or to exclude them, along the previously defined exclusion criteria. At that stage, we decided to be inclusive if uncertain. When no agreement was reached (n=5), a third author made the final decision. The main exclusion reasons during the screening phase are also depicted in Figure 1.

After the title and abstract screening, n=127 articles remained. Additional records were identified through reference checking and snowballing (n=1) and included if they had not shown up in our previous searches. In the next step, the pool of 127 articles was extracted for full text reading and a further specification of the sample ("Eligibility" stage in Figure 1). In case it was not possible to access an article, it was reported as unavailable (n=21). The full-text papers were stored manually using the Excel Workbooks and User Guides for Systematic Review (VonVille 2019). References were stored in the reference management software Citavi (n=106). Every full text was read independently by at least two researchers to ensure consistency. Exclusion criteria were the same as above. We reported the main reasons for exclusion by frequency and the exclusion process in Figure 1. Bibliographic information such as journal, author, year of publication and country of the study were extracted. This process resulted in a final sample size of 15 peer-reviewed articles.

Figure 1 Full PRISMA Flow Chart including exclusion reasons by frequency



Source: based and adapted on VonVille (2019) and Moher et al. (2009).

Note that the following abbreviations are used: Food loss and waste (FLW); Greenhouse gas emissions (GHG).

Analysis and synthesis

Given that the systematic literature search revealed only a very small number of studies that quantified the outcomes of grassroots initiatives (n=9), a quantitative analysis of the data was not justified. Instead, we extracted and synthesised the outcomes presented in the individual studies in the form of descriptive

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statistics. In a narrative synthesis, we review findings from the sampled studies to discuss the key characteristics of the studied initiatives, in particular their goals, organizational structure as well as the profiles of people engaged in the initiatives. Moreover, we discuss the resources available to grassroots initiatives tackling food waste as well as the outcomes of grassroots initiatives in terms of food waste reduction and climate change mitigation. The analysis of the peer-reviewed articles was conducted with the qualitative and mixed-method analysis software MAXQDA. The coding was organized around four key categories: (i) methodologies employed in the studies, (ii) type, goals, participants and resources of the grassroots initiatives studied, (iii) outcomes of the grassroots initiatives, and (iv) key success factors and challenges.

3. Review results

While the number of studies investigating grassroots initiatives to reduce and prevent food waste (according to our research interest and the resulting inclusion criteria) has increased since 2000, especially from 2015 onwards, the overall scholarly discussion about their contribution to reducing food waste and mitigating climate change remains modest. Grassroots initiatives were mainly studied in Australia (n=3), the United Kingdom (n=3), and the USA (n=5); followed by New Zealand (n=1), Sweden (n=1), Austria (n=1) and Singapore (n=1) (Table 3). All studies were conducted in urban areas (n=15).

Analytical scope

Research objectives of reviewed studies

The research objectives of the studies we reviewed can broadly be grouped into two complementary foci: The first group of studies explore grassroots initiatives to describe the collective and individual motivations and practices of reducing food waste. More specifically, studies conceptualize freegan collective dumpster dives as acts of political street theatre (Barnard 2011); describe how food gleaners in Australian cities identify with *freeganism* (Edwards and Mercer 2007); discuss the place of civil society organizations (CSOs) in urban food governance and debate grassroots CSOs in the context of food waste reduction (Warshawsky 2015); deconstruct popular views of food surplus and food aid (Caplan 2017); describe the workings of an Australian food rescue organization (Lindberg et al. 2014); develop a theoretical framework on citizen-driven initiatives for waste prevention to grasp their diffusion and contribution to social change (Campos and Zapata 2017); and document ICT-mediated shared food growing (Rut and Davies 2018).

The second broad group of studies investigates the outcomes of grassroots initiatives in reducing or preventing food waste, such as the social value of food rescue enterprises for the stakeholders and the communities (Miroso et al. 2016); how community gardening improves daily food consumption and waste management practices and thereby shrinks the carbon *foodprint* (Kim 2017); the economic and environmental impact of food rescue operations from charities and NGOs (Lee et al. 2017; Reynolds, Piantadosi, and Boland 2015; Sönmez et al. 2016; Walia and Sanders 2017); the comparative potential of online food sharing platforms to help prevent food waste (Sarti et al. 2017); and the impact of food donation on ecology, economy and society (Schneider 2013).

Design of the reviewed studies

To address these research objectives, our reviewed studies employed different research methodologies: The case study approach is adopted in four studies (n=4) with either one or several grassroots initiatives as the unit(s) of analysis. The specific cases selected for the studies are FoodShare, an urban social enterprise specialized in food redistribution (Miroso et al. 2016); the local Food Rescue CSO Food Forward (Warshawsky 2015); transition cafés (Caplan 2017); citizen-based food waste prevention initiatives (Campos and Zapata 2017); and a community food growing initiative (Rut and Davies 2018). Four studies

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(n=4) take an ethnographic approach to analyse food gleaners (Edwards and Mercer 2007), freegans (Barnard 2011), a food rescue social enterprise (Lindberg et al. 2014) and a shared food growing initiative (Rut and Davies 2018). Six (n=6) studies do not mention a specific research design but employ content analysis (n=3) (Sarti et al. 2017; Schneider 2013; Walia and Sanders 2017) and impact quantification methods (n=3) (Reynolds, Piantadosi, and Boland 2015; Lee et al. 2017; Sönmez et al. 2016). Finally, one study (n=1) is based on a cross-sectional web-survey design among gardeners in community gardens and food growing organizations (Kim 2017).

Type of data collected

Within their research designs, most studies (n=8) collect qualitative data via in-depth semi-structured interviews with stakeholders such as food donors, financial donors, recipient agencies (Miroso et al. 2016); government administrators, formal food grocers, farmers market sellers, food recovery CSO managers (Warshawsky 2015); food consumers (Warshawsky 2015), volunteers (Barnard 2011; Campos and Zapata 2017; Caplan 2017; Edwards and Mercer 2007; Kim 2017; Lindberg et al. 2014; Miroso et al. 2016; Rut and Davies 2018; Warshawsky 2015) and paid staff members. Interestingly, recipients' perspectives are not reflected in the studies unless they are volunteers or paid staff of the respective initiative. Three studies (n=3) use ethnographic and participant observations (Barnard 2011; Edwards and Mercer 2007; Warshawsky 2015). Two studies (n=2) collect data via web-based surveys with 79 volunteers and 48 community garden participants respectively (Kim 2017; Miroso et al. 2016). Finally, six studies (n=6) are mainly based on secondary data, such as documents and internet material (Schneider 2013), online platforms (Sarti et al. 2017) and organizations' administrative data (Lee et al. 2017; Reynolds, Piantadosi, and Boland 2015; Sönmez et al. 2016; Walia and Sanders 2017).

Main characteristics of the academically investigated grassroots initiatives

In the following sections we discuss the grassroots initiatives in our sample with regards to their goals, organizational structure and participants. Subsequently, we categorize the resources which the initiatives possess to work towards their goals.

Overall objectives/goals/missions

All studied grassroots initiatives embrace the goal of reducing food waste with a focus on human consumption which is in line with the food waste hierarchy (Papargyropoulou et al. 2014) pictured in Figure 2. The food waste hierarchy provides a framework of the available options for the prevention and management of food waste and sorts them by desirability. While some initiatives explicitly prioritise the prevention of avoidable food waste (and thus addressed the first priority of the food recovery hierarchy), others work primarily on the re-distribution and re-use of food surplus.

Grassroots initiatives focusing on food waste prevention (n=5) offer networks and tools to save surplus food and use it for the own consumption (Barnard 2011; Campos and Zapata 2017; Edwards and Mercer 2007; Sarti et al. 2017) or share the food surplus within the community (Caplan 2017; Sarti et al. 2017). Some initiatives critically question consumption practices (Barnard 2011), promote a radical anti-capitalist ideology (Barnard 2011; Edwards and Mercer 2007), and challenge middle-class taboos around food waste (Campos and Zapata 2017). These initiatives promote awareness of food waste generation and demonstrate how tasty and safe "waste food" is (Barnard 2011; Campos and Zapata 2017). Complementary to this, some grassroots initiatives (n=2) promote urban farming (Rut and Davies 2018) and community gardening (Kim 2017) which have the potential to limit food waste. These initiatives offer shared open spaces managed and operated by members of the local community for multiple purposes

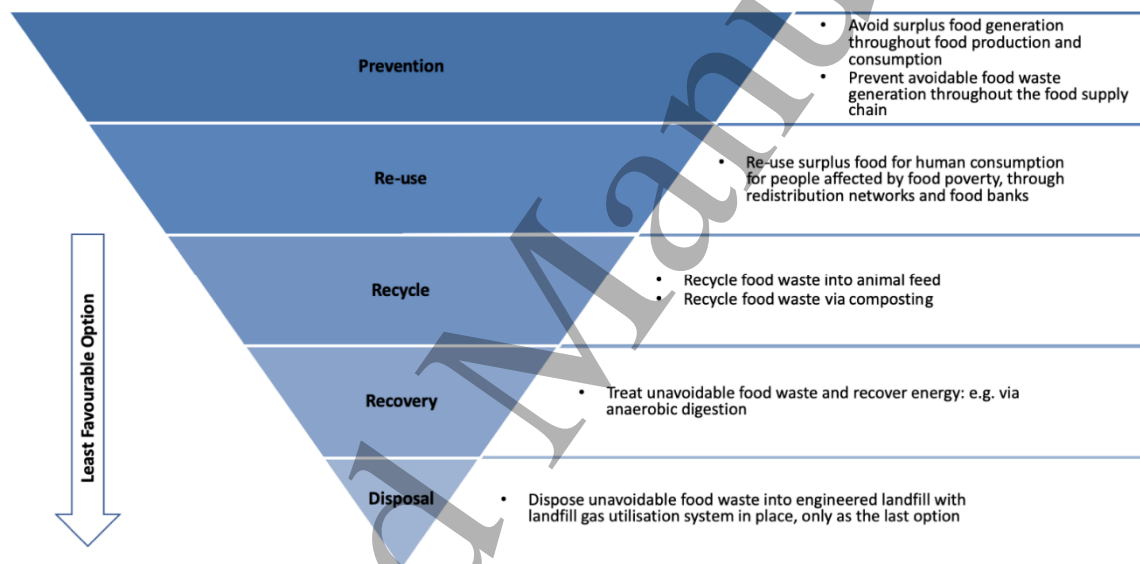
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such as vegetable growing (Kim 2017)¹² or knowledge and skills sharing about growing, eating healthy and reducing waste (Rut and Davies 2018). They promote another model of food consumption and production with the goal of reducing the carbon foodprint, notably via the reduction of food waste (Kim 2017)³, and fostering well-being (“Grow food, cook well, eat well, live well”, Rut and Davies 2018, p.282).

Grassroots initiatives emphasizing food redistribution seek to divert edible food from the bin by redistributing it to people in need, addressing the second priority in the food waste hierarchy (n=8). The common concept of food redistribution has many names: food rescue (Lindberg et al. 2014; Reynolds, Piantadosi, and Boland 2015; Warshawsky 2015), food rescue social enterprise (Miroso et al. 2016; Walia and Sanders 2017), food rescue CSO (Warshawsky 2015), food redistribution from gleaning (Edwards and Mercer 2007; Lee et al. 2017) or food donation (Schneider 2013). At the nexus of food security and food waste (Miroso et al. 2016; Lee et al. 2017), these initiatives re-use surplus food to reduce hunger and food inequality.

Figure 2 Food Waste Hierarchy



Source : Papargyropoulou et al. 2014

The organizational structure of the initiatives

Grassroots initiatives take complex institutional forms and have different organizational structures (Table 2). While having in common a strong volunteer basis (Reynolds, Piantadosi, and Boland 2015), they differ greatly in size, number of volunteers, amount and volume of food saved, degree of professionalization, as well as funding and recognition.

Three studies (n=3) focus on loosely formalized, connected initiatives belonging to a broader, global food movement which prioritize individual and community-directed actions (Barnard 2011). The Food Gleaners and Dumpster Divers are respectively embedded in the Food Not Bombs group and the Freegan movement, both of which are global in reach (Barnard 2011; Edwards and Mercer 2007). The Community

¹ To facilitate the reading, we refer in the text to the authors of the sampled reviewed studies. Secondary citations are given as footnote.

² Holland (2004) cited in Kim (2017) p. 365.

³ Abrams (2014) cited in Kim (2017), p. 366.

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Transition Café Bro Gwaun described in Caplan (2017) recycles local surplus food to serve meals at affordable prices and is part of the Transition Network. These three grassroots food movements for food waste reduction have at least two aspects in common: a flat hierarchy and a high level of engagement of activists who are the backbone of the initiatives. Such food movements are analysed by the New Social Movements literature as a repertoire of practices encompassing more than only food, although dumpster diving is the most central, i.e. getting food from the trash and eating it (Barnard 2011).

Four studies (n=4) discuss citizen-led initiatives (Campos and Zapata 2017; Kim 2017; Rut and Davies 2018; Sarti et al. 2017) that encompass informal and self-organized community groups. Conceptualized in Campos and Zapata (2017, p. 17) they “*share the capacity to mobilize people and get them to work, regardless of whether volunteers, participants, and employees shared the values and rationales of the organizers*”. One example are social not-for-profit platforms, which facilitate the sharing and exchange of food surplus in a peer-to-peer approach. These are flexible and free of charge but depend on the work of voluntary food savers (Sarti et al. 2017).

CSOs and social enterprises are studied in nearly half of the reviewed articles (n=7). These are non-governmental not-for-profit entities that originated in civil society. Because of paid staff and management, they are often able to secure and provide advocacy and other services (Warshawsky 2015). Although they present professionally-led voluntary organizations, they have flexible structures and are attentive to local communities and non-governmental funding (Warshawsky 2015). Examples of social enterprises are: Food Forward (Warshawsky 2015), the Social Enterprise (Miroso et al. 2016), SecondBite (Lindberg et al. 2014; Reynolds, Piantadosi, and Boland 2015), the Inter-Faith Food Shuttle and Second Helpings (Walia and Sanders 2017), Team Österreich Tafel (Schneider 2013) and the Food Bank of the Southern Tier (FBST) (Lee et al. 2017; Sönmez et al. 2016), which provide food stores and farmers with food surplus and food waste collection services or gleaning operations.

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Table 3 Overview of the sampled studies and the studied grassroots initiatives

Priority	Name of the grassroots initiative	Activities	Enabling factors	Organization	Location	Start time of the initiative	Study
	Food Rescue	Food Rescue Parties: Cooking rescued food in social events Food Rescue free markets Pop-up restaurant during the Restaurant Day Festival	Development of contextualized knowledge and competences related to food waste prevention	Food movement network/citizen-based initiative	Gothenburg (Sweden)	2012	Campos and Zapata 2017
	FoodSharing Platform	Connects a community of foodsharers to save and re-distribute food surplus among them Connects volunteer foodsavers and organize rescue operations at markets and supermarkets	Vivacious community and critical mass of users on a single platform	Citizen-based initiative/digital social platform	Germany	2012	Sarti et al. 2017
	Transition Community Café Bro Gwaun	Serves meals at affordable prices, made of local surplus food.	Embedment into the global Transition network	Global food movement (Transition network)	West Wales (UK)	N/A	Caplan 2017
Environmental Priority	Freegans	Practice of dumpster diving for discarded food for individual consumption and other anti-consumerist practices	Embedment into the global Freegan network Media exposure and audience's attention Easiness of participation	Global food movement	New York City (USA)	2000	Barnard 2011
	Dumpster divers	Practice of dumpster diving for discarded food for individual consumption	Alliances with smaller shops Embedment into the global Freegan network	Global food movement	Australia	1980s	Edwards and Mercer 2007
	Community gardens	Local food growing	Easing legal and regulatory framework Supportive social environment Embedment in local network	Citizen-based initiative / community gardening	London (UK)	N/A	Kim 2017
	The Collective	Local food growing Mapping of edibles in Singapore Online Platform for knowledge and skill-sharing about growing, healthy eating and waste reduction	Strong volunteer engagement Embedment in the local and larger food community network (informal groups, community gardening, dumpster diving) and strategic partnerships with entrepreneurs and CSOs	Citizen-based initiative / community gardening /online platform	Singapore	2015	Rut and Davies 2018

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	Collection of surplus food from markets to cook and serve to people on the street	Embedment into the global Freegan network	Australia	1980s	Edwards and Mercer 2007
	Food Not Bombs	Easing legal framework			
	Practice of gleaning from farmers and offering of fresh food to food assistance recipients	Scheduling capacity, amount and eagerness of volunteers	Boston metropolitan area New York State (USA)	N/A	Lee et al. 2017; Sönmez et al. 2016
	Food Bank of the Southern Tier (FBST)'s gleaning program				
	Collection and redistribution of donated food surplus	Access to fresh surplus food Positive reputation of saving and distributing nutritious fresh food Network and collaboration for increased access to food wastes supply and social reach	New Zealand	2012	Miroso et al. 2016
	FoodShare				
	Collection from wholesales and farmer markets and redistribution of recovered food to local CSOs backyard harvesting program	Diversification of funding sources Successful framing of food waste as an issue	Los Angeles (USA)	2009	Warszawsky 2015
	Food Forward				
	Collection and redistribution of surplus fresh food	Positive reputation of saving and distributing nutritious fresh food Access to fresh surplus food Abundant pool of volunteers	Victoria, Tasmania, Queensland, and New South Wales (Australia)	2005	Lindberg et al. 2014 Reynolds, Piantadosi, and Boland 2015
	Community capacity building in food skills and nutrition Advocacy				
	SecondBite				
	Collection and redistribution of donated food	Financial donations	Australia	N/A	Reynolds, Piantadosi, and Boland 2015
	FareShare OzHarvest FoodBank				
	Collection and redistribution of donated food	Volunteers' engagement EU regulatory frameworks	Austria	2010	Schneider 2013
	Collection, sorting and distribution of donated food from companies and supermarkets at the Austrian Red Cross				
	Team Österreich Tafel				
	City Harvest	Extensive network of food waste suppliers	New-York City (USA)	Early 1980s	Walia and Sanders 2017
	Collection and redistribution of donated food	Early local scale up	North Carolina (USA)	1980s	
	Inter-Faith Food Shuttle	Holistic approach to the food recovery process	Indianapolis (USA)	1980s	
	Culinary job training program for disadvantaged adults				
	Second Helpings				

Social
Priority

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Participants in the initiatives and motivation

There is relatively little information provided about the socio-demographic profile of the people who initiate and engage in grassroots food waste initiatives. Edwards and Mercer (2007) describe dumpster divers and volunteers in Food Not Bombs as predominantly male, mid-20s, well-educated and middle-class. Kim (2017) observes a majority of female practitioners in community gardens.

Several studies look at the motivations of the participants, volunteers or activists of the initiatives for engaging in collective action to reduce food waste or redistribute food surplus. Awareness of global food production systems (Edwards and Mercer 2007) and strong ideological beliefs, such as dropping out of capitalism (Barnard 2011; Edwards and Mercer 2007), are critical motivation factors. Preference for a common use of natural and material resources instead of owning and consuming (Barnard 2011; Campos and Zapata 2017) also elicits a motivation to engage in movements like *freeganism*, as this allows to express political and moral concerns while engaging locally in freegan practices (Barnard 2011; Campos and Zapata 2017; Edwards and Mercer 2007). The adoption of other activities associated with *freeganism* such as squatting, scavenging, community living, cycling, and second-hand shopping are further factors which support and sustain engagement in food waste prevention practices such as dumpster diving or food gleaning (Barnard 2011; Edwards and Mercer 2007). The development of contextualized knowledge and competences (Barnard 2011; Miroso et al. 2016; Rut and Davies 2018) needed “to transform unwanted resources into commons” (Campos and Zapata 2017, p. 1069), as well as the knowledge “about what works in a locality and what matters to local people” (Seyfang and Smith 2007, p. 593-4 cited in Campos and Zapata 2017) are also motivational factors.

Participants of food waste grassroots initiatives commonly pursue alternative diets, often reflecting the organic food, freegan or vegan discourse (Edwards and Mercer 2007). According to Edwards and Mercer (2007), demand for ethically acceptable products (i.e. acceptable producer history and labour conditions, absence of “chemicals, pesticides, industrial waste-ridden food” (Edwards and Mercer 2007, p. 286) and animal cruelty) is stronger than considerations like quality and quantity of food or ease of access.

Reducing food waste for environment benefits and to fight climate change is also a reason for volunteers to invest time and effort in grassroots initiatives (Edwards and Mercer 2007; Lindberg et al. 2014). According to Caplan (2017), the goal is primarily environmental and consists of developing “community sustainability and resilience”, while feeding poorer people is seen as incidental. Other authors point to the fight against “food poverty” as a main driver for engagement (Lindberg et al. 2014) or emphasized further factors such as altruism, a common praxis and shared ideas (Barnard 2011; Edwards and Mercer 2007); a sense of community involvement and community empowerment (Edwards and Mercer 2007; Lindberg et al. 2014; Miroso et al. 2016; Rut and Davies 2018), friendship and socialising (Edwards and Mercer 2007; Miroso et al. 2016), or emotional benefits gained when participants make new connections with others (Miroso et al. 2016). Spiritual motivation is also a factor to engage in food waste prevention and rescue (Barnard 2011; Campos and Zapata 2017).

Availability of resources

Jenkins (1983) provides the Resource Mobilisation Theory framework of social movements which allows the systematic categorization of the resources which social movements possess to secure control and increase their potential to act towards their goals. We employ this framework to review the resources analysed in the reviewed studies.

Volunteer efforts

Many studies emphasize the role of volunteers in grassroots initiatives. Indeed, analysed as low-budget and labour- and time-intensive, grassroots initiatives rely heavily on a strong basis of volunteers (Campos and Zapata 2017; Reynolds, Piantadosi, and Boland 2015). Lee et al. (2017) and Sönmez et al. (2016) relate

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the success of gleaning operations to the supply of volunteer gleaners, their eagerness to attend an operation, and the scheduling capacity of the organization. Most grassroots initiatives engaging in food waste redistribution relied either exclusively (Barnard 2011; Campos and Zapata 2017; Rut and Davies 2018; Sarti et al. 2017; Schneider 2013) or primarily (Edwards and Mercer 2007; Miroso et al. 2016; Lee et al. 2017) on a volunteer or activist basis. Volunteers provide time, professional skills and knowledge, fuel and cars (Miroso et al. 2016), and engage in physical, complex and tiring work collecting, sorting, and redistributing food (Warshawsky 2015).

Types of food (waste) reduced

Interestingly, the reviewed studies provide only limited information on the type of food rescued by the grassroots initiatives, thus eluding the question of the trade-offs between food-related resources and effort mobilization. The studied grassroots initiatives rescue any type of edible, not spoiled food (Barnard 2011) about to be wasted, both fresh and long-life (Caplan 2017), approaching or past its expiry date (Campos and Zapata 2017) or use-by date (Reynolds, Piantadosi, and Boland 2015), or surplus to the requirements of events (Reynolds, Piantadosi, and Boland 2015). Schneider (2013) distinguishes three categories, namely bread and pastry, fruits and vegetables, and dairy products without indicating a priority in food rescue choice. The nature and quantity of the food supply may vary seasonally and thus demand different degrees of effort and capacity from the grassroots organizations (Lee et al. 2017). For the estimation of the grassroots initiatives' contribution to the reduction of GHG emissions, the differentiation between the product groups would be essential.

Lindberg et al. (2014) and Walia and Sanders (2017) discuss the choice of SecondBite and the Inter-Faith Food Shuttle to prioritize healthy foods, mostly fruits and vegetables, to redistribute to people in need. Miroso et al. (2016) discuss how a focus on fresh food may enhance the social organization's reputation and increase their reach within the community. Yet, the random nature of food rescued and its inconsistency with an overall healthy diet creates challenges in managing the gaps between supply of rescued food and demand (Reynolds, Piantadosi, and Boland 2015). Moreover, the complexity of meeting users' needs (i.e. religious, cultural, taste) with dignity poses a wider problem in the food re-distribution sector, in addition to food safety aspects. In another study, Edwards and Mercer (2007) analyse how within the Freegan movement, the redistribution of (any kind) of rescued food conflicts with the issue of maintaining a strict vegan diet.

Food rescued from the trash and handled by the participants emanates mostly from the private food sector, in particular the tertiary (n=8) and to a lesser extent the secondary sector, including the hospitality sector (Reynolds, Piantadosi, and Boland 2015; Walia and Sanders 2017). Food surplus is collected from food wholesalers (Caplan 2017) and retailers (Barnard 2010; Campos and Zapata 2017; Caplan 2017; Miroso et al. 2016; Walia and Sanders 2017; Warshawsky 2015) which include supermarkets (Barnard 2010; Caplan 2017; Edwards and Mercer 2007; Miroso et al. 2016), small local stores (Reynolds, Piantadosi, and Boland 2015) and organic market stallholders (Edwards and Mercer 2007; Warshawsky 2015). According to Edwards and Mercer (2007) freegans privilege small local independent stores since they tend to be more resource-oriented than bigger stores, are more likely to consider a community-benefit orientation, and thus are more prone to cooperation. Besides, small stores provide gourmet or health-related produce and help support local sustainable food production (Edwards and Mercer 2007). Nonetheless, the choice to dumpster dive in big supermarket chains over smaller independent stores is perceived as more effective (Barnard 2010) and allows for a symbolic power reversal against capitalist natural resource and human exploitation (Edwards and Mercer 2007).

Two studies (n=2) discuss initiatives that take food donations from the food manufacturing sector (Reynolds, Piantadosi, and Boland 2015; Schneider 2013). Two studies (n=2) analyse food waste prevention through gleaning at farm level (Lee et al. 2017; Walia and Sanders 2017). In Sarti et al. (2017),

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the food surplus discussed emanates from private consumers. The public sector barely features in the scholarly discussion of sectors; Campos and Zapata (2017) highlight the failure to extend the initiative to food handled by municipalities.

Financial resources

The success of grassroots initiatives also depends highly on their capacity to secure financial resources (Campos and Zapata 2017; Miroso et al. 2016), such as governmental financial support from the local city council (Miroso et al. 2016). Yet, local and global economic crises have led to a withdrawal of government support and necessitated mixed funding streams from foundations, individuals and corporate philanthropic fundraising (Caplan 2017). This can also be supplemented with income earned as a social enterprise (Warshawsky 2015).

Legal and regulatory framework

Some studies discuss how national and local regulatory frameworks facilitate food rescue and food waste prevention (Edwards and Mercer 2007; Miroso et al. 2016; Schneider 2013). National food safety regulation is a strong obstacle to the rescue and donation of food, particularly when originating from "waste", due to the expected safety risk. In the US, the Good Samaritan Law 2002 / Bill Emerson Good Samaritan Food Donation Act "*protects donors from liability when donating to a non-profit organization as well as from civil and criminal liability if a product, donated in good faith, later causes harm to one of the needy beneficiaries*" (Schneider 2013, p. 761). Similarly, in New Zealand, the Food Act 2014 provides "Immunity of Food Donors" to donate the edible surplus food with limited legal risk (Miroso et al. 2016). Sarti et al. (2017) note the lack of clear food safety regulations surrounding food sharing and donation practices which hamper the wider diffusion of food sharing initiatives. The local waste management system can also set constraints on the access to food which has already landed in the bin. For example, in the New York City waste management system, dumpster diving is considered as theft (Barnard 2011).

Media coverage

Grassroots initiatives for food waste reduction critically seek media attention to raise awareness of their cause. The mainstream print and electronic media, including social media and movies, play a role in publicizing the activities of grassroots initiatives against food waste (Barnard 2011; Edwards and Mercer 2007). Mobilization and awareness-raising is also done online. Barnard (2011) examines how freegans practicing dumpster diving in New York City interact with the media to gain public awareness and support. During trash tours in New York City, they hold public presentations called "*Waving the Banana speeches*", a critical performance meant not only to catch the passers-by's attention but also that of the mass media (Edwards and Mercer 2007). However, this media exposure also poses a threat, as it directs the attention of retailers to the activity and leads them to constrain dumpster diving by locking dumpsters or donating "waste food" to central collection agencies (Barnard 2011).

Networks and collaboration

Grassroots initiatives rely on networks and collaborations to share their cause and gain support. The opportunity for private wholesalers, retailers or farmers to partner up with a grassroots initiative is discussed in several studies (Barnard 2011; Caplan 2017; Lee et al. 2017; Miroso et al. 2016; Reynolds, Piantadosi, and Boland 2015; Schneider 2013; Warshawsky 2015). Lee et al. (2017) point to the increase of total gleaned volume by 50 % only by expanding the pool of partner farms by 24 %. Miroso et al. (2016) note that collaborating businesses donated food benevolently to increase community involvement. On the other hand, Warshawsky (2015) emphasizes the barriers for private wholesalers and retailers to partner with food rescue organizations such as the goals of profit maximization and brand leverage through marketing. Barnard (2011) analyses the ambiguous relationship that freegans entertain with retail stores: while contradicting the capitalist logic of supermarkets, freegans, dumpster divers and gleaners need to ensure access to the food surplus in the dumpsters, and thus need to secure a positive or neutral stance

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4 towards the retailers. Reynolds, Piantadosi, and Boland (2015) note that many of the services provided by
5 volunteer-driven and charity-based grassroots initiatives cannot be offered by the private sector without
6 philanthropic or government support. The local government is also a central actor that grassroots
7 initiatives seek collaboration with, mostly to access financial support, but also to ensure “laissez-faire”
8 (Campos and Zapata 2017; Kim 2017; Rut and Davies 2018). Finally, studies have examined how certain
9 grassroots initiatives are embedded in an international food movement network from which they can seek
10 support. The food movement networks operate at multiple levels: neighbourhood, municipal, regional,
11 national and international (Campos and Zapata 2017) and allow for networking, exchange and
12 collaboration, via e.g. representation on international websites and participation in annual international
13 gatherings or conferences.
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19 Measurement of outcome and impact of the grassroots initiatives

20 In this section, we address our second research objective: to review scholarly evidence of the contribution
21 of grassroots initiatives to reduce food waste and GHG emissions. In our sample, a first strand of studies
22 aims to quantify the food rescued and redistributed by grassroots initiatives and/or measures the GHG
23 emissions avoided by saving food from going to waste. A second strand of studies describes the effects of
24 grassroots initiatives in a qualitative manner.
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26 Quantified impacts

27 Nine studies (n=9) report the amount of food rescued and redistributed through the studied grassroots
28 initiatives, mostly in kilograms or tonnes of food, or in the number of equivalent meals which were served
29 with the rescued food (Table 4).
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32 The reported amounts of food waste recovered in tonnes/per year vary widely, from 0.6 tonnes in the
33 case of the Transition Café Bro Gwaun (Caplan 2017) to 22 680 tonnes for the City Harvest food rescue
34 organization (Walia and Sanders 2017). Evidently, the amount of food rescued depends on the size of the
35 initiative, in particular the number of members or volunteers (e.g. 25 000 voluntary food savers for
36 Foodsharing vs. 20 volunteers at the Transition Café Bro Gwaun). Smaller grassroots initiatives have limited
37 capacity to handle more than a certain amount of food (Caplan 2017; Lee et al. 2017), especially when
38 they want to focus on the local community level. Reynolds, Piantadosi, and Boland (2015) conclude that
39 food rescue is a less attractive waste disposal option compared to landfill or composting, due to higher
40 economic costs and a higher waste generation rate, although the additional waste generated by food
41 rescue would still be a very small part of the total Australian footprint. Similarly, Warshawsky (2015)
42 suggests that food rescue has a minimal effect on reducing food waste. A major obstacle to assessing and
43 comparing the impacts of grassroots initiatives is that data is mostly estimated by donors or reported from
44 study participants, and measurement methodologies varied widely. Moreover, while studies report the
45 amount of food recovered by the grassroots initiatives, only one study (Schneider 2013) compares the
46 quantities of the redistributed food to the amount of rescued food thrown away, and reports that the
47 quantity distributed was 92% of the mass of the rescued food (517 tonnes). However, no study investigates
48 whether the food saved was then actually consumed by the recipients.
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53 The ecological effects of food donations in terms of GHG emissions is discussed only in three (n=3) studies
54 (Table 5). The GHG emissions saved from food waste prevention are calculated in tonnes CO₂ equivalents
55 per year; we assume they include major GHG gases such as carbon dioxide, methane and nitrous oxide.
56 Schneider (2013) estimates the GHG emissions avoided between March 2010 and March 2011 because of
57 food surplus donation and redistribution through Team Österreich Tafel at 122 tonnes CO₂-eq. In Lindberg
58 et al. (2014), 1 000 tonnes of rescued food equates to 74 million litres of water and 6 000 tonnes CO₂-eq
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of GHG saved (Lindberg et al. 2014)⁴. Based on this, we find GHG emissions saved by SecondBite to amount to 23 400 tonnes CO₂-eq in 2013. Reynolds, Piantadosi, and Boland (2015) calculate the embodied CO₂-eq of the four Australian main food rescues amounting to 148 000 tonnes CO₂-eq in 2008. They base their calculation of the CO₂ impact on an extended Input-Output Analysis (Reynolds et al 2015). This does not include the resources used or GHG emissions generated as part of the food rescue operations. We estimated the potential GHG savings in tonnes CO₂eq per year per participant of the grassroots initiative. This amounts to potential annual savings of 0.25 tonnes CO₂-eq per capita for the Team Österreich Tafel (Schneider 2013). However, based on data provided by Reynolds, Piantadosi, and Boland (2015), we calculated a higher GHG saving potential of 4.43 tonnes CO₂-eq per person who could be fed daily from one of the four main Australian food rescues (Reynolds, Piantadosi, and Boland 2015).

To estimate the amount of GHG emissions connected to food waste prevention and reduction, reliable data on the type and amount of food waste avoided is needed. Thus, unspecific food waste data as provided by Barnard (2011), Warshawsky (2015), Miroso et al. (2016), Campos and Zapata (2017), Sarti et al. (2017), Lee et al. (2017) or Walia and Sanders (2017) is not sufficient to assess the potential of grassroots initiatives to reduce GHG emissions via food waste reduction.

Table 4 Recovered or prevented food waste reported in sampled studies

	Amount of food recovered		Year	Study ⁵
	tonnes / per year	meals		
FoodShare	N/A	30 000 meals per month	2015	Miroso et al. 2016
Four main Australian food rescues	18 065	12 million meals per day		Reynolds, Piantadosi, and Boland 2015
OzHarvest	289	N/A	2008	
Foodbank	17 573	N/A		
FareShare	3	N/A		
SecondBite	240	N/A		
	3 900*	8 million meals	2013	Lindberg et al. 2014
Foodsharing platform	1 600**	N/A	2017	Sarti et al. 2017
Olio app	N/A	77 288 meals	Unknown	
Team Österreich Tafel	110	N/A	2010	Schneider 2013
Food Forward	150-200	N/A	2014	Warshawsky 2015
Transition Café Bro Gwaun	0.6	N/A	2015	Caplan 2017
Food Bank of the Southern Tier	4 400***	N/A	2013	Lee et al. 2017; Sönmez et al. 2016
City Harvest	22 680	N/A	2015	
Inter-Faith Food Shuttle	3 175 ****	N/A	2015	Walia and Sanders 2017

* fresh fruits and vegetables ** computed based on the overall sum of 8 000 tonnes saved since the foundation of the platform until February 2017 *** computed from the output rate (pounds per season) of apple, cabbage, onion, sweet corn and potato **** computed based on 18 tonnes of food cooked per week.

⁴ Niklaus et al. (2012) cited in Lindberg et al. (2014) p 1486.

⁵ The authors presented are those whose study was included in the sample. Yet, the authors did not necessarily produce the present outcomes but instead derived them from secondary sources, such as grey literature generated by the grassroots initiatives themselves. For clarity, we only refer to the authors of the studies included in our sample.

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N/A: not available

Table 5 Ecological impact in terms of prevented GHG emissions (CO₂-eq tonnes) measured in sampled studies

	Ecological impact of food recovered in GHG			Study
	tonnes CO ₂ -eq / year	tonnes CO ₂ -eq / year / tonne of food recovered	tonnes CO ₂ -eq / year / capita	
Four main Australian food rescues	148 000	8.17	4.43*	Reynolds, Piantadosi, and Boland 2015
SecondBite	23 400	6	3.20**	Lindberg et al. 2014
Team Österreich Tafel	122	1.1	0.25***	Schneider 2013

* computed based on the estimates in Reynolds, Piantadosi, and Boland (2015) of the total number who could be fed in one single day from the yearly food rescued. ** computed based on the number of meals saved in one year in Lindberg et al. (2014) and the assumption of a 3-daily-meal diet. *** computed based on the number of recipients of the initiative reported in Schneider (2013).

Qualitative impacts

Beyond the nutritional and environmental value within the local community, several studies examine other impacts of grassroots initiatives. Miroso et al. (2016) analyse the social value created by the food rescue social enterprise for its stakeholders and volunteers (such as meeting new people; sense of accomplishment in helping others; learning new skills; being involved in the community; improved consumer perceptions of the corporate's social responsibility).

Two studies (n=2) capture the potential of community gardening to change attitudes and behaviour towards sustainable food consumption patterns including food waste reduction (Kim 2017; Rut and Davies 2018) which can potentially lead to a footprint reduction. In Kim (2017), the longer a gardener engages in the community garden, the more likely she/he is to report food waste reduction behaviours. However, the findings do not address the directionality of the correlation as people might engage in grassroots initiatives against food waste because they already have a positive attitude and behaviour towards food waste reduction. The potential of grassroots initiatives to change attitudes and practices among food donors towards more environment-friendly food waste management is discussed in two studies (n=2). Miroso et al. (2016) and Barnard (2011) respectively report a better dealing with supermarket overstocks and a greater awareness of donors as an outcome of the broadcasting of Freegan.info and the actions of FoodShare. These reported changes are traced back to the stakeholders' new subjective beliefs that changing food waste management brings positive outcomes for the council and greater community and therefore attracts rewards.

Success factors

Despite the lack of numeric data on GHG emissions saved through food waste prevention and reduction activities by grassroots initiatives, the potentials these initiatives hold for climate change mitigation are still relevant to discuss further. In this section we distil the key success factors of grassroots initiatives to address food waste reduction. We employ the analytical framework from Grabs et al. (2016) who define success factors at three inter-connected levels on which grassroots initiatives can initiate and drive change: the individual, the group, and the societal level. To contextualize and discuss further the success factors of

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the reviewed grassroots initiatives in relation to theory, we use and cite additional literature on grassroots movements⁶.

Individual-level success factors

Fostering the involvement of volunteers and users

Volunteer engagement, both in terms of numbers and their motivation to participate in a food waste prevention operation (Lee et al. 2017), is a cornerstone of grassroots initiatives. Moreover, the importance of a vivid community to ensure the success and sustainability of the initiatives should be stressed. We identified several drivers for fostering the involvement of a community of users and volunteers.

First, the capacity of grassroots initiatives to convey their message in a convincing manner to raise awareness of social or environmental problems is a precondition to spurring action (Bamberg and Möser 2007). Awareness-raising actions through public relations, media, talks, events, or apps (Barnard 2011; Campos and Zapata 2017; Edwards and Mercer 2007) provide keys to the question of “Why is change necessary?” (Grabs et al. 2016). Similarly, the analysis by Grabs et al. (2016) traces the success of the Foodsharing movement back to the simultaneous employment of a functional and interactive website as well as large-scale outreach and awareness-raising efforts. Digital social networks and sharing platforms as described in Sarti et al. (2017) allow people to connect online and negotiate ways to engage in collective action offline (Ganglbauer et al. 2014).

Second, grassroots initiatives provide alternative value systems and worldviews which respond to the question, “Why should I get engaged?” (Grabs et al. 2016). Nonetheless, in the context of food waste reduction, success is reflected rather in attracting a diverse audience both within media and the general public rather than in other groups with similar alternative ideologies. This supports the urge to frame the message in terms of respecting people's abilities to come to their own conclusions and/or avoiding depicting a purely ideological freegan identity (Barnard 2011).

Third, it is essential to make the participation in the initiative easy, and to provide answers to the question, “How can I make change happen?” (Grabs et al. 2016). Our systematic review provides illustrations from the freegan and Foodsharing movements which managed to attract attention and facilitate food waste reduction. Yet, the role of households and communities in driving social change and limiting food waste might be overestimated (Warshawsky 2015). Moreover, the fragmentation of users in sharing economy sectors and the lack of a critical mass can be barriers to tackling food waste (Sarti et al. 2017). Community engagement might be achieved not only in a bottom-up manner, but also through agents who administrate the initiatives and appeal to the local community for engagement in a top-down manner via information sharing (Ganglbauer et al. 2014).

Fostering the engagement of recipients

Despite the strong links between food waste and food insecurity, the sampled studies rarely discuss the perspectives of the recipients of recovered food. Important social aspects yet neglected include how recovered food can affect people's dignity (Lindberg et al. 2014) or lead to stigmatization of the poor (Caplan 2017; Schneider 2013). As Caplan (2017) shows in the case of the Transition Café Bro Gwaun, grassroots initiatives might experience local opposition due to conceptions of rescued food as dubious since given away by food outlets, and as intended for poorer people only. This tension reveals the need for strong involvement and communication in recipient communities to underline the adequacy of recovered food for consumption. In Walia and Sanders (2017), a culinary job-training program for

⁶ These additional studies are not part of the sampling process. The sample of studies resulting from the systematic review process is given in Table 3. For easy reading we do not highlight the paragraphs particularly.

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unemployed adults uses rescued food, empowering the participants as agents in food waste reduction efforts.

Group-level success factors

The organizational structure and size of grassroots initiatives can be relevant success factors (Grabs et al. 2016). However, limited and inconsistent resource flows often force grassroots initiatives to choose between the maintenance of operations and expansion into new communities (Warshawsky 2015). This is especially problematic when it comes to handling perishable food. Yet, we consider Mihaylov and Perkins's (2015) argument about environmental activism's spread from local to global: transcending the local is necessary because the global issue of food waste needs to be put on the national and global political agenda. Moreover, as Warshawsky (2015) notes, reinforcing the local trap as well as sidestepping the structural reasons for food insecurity and food waste should be avoided. Grassroots expansion, i.e. the capacity to reach out and [internationally] mobilize networks may be one way to achieve this (Grabs et al. 2016; Mihaylov and Perkins 2015; Rut and Davies 2018). Networks for broader collaboration via exchange of knowledge, resources and good practices can expand horizontally, with informal groups, and vertically, with organizations, private companies and stakeholders (Rut and Davies 2018). The informal group provides a relatively intimate, supportive social environment in which participants gain the opportunity to question and discuss sustainable food behaviours (Barnard 2011; Kim 2017). The relatively protected environment of the small group advances social learning (Grabs et al. 2016; Kim 2017), which includes the sharing of experience and pro-environmental lifestyles (Kim 2017) as well as social experimentation (Kim 2017; Rut and Davies 2018). The larger network in which they are embedded can act as a platform for disseminating and replicating the shared knowledge and experiences in other contexts (Kim 2017; Mihaylov and Perkins 2015).

Societal-level success factors

Food regulation, infrastructure, and ethics

Stringent food safety laws and the lack of common regulations for food donation are a major challenge for grassroots initiatives engaged in the recovering, sharing and redistributing of food. Where food donation regulations exist, as in the EU, these appeared to add costs to participating member states and make food donation less attractive (Schneider 2013). In the case of food sharing, there is a denial of responsibility for any food-related products shared by users (Sarti et al. 2017). Food safety concerns are also often used as an excuse by potential donors for not donating food (Schneider 2013). Thus, what is needed are clear guidelines for onsite food donation management (i.e. which products are suitable for donation, how to handle specific goods, agreement templates) (Schneider 2013). Furthermore, there is a need for an improved infrastructural framework for separated food waste disposal. Walia and Sanders (2017) suggested an identifiable food waste bin; the end-use destination for food waste and an automated sorting mechanism to account for the disposal of non-food waste in the food waste bin. Lastly, a broader discussion should be held at society level about the ethics of selling goods whose best-before date has passed. The confusion between the meaning of best-before and use-by dates should be overcome by increasing public awareness and informing (Schneider 2013).

4. Discussion

Food insecurity vs. climate change?

The systematic review revealed a somewhat surprising lack of connection between food insecurity (social priority) and climate change mitigation (environmental priority) (Table 3). This appears notably in the narratives of grassroots initiatives emphasizing food redistribution, which elude climate change mitigation as a major goal. Miroso et al. (2016) shows the failure of stakeholders to identify the environmental

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outcomes associated with their work with FoodShare. This is due to FoodShare's focus on nutrition and combatting food insecurity, which compel narratives of human hardship rather than climate change mitigation.

Additionally, there is a scholarly debate on whether the food charity sector and to an extent the food waste and surplus recovery sector are unsustainable with respect to the health dimension of sustainability when the food rescued is nutritionally inadequate. This in turn leads to many of those getting the food to remain food insecure (Poppendieck 1999; Warshawsky 2015) or feeling ashamed and humiliated (van der Horst, Pascucci, and Bol 2014). While food rescue serves an urgent, short-term moral imperative to feed hungry people, the activity can undermine social justice and long-term access to adequate food and nutrition. This poses the question of whether cherry-picking food which is more "worthy" of being saved is ethically and environmentally justifiable. Lindberg et al. (2014) argued for rescuing "valuable" and "most nutritious" food to lower the risk of diet-related disease, setting food waste reduction and food insecurity reduction as both complementary and competing missions. Furthermore, this raises the question as to the criteria by which this priority-setting should take place. One could argue differently, in favour of privileging the rescue of the most culturally and socially adapted food or rather following environmental criteria and privileging the most environment-friendly food, or on the contrary the food which required the most resources to be produced.

Finally, the reviewed studies cannot show efficiencies of food waste prevention grassroots initiatives. While the prevention and recovery of food is more desirable than its wastage, both morally, ethically and environmentally speaking, the grassroots work needs to be scaled up along the entire supply chain, rather than solely focusing on the consumer. Instead of only handling food surplus at high social and economic costs, grassroots initiatives could redirect their collaboration towards the supply chain to mitigate the occurrence of surplus food (Lindberg et al. 2014; Warshawsky 2015). This would help to address the first sub-priority in the Food Waste Hierarchy: avoiding surplus food generation through food production and consumption (Papargyropoulou et al. 2014). Besides, the potential of grassroots initiatives for food waste reduction to limit GHG emissions could be strengthened through a more holistic approach. This could address not only the symptom of food waste, but also link it to the promotion of sustainable dietary choices, food shopping habits, food waste management (Barnard 2011; Kim 2017), or social integration through return to work training (Caplan 2017; Walia and Sanders 2017).

Limitations of the review

In spite of searching for studies in three languages and with no geographical restriction, the final sample comprises studies conducted exclusively in urban areas of high-income, mostly Anglo-Saxon countries, published in English. This makes a generalization of the findings to other contexts difficult. Given the small sample size, it is only partly possible to compile and analyse quantitative impacts in terms of GHG emissions. Instead, we provide a narrative analysis while also extracting and compiling any outcome measures when available. The focus on peer-reviewed work entails a trade-off with exhaustiveness; the grey literature would have narrowed the knowledge gap left by the academic literature (Adams, Smart, and Huff 2017). Within the sample, the variety of analytical breadth and study designs hampered their comparability. Nonetheless and paradoxically, this variety offered a way to triangulate the findings of the studies and develop a more comprehensive understanding of grassroots level food waste reduction.

Conclusion

This systematic review examined the peer-reviewed evidence on grassroots initiatives' potential to limit food waste and GHG emissions. We found 15 relevant studies which represent a small but recent and growing interest in the topic. The findings of the studies are mostly of a qualitative nature, exploring the

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initiatives' organizational structure, goals and available resources. All grassroots initiatives studied embrace the goal of avoiding food going to landfill and considering human consumption as a priority. Each initiative's focus is on one of two specific priorities: (1) preventing avoidable food waste or (2) promoting the redistribution of food surplus to people living in food poverty.

The organizational structures of the grassroots initiatives take a variety of forms. These range from low-profile, informal but highly connected social endeavours, such as global food movements, or more localized citizen-led initiatives including online social platforms, to high-profile, professionalized CSOs or social enterprises. All reviewed initiatives rely highly on an important pool of volunteers that compensate for their low budgets.

Few studies provide information on the composition of the rescued food, mostly referring to any type of non-spoiled edibles. Some nonetheless discuss the decision to privilege the rescue of healthy food, evoking the complexity of combining the ethical and social requirements of initiatives that prevent food waste by saving and redistributing it. Initiatives secure collaboration across public and private sectors as a crucial way to share their cause and gain support as well as a supply of food to save from the bin. The food "waste" supply mostly emanates from the tertiary and secondary sectors, which are also being increasingly called upon to provide financial and material support. The public sector is mobilized to rescue food to a limited extent. It appears as a stakeholder to mobilize and secure funds as well as for the (tacit) authorization to collect food about to be wasted and to redistribute it. Some developments in legal and regulatory frameworks have eased food prevention activities of grassroots initiatives but hurdles in food safety regulations and local food management systems still hamper the work of grassroots initiatives. Their success in food waste reduction also relies greatly on their capacity to capture media attention. This allows them to increase awareness among the general public as well as retailers on the issue of food waste and to show the ease of addressing the problem.

Predictably, few studies attempt to identify quantifiable outcomes of the grassroots initiatives, either in terms of amounts of food rescued or redistributed or in GHG emissions avoided by saving food from going to waste. The few studies which include an ecological assessment of the GHG emissions avoided focus on food recovery via bigger long-established food surplus rescues. The amounts of food saved are highly dependent on the sizes of the initiatives, in particular the volume of users or participants. The organizational structure is another factor which can constrain the volume of food grassroots initiatives handle and save.

The food waste and ecological outcomes presented in the studies lack comparability and external validity due to the diversity of methodologies used and because they are compiled from secondary sources, mostly originating from the grassroots initiatives themselves. Only four studies (n=4) discussed the potential of grassroots initiatives to reduce food waste and GHG emissions and conclude that although it is preferable to landfilling or composting, the effect of food rescue by the investigated grassroots initiatives is minimal. Moreover, apart from one study which compiled how much of the food saved was actually distributed, estimates of the saved and ultimately eaten food are missing. Compared to the mean per capita GHG saving potential of reducing avoidable food waste in households compiled in Ivanova et al. (2020), the computed GHG saving potential of food waste prevention and reduction achieved through grassroots initiatives seems high but would need to be further investigated.

The systematic review raises these main directions for future research. Notably, there is a knowledge gap to be filled: to date, tangible estimates of the extent to which rescuing and redistributing food reduces food waste and GHG emissions are missing. The generation of data quantifying the food rescued and subsequently eaten by humans is needed. This suggests more academic knowledge in the black box between the group level and the individual level, i.e. the recipients and users of food saved. At the same

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time, there is a need for studies to show how other community-based efforts to promote alternative ways of producing and eating food, such as those promoting diet shifts, overlap with efforts fighting food waste.

Author contributions

MN conceived and coordinated the review, conducted the initial search strategy, supervised the reference management, screened on title and abstract followed by full text, conceived the coding system, drafted the initial manuscript and implemented revision of the draft.

KD assisted with the initial search strategy, adjusted conflicts between screeners at abstract and title screening level, provided critical inputs on the coding system, read full texts, provided critical inputs with the revised manuscript draft.

AW screened on title and abstract, adjusted conflicts between screeners at full text reading level, provided critical inputs on the coding system, read full texts, and provided critical input on the initial manuscript draft.

VK screened on title and abstract, completed data extraction, assisted in the reference management (sourcing full text articles), screened on title and abstract followed by full texts, and assisted with the initial and revised manuscript draft.

NL had the research idea, composed the team, provided critical input to the methods and overall guidance through the review and provided critical inputs on the manuscript draft.

All authors provided input on drafts.

Conflicts of interest

The authors have no conflicts of interest to disclose.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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Appendix

Appendix A. Search Strategy (Web of Science, English language)

	TERM 1	AND	TERM 2	AND	TERM 3
	„food wast*“		communit*		„greenhouse gas*“
OR		OR	„collective action“	OR	GHG*
OR	„food spoilage“	OR	grassroots	OR	„carbon dioxide“
OR	„wast* food“	OR	grass-root	OR	CO2
OR	„edible food“	OR	initiative*	OR	methane
OR	„plate waste“	OR	movement*	OR	CH4
OR	„beverage waste“	OR	citizen*		„nitrous oxide“
OR	leftover*	OR	„ bottom*up “	OR	„nitrus oxide“
OR		OR	„circular economy“	OR	N2O
OR	„ Food surplus“	OR	household*	OR	Hydrofluorcarbon\$
OR	„Surplus food “	OR	„small*scale“	OR	HFC*
OR	“Food loss“	OR	consumer*		F-gas*
		OR	NGO*		„fluorinated gas*“
		OR	„civil society“	OR	emission*
		OR	CSO*	OR	„carbon footprint“
		OR	food\$sharing	OR	footprint
		OR	responsible	OR	„climate change“
		OR	ethic*	OR	„climate impact“
		OR	sustainabl*	OR	
		OR	engage*	OR	„environmental impact*“
		OR	project*	OR	„ Global warming“
		OR	„food bank*“	OR	foodprint
		NOT	microbial		

Appendix B. Search Strings

	English	French	German
Web of Science Using Social Sciences Citation Index (SSCI) -- 1956-present 2000-2018	<p>(TS= ("food waste" OR "food wastage" OR "wasting food" OR "food spoilage" OR "edible food" OR "plate waste" OR "plate wastage" OR "beverage waste" OR leftover* OR "wasted food" OR "organic waste" OR "wasted food" OR "food surplus" OR "surplus food" OR "food loss"))</p> <p>AND TS= (communit* OR "collective action" OR grassroot* OR grass-root OR initiative* OR movement* OR citizen* OR consumer* OR bottom*up OR "circular economy" OR household* OR "small-scale" OR NGO* OR "civil society" OR CSO* OR "food sharing" OR responsib* OR ethic* OR sustainab* OR engage* OR project* OR "Food bank" OR "Food banks"))</p> <p>AND TS= ("greenhouse gas" OR "greenhouse gases" OR GHG* OR "carbon dioxide" OR CO2 OR methane OR CH4 OR "nitrous oxide" OR "nitrus oxide" OR N2O OR hydrofluorcarbons OR HFC* OR F-gas* OR "fluorinated gas" OR "fluorinated gases" OR emission* OR "carbon footprint" OR footprint OR "climate change" OR "climate impact" OR environment* OR "environmental impact" OR "global warming" or "foodprint")</p> <p>NOT TS= microbial)</p> <p>AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)</p>	<p>TS=(gasp* OR "gaspillage alimentaire" OR "reste* alimentaire*" OR "invendu* alimentaire*" OR "perte* alimentaire*" OR "déchêt\$ alimentaire*" OR denrées OR alimentaire OR gâch*)</p> <p>AND TS=(anti\$gasp* OR zéro\$gasp* OR communaut* OR initiative\$ OR populaire\$ OR citoyen* OR bottom\$up OR "économie circulaire" OR ménage\$ OR consommat* OR ONG\$ OR association\$ OR "Société civile" OR OSC\$ OR "consommation collaborative" OR food\$sharing OR responsable\$ OR éthique* OR durable\$ OR engage*)</p> <p>AND TS=("gaz à effet de serre" OR "GES" OR "dioxyde de carbone" OR CO2 OR méthane OR CH4 OR "protoxyde d'azote" OR N2O OR hydrofluorcarbures OR HFC\$ OR emission\$ OR "fluide* frigorigène*" OR "empreinte carbone" OR "empreinte" OR "changement climatique" OR "réchauffement climatique" OR "impact* environnement*")</p> <p>NOT microb*</p> <p>AND LANGUAGE: (French) AND DOCUMENT TYPES: (Article)</p>	<p>TS=(Lebensmittelabfälle* OR Küchenabfälle* OR Nahrungsmittelabfälle* OR Essenreste* OR Essenabfälle* OR Speisereste* OR Lebensmittelverschwendung OR "Verschwendung von Lebensmittel" OR Speiseabfälle* OR Lebensmittelüberschuss OR Nahrungsmittelüberschuss OR "überschüssige* Lebensmittel*" OR "überschüssige* Nahrungsmittel*" OR "Wegwerfen von Lebensmitteln" OR Lebensmittelverluste* OR Getränkeabfälle*)</p> <p>AND TS=(Gemeinschaft* OR Zivilgesellschaft OR Initiativ* OR Bewegung* OR Bürger* OR Kreislaufwirtschaft* OR Haushalt OR Verbraucher OR Konsument* OR NGO OR NPO OR NRO OR food\$sharing OR Grass*root\$ OR "Lebensmittel rett*" OR verantwort* OR ethisch* OR nachhaltig* OR Engagement OR engagier* OR Projekt OR Tafel)</p> <p>AND TS=(Emission* OR Kohlendioxid* OR CO2 OR Methan* OR Treibhausgas* OR Distickstoffmonoxid OR Lachgas OR Fluorkohlenwasserstoffe OR F\$KW OR HFC-Gase OR *Fußabdruck* OR Klimawandel OR Footprint OR Foodprint OR Umweltauswirkung* OR Umweltbelastung*) NOT TS=mikrobiell*</p> <p>AND LANGUAGE: (German) AND DOCUMENT TYPES: (Article)</p>
Science Direct	<p>("Food waste" OR "food surplus" OR "food loss") AND ("civil society" OR grassroots) AND ("greenhouse gases" OR footprint OR "climate change") NOT microbial</p>	<p>("gaspillage alimentaire" OR "invendus alimentaires" OR "pertes alimentaires" OR gaspil* OR "restes alimentaires" OR gâcher) AND</p>	<p>(Lebensmittel OR Verschwendung OR Essenabfälle OR Lebensmittelverschwendung) AND (Gemeinschaft OR Zivilgesellschaft OR</p>

		("société civile" OR "initiative" OR bottom-up) NOT microb*	Initiativ) AND (Emission OR Fußabdruck OR Klimawandel)
AGRI	"food waste" -"microbial"	"gaspillage alimentaire" - "microb"	n/a
Journal articles Books	("food waste" + "civil society" (optional) + "greenhouse" (optional) -"microbial" : 4 hits, including 3 duplicates)		
Scopus	(TITLE-ABS-KEY ("food waste" OR "food wastage" OR "wasting food" OR "food spoilage" OR "edible food" OR "plate waste" OR "plate wastage" OR "beverage waste" OR leftover* OR "wasted food" OR "organic waste" OR "food surplus" OR "food loss")	("gaspillage alimentaire" OR "reste* alimentaire*" OR "invendu* alimentaire*" OR "perte* alimentaire*" OR "déchêt\$ alimentaire*" OR denrées OR alimentaire OR gâch*)	n/a
2000-2018			
Journal articles	AND TITLE-ABS-KEY (communit* OR "collective action" OR grassroot* OR grass-root OR initiative* OR citizen* OR consumer* OR bottom*up OR "circular economy" OR "small- scale" OR "ngo\$" OR "civil society" OR "food sharing" OR responsib* OR ethic* OR engage* OR "Food banks")	AND (anti\$gaspi* OR zéro\$gaspi* OR communaut* OR initiative\$ OR populaire\$ OR citoyen* OR bottom\$up OR "économie circulaire" OR ménage\$ OR consommat* OR "ONG\$" OR association\$ OR "Société civile" OR "OSCS" OR "consommation collaborative" OR food\$sharing OR responsable\$ OR éthique* OR durable\$ OR engage*)	
	AND TITLE-ABS-KEY ("greenhouse gas" OR "greenhouse gases" OR "carbon dioxide" OR methane OR "nitrous oxide" OR "nitrus oxide" OR hydrofluorcarbons OR "fluorinated gas" OR "fluorinated gases" OR "footprint" OR "climate change" OR "environmental impact" OR "global warming")	AND ("gaz à effet de serre" OR "GES" OR "dioxyde de carbone" OR co2 OR méthane OR ch4 OR "protoxyde d'azote" OR n2o OR hydrofluorcarbures OR hfc\$ OR emission\$ OR "fluide* frigorigène*" OR "empreinte carbone" OR "empreinte" OR "changement climatique" OR "réchauffement climatique" OR "impact* environnementa*")	
	AND NOT TITLE-ABS-KEY (microbial) AND DOCTYPE (ar) AND PUBYEAR > 1999 AND PUBYEAR < 2019	AND NOT TITLE-ABS-KEY (microbial) AND DOCTYPE (ar) AND PUBYEAR > 1999 AND PUBYEAR < 2019 AND LANGUAGE (french)	
CAIRN	n/a	(gaspi* OU "gaspillage alimentaire" OU "restes alimentaires" OU "invendus alimentaires" OU "pertes alimentaires" OU déchets alimentaires" OU denrée* OU gâch*)	n/a

		<p>ET (communaut* OU initiative OU populaire OU citoyen OU bottom w/1 up OU "économie circulaire" OU ménage OU consommat* OU ONG OU Association OU "société civile" OU OSC OU "consommation collaborative" OU food*sharing OU responsable OU éthiqu* OU durable OU engage*)</p> <p>ET ("gaz à effet de serre" OU "GES" OU "dioxyde de carbone" OU CO2 OU méthane OU "protoxyde d'azote" OU N2O OU hydrofluorocarbures OU HFC OU émission OU "fluides frigorigènes" OU "empreinte" OU "changement climatique" OU "réchauffement climatique" OU "impact") SAUF(microbien)</p>	
<p>Google Scholars</p> <p>Articles and contribution in books excluding citations.</p>	<p>("Food Waste" "Food surplus" "Food Loss") ("civil society" grassroots) ("greenhouse gases" footprint "climate change") -microbial</p>	<p>("gaspillage alimentaire" "invendus alimentaires" "pertes alimentaires" gaspil* "restes alimentaires" gâcher) ("société civile" "initiative" bottom-up) ("gas à effet de serre" empreinte "changement climatique") -microb</p>	<p>(~Lebensmittelabfälle ~Lebensmittelverschwendung Speisereste* "Wegwerfen von Lebensmitteln") (Zivilgesellschaft Initiativ* Grassroot*) (Emission* Treibhausgas* ökologische* *Fußabdruck* Klimawandel*) -mikrobiell</p>
<p>INRA</p>	<p>n/a</p>	<p>gaspillage alimentaire (n=144) gaspillage alimentaire initiative (n=16) gaspillage alimentaire et communaut* (n=15) gaspillage alimentaire populaire (n=1) gaspillage alimentaire "société civile" (n=4) gaspillage alimentaire bottom-up (n=0) gaspillage alimentaire citoyen (n=6) gaspillage alimentaire association (n=19) gaspillage alimentaire ONG (n=0) gaspillage alimentaire "économie circulaire" (n=9) gaspillage alimentaire "consommation collaborative" (n=10) gaspillage alimentaire food sharing (n=0) gaspillage alimentaire responsable (n=8) gaspillage alimentaire éthique (n=9)</p>	<p>n/a</p>

1 2 3 4 5 6 7 8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46	WiSo Articles and eBooks German	n/a	n/a	(~Lebensmittelabfälle OR ~Küchenabfälle OR Speisereste* OR Verschwendung OR "Wegwerfen von Lebensmitteln") AND (Zivilgesellschaft OR Initiativ* OR Bewegung*) AND (Emission* OR Treibhausgas* OR ökologische* *Fußabdruck* OR Klimawandel*) NOT mikrobiell
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