Mitigating Climate Change via Food Consumption and Food Waste

A Systematic Map of Behavioral Interventions

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Review

Mitigating climate change via food consumption and food waste: A systematic map of behavioral interventions

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ABSTRACT

Demand-side policies for mitigating climate change based on behavioral insights are gaining increased attention in research and practice. Here we describe a systematic map that catalogues existing research on behaviorally informed interventions targeting changes in consumer food consumption and food waste behavior. The purpose is to gain an overview of research foci and gaps, providing an evidence base for deeper analysis. In terms of food consumption, we focus on animal protein (meat, fish, dairy, and eggs) and its substitutes. The map follows the standards for evidence synthesis from the Collaboration for Environmental Evidence (CEE) as well as the RepOrting Standards for Systematic Evidence Syntheses (ROSES). We identified 49 articles including 56 separate studies, as well as 18 literature reviews. We find a variety of study designs with a focus on canteen and restaurant studies as well as a steep increase of publications since 2016. We create an interactive evidence atlas that plots these studies across geographical space. Here, we find a concentration of research in the Anglo-Saxon world. Most studies follow multi-intervention designs and focus on actual food consumption behavior, fewer on food waste behavior. We identify knowledge clusters amenable for a systematic review focusing on the effectiveness of these interventions, namely: priming, disclosure, defaults, social norms, micro-environment changes, and ease of use. The systematic map highlights knowledge gaps, where more primary research is needed and evidence cannot support policy; it identifies knowledge clusters, where sufficient studies exist but there is a lack of clarity over effectiveness, and so full synthesis can be conducted rapidly; finally, it reveals patterns in research methods that can highlight best practices and issues with methodology that can support the improvement of primary evidence production and mitigation of research waste. To the best of our knowledge, this is the first systematic study mapping this specific area.

Contents

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1. Introduction

As the recent Intergovernmental Panel on Climate Change (IPCC) *Special Report on Climate Change and Land* has revealed, food production, agriculture, forestry, and other human activities related to land use accounted for about one third (21–37%) of anthropogenic greenhouse-gas (GHG) emissions within the last monitored decade (2007–2016) (Intergovernmental Panel on Climate Change (IPCC), 2019). An increasingly discussed strategy to lower anthropogenic environmental pressures (on land, air, water, and biodiversity) is to reduce our meat consumption in favor of balanced diets, featuring plant-based nutrition.

Indeed, household consumption in general puts extensive pressure on the environment, accounting for approximately 60% of global GHG emissions and 50–80% of total resource use (Ivanova et al., 2016). Together with housing and mobility, food is among the most significant consumption domains when it comes to carbon impact (Wellesley et al., 2015). A recent global environmental footprint study singled out air travel and meat consumption as well as heating and cooling as the most impactful consumption areas (Ivanova, 2018). These findings confirm previous research, dating back at least a decade, suggesting that meat-heavy diets of developed countries significantly contribute to the overall carbon footprint (Hertwich and Peters, 2009). The production and consumption of certain foods are associated with higher GHG emissions than others: Field-grown foods (i.e., grains, fruit, and vegetables) have a rather low impact while products from ruminant animals have a high impact on GHG emissions (Clune et al., 2017).

Western diets are, however, typically high in animal protein, and these diets are spreading around the globe. A recent report for the United Kingdom (UK) (CCC, 2019) suggests that a 20% reduction in beef, lamb, and dairy consumption by 2050 – which can be seen as a relatively modest target compared to other major reports' suggested reduction targets (e.g., Lorenz-Walther et al., 2019) – would be acceptable when achieved in tandem with other decarbonising and negative emissions efforts. Whatever the appropriate scale might be: Shifting food consumption patterns to become less GHG-intensive and less wasteful certainly and decidedly matters for climate change mitigation (Tilman and Clark, 2014). An evidence base that informs the selection of suitable demand-side policy strategies and instruments to promote more climate-friendly consumption patterns could help policymakers and their countries to achieve their commitments under the Paris Agreement and the 2030 Agenda. As Creutzig et al. (2018, p. 260) suggest, these demand-side policies may include "strategies targeting technology choices, consumption, behavior, lifestyles, coupled production-consumption infrastructures and systems, service provision, and associated socio-technical transitions." At the core of these policies lies the challenge to support consumers in making behavioral changes towards more sustainable choices. Examples of promising demand-side policies reducing animal protein consumption cover a wide range: from climate taxes (Gren et al., 2019) to awareness-raising information and communication campaigns (Röös et al., 2014), from the use of positive models (Funk et al., 2020) to promoting meat replacers (Van Mierlo et al., 2017).

The present study focuses on another, less discussed type of such demand-side policies: *behaviorally informed policies* (Sunstein, 2014a). These so-called "nudges" are small, low-cost, choice-preserving, low intrusion approaches to steer people's choices in a specific direction without forcing people or providing financial incentives or penalties (Thaler and Sunstein, 2008). These stimuli are "behaviorally informed" since they systematically take into

account how consumers make their decisions, how they actually, empirically choose or waste food, for instance, as opposed to theoretical models. Behavioral economics incorporates psychological knowledge about the drivers and barriers of behavior change: People are guided by biases (e.g., status quo bias, endowment effect, mental accounting), influenced by environments and situations (e.g., music, temperature, time pressure), and often employ frugal approaches to information search and use, applying simple heuristics, based, e.g., on availability or salience (Reisch and Zhao, 2017). Examples of nudges are reminders, warnings, salient disclosures such as labels, social norms, and defaults of choice situations (see Table 1). All of these aim to make the desirable choice – in our case: food choices that have less GHG impact – easier, more socially relevant, timelier, and otherwise more attractive, and therewith more likely to happen.

In this paper, we investigate the available evidence regarding research on policies that induce such changes of consumption levels with a focus on animal protein (i.e., meat and meat products, fish, dairy, and eggs), as well as on plant-based protein sources substituting animal protein. Additionally, we look at interventions that address the level of food waste in general. Loss and waste of food occurs throughout the entire food system, currently accounting for one-third of all food or 1.3 billion tons every year (FAO, 2011). Moreover, food loss and waste constitute a major source of GHG emissions, together accounting for about 8% of global anthropogenic GHG emissions according to the FAO (2017). Reducing these numbers would contribute not only to meeting food security demands, but also to reducing some of the associated climate impacts of our food system. While food loss can occur along the whole supply chain from production to transportation, the present study concentrates on "food waste", defined as edible food that is lost at the end of the food supply chain, relating to retailer and particularly, consumer behavior (Parfitt et al., 2010).

Demand-side policies for mitigating climate change are now gaining increased attention in research (Warren, 2018) and climate politics (Creutzig et al., 2018). The next Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report will feature – for the first time – a chapter on demand-side climate policies. While these encompass the classical instruments such as consumer information and education, taxes and regulation, our interest lies in a new kind of policy tool, so-called behaviorally informed policies (e.g., Sunstein, 2014a). This does, of course, not imply that we assume general superiority of the latter over the former; rather, the best policy applied will be a matter of cost and benefits, acceptability, public approval, type of policy problem, and target group (Troussard and van Bavel, 2018). Behavioral economists emphasize that "choice architecture", understood as the background against which decisions are made, can have major consequences for both decisions and outcomes (Thaler, 2015). In the literature on behavioral public policy in general and behavioral environmental policy in specific, there is growing empirical evidence that nudges and choice architecture promise highly beneficial environmental effects (Sunstein and Thaler, 2003) and are potentially both effective and cost-efficient (Benartzi et al., 2017). Moreover, most of these instruments seem to be well accepted by the public in many countries worldwide, which makes them an attractive choice for policymakers who are increasingly under pressure to act (Sunstein and Reisch, 2019). Recent literature reviews (e.g., Schanes et al., 2018) have mapped the determinants of food waste generation and have identified behavioral cues such as plate size and social norms as entry points to prevention strategies.

For our systematic map, we use a practitioners' approach to classify nudges, consistent with the approach in Sunstein (2014b) and Thaler (Thaler and Sunstein, 2008). Table 1 below provides an overview of the interventions searched for in our study.

While the evidence base regarding the cost-effectiveness of such behaviorally informed policies has grown over the years, syntheses of this evidence in the form of systematic reviews or maps are rare. Despite our best efforts, we found only a few systematic literature reviews (e.g., Byerly et al., 2018; Hartmann and Siegrist, 2017; Nisa et al., 2019; Taufik et al., 2019) and a small number of other literature reviews and policy overviews (e.g., Hebrok and Boks, 2017; Vandenbroele et al., 2020; Wynes et al., 2018) that focus on animal-protein consumption and food waste. This includes several systematic reviews assessing the effectiveness of behavioral interventions on pro-environmental behavior in terms of reducing meat demand (Bianchi et al., 2018a, 2018b) and reducing consumer food waste (Stöckli et al., 2018). In particular, we have not found a systematic map focusing on behaviorally informed interventions targeting food consumption (meat, fish, dairy, eggs, and respective substitutes) and food waste within a climate frame. This is what the present study sets out to do.

Following a preregistered protocol developed according to the standards for evidence synthesis from the Collaboration for Environmental Evidence (CEE) as well as the RepOrting Standards for Systematic Evidence Synthesis (ROSES) (see Reisch et al., 2019b for the a priori published protocol and Supplementary Material 1 for the report), we searched and compiled empirical studies of demand-side behavioral mitigation approaches for climate change with a focus on food consumption and consumer food waste. We were interested in all types of empirical studies, quantitative and qualitative, using different methods (experimental and others),

Table 1
Interventions used in the search.

	Behavioral intervention	Abbreviation	Examples
1	Default rules	Defaults	Introducing "Meatless Mondays" in public canteens
2	Simplification	Simplification	Simplifying access to vegetarian menu choices
3	Use of social norms	Norms	Emphasizing what most people are doing and eating
4	Increase in ease and convenience	Ease	Making low-carbon options more visible and access easy and convenient
5	Disclosure	Disclosure	Disclosure of environmental costs associated with meat consumption on a menu
6	Warnings	Warnings	Colored carbon warning labels on meat products
7	Pre-commitment strategies	Pre-commitment	Self-pledge to reduce food waste by a certain percentage
8	Reminders	Reminders	Reminding people of their plans, e.g., via e-mail or text message
9	Eliciting implementation intentions	Intentions	Asking: "Do you plan to eat less meat?"
10	Informing people of the nature and consequences of their own past choices	Past choices	Disclosing what earlier food choices meant, e.g., in GHG savings
11	Priming	Priming	Using visual or spatial – or other – primes (e.g., store design, signs in shops)
12	Physical or digital micro- environment changes that alter the context of a choice	Micro-environment	Ordering products on shelf spaces in supermarkets or of choices on a website; changing the affordances and signalling atmosphere of a building
13	Other	Other	Applying other nudges not covered (e.g., framing, herding, feedback, and praise)

describing some form of behaviorally informed intervention and measuring changes in food consumption or consumer food waste and thereby, indirectly, GHG emissions. Moreover, we were interested in all types of academic literature reviews (both systematic and non-systematic).

The question we aimed to answer with this research is: Which behaviorally informed demand-side interventions and demand-side policies have been implemented and studied that target individual consumers as well as private and large households with the aim of reducing their GHG emissions resulting from food (animal protein and substitutes) consumption and consumer food waste?

The research question reflects the four "PICO" elements to be defined in a systematic review or map (CEE, 2018): The study *population* (P) covers individual consumers, private households as well as large households (such as public or corporate canteens) that consume food (animal protein or substitutes) or that produce food waste. The focus lies on *interventions* (I) that use behavioral insight-based policies such as nudges or choice architecture, initiated by both public and private (or public-private) actors. While we do not select a specific *comparator* (C), eligible studies must compare levels of consumer food consumption or food waste, either against a type of control group or in a before-after intervention comparison. The *outcomes* (O) of the studies we include are changes in food consumption (animal protein or substitutes) and/or consumer food waste. We add a fifth element, including only studies that use some sort of environmental or climate *framing* (F) as their motivation. And finally, we include all types of empirical study types (S) that provide primary data and all types of academic literature reviews serving for completeness checks of our core articles. Studies with an exclusive health focus or with a focus on other sustainability issues do not qualify. In the methods section below, Table 2 provides a detailed overview of the inclusion and exclusion criteria.

The results of our systematic search – 49 articles and 56 studies overall – were coded, analysed, and synthesized. In addition, we retrieved 18 relevant review articles that we did not code individually but list in Supplementary Material 2 as a separate database.

The present systematic map can be used by policymakers and researchers to attain a broad overview of available evidence in existing research clusters and to detect knowledge gaps in this area. Ideally, it will support decision makers in outlining an impactful research agenda and finding effective demand-side policies for mitigating climate change.

2. Material and methods

2.1. Systematic mapping

2.1.1. Systematic map vs systematic review

The systematic map was based on the standardized procedure suggested by the Collaboration for Environmental Evidence (CEE, 2018; see also Haddaway et al., 2017). Like systematic reviews, systematic maps can provide a reliable and objective way of synthesizing existing evidence by summarizing large bodies of scientific publications (Haddaway et al., 2016). In contrast to systematic reviews, systematic maps do not focus on estimating the effectiveness or efficacy of interventions. In addition, they usually do not even report on study results, as this may encourage vote-counting, i.e., counting and weighting the number of statistically significant results for and against a hypothesis, which is strongly discouraged in the literature (CEE, 2018). Instead, systematic maps catalogue existing evidence, typically focus on multiple interventions, and the underlying research questions are often framed in a broader sense (Haddaway et al., 2016). The goal is to extract, compile, and present relevant descriptive information about the studies' methods, contexts, and outcomes (so-called "metadata") based on predetermined coding criteria, and then describe the distribution and quantity of evidence to identify potential knowledge gaps and knowledge clusters. Systematic maps can thus be used both for appraising past research and for supporting the direction of funding and effort around future research.

2.1.2. Preregistration (protocol)

Before starting the search, we published the full systematic map protocol following the RepOrting Standards for Systematic Evidence Syntheses (ROSES) on the Open Science Framework (see Reisch et al., 2019a). Reporting standards like ROSES and PRISMA are widely accepted in the evidence synthesis community to support transparency and rigor of the research (Haddaway and Macura, 2018). We used this protocol to guide our search, as well as for the screening and coding process. Throughout the study, we deviated only slightly from this protocol, namely in regard to the coding scheme, which we finetuned in an iterative manner. Here we made several adaptations while screening and coding the studies. The full coding scheme and an indication of deviations from the protocol can be found in the Supplementary Material 3.

2.2. Searching

The search was performed by two authors, with the support of a research assistant and guided by one methodologist as well as one external search mentor. As outlined in the introduction, we searched in various bibliographic databases, Google Scholar, a theses repository, and on 30 organizational websites. We also conducted supplementary searches as outlined below.

2.2.1. Developing and finalizing the search strings

As a first step of conducting this systematic map, a full Boolean search string (String 1 in Fig. 1) was developed. The search string was tested and adapted in an iterative manner during team meetings by examining search results in two core databases, the Web of Science

Table 2
Bibliographic databases and search information.

No	Database	Platform access	Search restrictions
1	ABI/Inform Collection	ProQuest	Everywhere except full text
2	Academic Search Premier	Academic Search Premier	No search restriction
3	Business Source Premier	Ebsco	No search restriction
4	International Bibliography of the Social Sciences (IBSS)	ProQuest	Everywhere except full text
5	Medline and associated databases	PubMed	No search restriction
6	PAIS Index	ProQuest	Everywhere except full text
7	PsychInfo	Ebsco	No search restriction
8	Science Direct	Science Direct	No search restriction
9	Scopus	Scopus	Only title, abstract, and keywords
10	Sociological Abstracts	ProQuest	Everywhere except full text
11	Web of Science Core Collections	Web of Science	No search restriction

Core Collection (see Supplementary Material 4 for a list of sub-databases included in the Web of Science Core Collection) and SCOPUS. On principle, String 1 was applied to all selected sources. If the database or search facility did not allow for using String 1, the syntax was shortened and adapted as necessary (Strings 2 and 3). For instance, we do not know what Google Scholar is exactly doing with wildcards and asterisks, so after consultation with our search mentors, an adapted String 3 was created, and a second Google Search was performed. Fig. 1 below provides an overview of the three search strings. We present a detailed report on the stepwise development of the search strings in Supplementary Material 4.

2.2.2. Language and time restrictions

In all searches, we included only results in English. Exceptions were a few German institutional websites and grey literature sources that were searched with the same but adapted German search terms (see Supplementary Material 4). "Grey literature" describes documents not published by commercial publishers. It includes academic theses, organization reports, government papers, and similar publications and may prove highly influential in syntheses, despite not being formally published in the same way as traditional academic literature (Haddaway et al., 2015). Searches were executed within a six-month period (January through June) in 2019; no update of searches were conducted because of this relatively short time-frame. No time restrictions in regard to publication date of the studies were applied.

2.2.3. Bibliographic databases

The core search was performed in the following bibliographic databases that were chosen based on their assumed relevance for our research question (see Table 2 above). We used The London School of Economics and Political Science as well as Ruhr-University Bochum library subscription. For hand searches, we also used Copenhagen Business School and Zeppelin University Friedrichshafen library services.

We searched in topic words, abstracts, titles, and keywords according to the available features of each database. We also searched in full texts where the database would allow us. We tested whether a benchmark list of five relevant articles (see Supplementary Material 4) could be found in these databases with our search strings.

2.2.4. Search engines and theses repository

A search with Search String 2 (see Fig. 1) was performed in the search engine Google Scholar, which has proven to be a relevant source particularly for grey literature that is typically not represented in the bibliographic databases (Haddaway et al., 2015). Because searches were restricted quantitatively by Google Scholar, only the first 1000 records could be screened manually. The theses repository ProQuest Dissertations and Theses was searched using the full Boolean search string. Search results from Google Scholar and from ProQuest were added to the workflow for duplication removal alongside the results from bibliographic databases. Since it was not possible to detect exactly how Google Scholar treats

1. Full Boolean Search String

((nudg* OR bias* OR "choice-architecture") OR (behavio$r* AND (stimul* OR polic* OR interven*)))

AND
(((food* OR meat* OR beef OR bovine OR veal OR cattle OR lamb OR ovine OR pork OR poultry OR chicken OR turkey OR egg* OR fish OR fisher* OR seafood OR dairy OR milk OR "animal protein" OR "non-plant" OR "plant-based" OR vegetabl* OR vegetar* OR vegan* OR flexitarian*)

AND

(consum* OR intak* OR intention* OR purchas* OR choos* OR select* OR prefer* OR demand* OR buy* OR avoid* OR choice* OR use OR using OR eat OR eating OR drink* OR diet*OR "reduc*"))
OR
("food waste" OR "food wast*" OR "food loss" OR "food scrap*" OR "food remain*" OR compost* OR recycl* OR "source separat*" OR "source segregat*" OR "waste" OR dispos* OR rubbish OR "left over*" OR "throw* away*" OR bin* OR garbage OR loss OR leftover* OR "over-consumption" OR uneaten OR "doggy-bag*" OR "waste-prevent*" OR "ugly-food"))

AND ("climate change" OR "global warming" OR "greenhouse gas*" OR carbon OR methane OR "low-carbon" OR emission* OR CO2 OR CH4 OR sustainab*)

2. Short Search String

((nudg* OR bias* OR "choice-architecture") OR (behavio$r* AND (stimul* OR polic* OR interven*)) AND ((food* OR meat* OR fish OR dairy OR milk) OR ("food wast*" OR "waste")) AND (climate OR emission* OR "greenhouse gas*" OR carbon OR methane))

3. Google Scholar Search String

((nudge OR bias OR "choice-architecture") OR (behavior OR behaviour AND (stimuli OR policy OR policies OR intervention)) AND ((food OR meat OR fish OR dairy OR milk) OR ("food waste" OR "waste")) AND (climate OR emission OR "greenhouse gas" OR carbon OR methane))

Fig. 1. The three search strings.

wildcards and asterisks in search strings, a second search was conducted, using Search String 3. The results of this second Google Scholar search were again screened manually at the title level. The results were also added to the workflow for abstract screening as shown below (see Fig. 2).

2.2.5. Specialist websites

Beyond Google Scholar, grey literature was manually searched on 30 specialist and practitioner-oriented websites that were selected based on desk research, on solicited experts' opinions as well as on the authors' policy and research expertise:

- Behaviour and Health Research Unit, University of Cambridge, UK, www.bhru.iph.cam.ac.uk/
- Behavioural Economics in Action at Rotman University of Toronto, CA, www.rotman.utoronto.ca/FacultyAndResearch/ResearchCentres/BEAR
- Behavioural Economics Team of the Australian Government, AUS, www.behaviouraleconomics.pmc.gov.au/
- Behavioural Insights Team, UK, www.bi.team/
- Behavioural Science and Policy Association, www.behavioralpolicy.org/
- Deloitte Insights, www2.deloitte.com/insights/us/en.html
- Department for Environment, Food & Rural Affairs, UK, www.gov.uk/government/organisations/department-for-environment-food-rural-affairs
- Environment Agency, UK, www.gov.uk/government/organisations/environment-agency
- Environmental Protection Agency, USA, www.epa.gov/
- European Commission Joint Research Centre, EU, www.ec.europa.eu/jrc/en
- European Environment Agency, EU, www.eea.europa.eu/
- Federal Environment Agency, GER, www.umweltbundesamt.de/
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, GER, www.bmu.de/
- Federal Ministry of Food and Agriculture, GER, www.bmel.de/
- Harvard Kennedy School Centre for Public Leadership, Behavioral Insights Group, US, www.cpl.hks.harvard.edu/behavioral-insights-group
- ideas42, www.ideas42.org/
- International Institute for Environment and Development, www.iied.org/
- NSW Government Behavioral Insights Unit, AUS, www.bi.dpc.nsw.gov.au/
- Organisation for Economic Co-operation and Development, www.oecd.org/
- PBL Netherlands Environmental Assessment Agency, NL, www.pbl.nl/en/
- Rare, www.rare.org
- The European Nudge Network, www.tenudge.eu/
- The Food and Agriculture Organization of the United Nations, www.fao.org/home/en/
- The London School of Economics and Political Sciences (LSE), Centre for Analysis of Risk and Regulation, UK, www.lse.ac.uk/accounting/CARR
- The World Bank, www.worldbank.org/
- Thünen-Institute, GER, www.thuenen.de/
- United Nations Development Programme, www.undp.org/
- United Nations Environment Programme, www.unenvironment.org/
- United Nations Framework Convention on Climate Change, www.unfccc.int/
- United States Department of Agriculture, USA, www.usda.gov/

2.2.6. Supplementary searches

A supplementary hand search was conducted in two academic journals that are known by the authors to be two hotspots of the type of research we were focusing on: *Behavioral Public Policy* and *Decision — A Journal for Research about Judgment and Decision Making*. The journals are not covered by the bibliometric databases above but were identified by the authors as being particularly relevant. Moreover, we screened the bibliographies of all relevant literature reviews identified during systematic map searches and screening. Finally, a call for evidence, asking for literature suggestions, was placed on social media (Twitter, ResearchGate) to locate additional studies, include external stakeholders in the search process, and enhance the comprehensiveness of the search. Again, all findings were added to the workflow.

2.3. Eligibility screening and inclusion criteria

2.3.1. Screening strategy

All search results were downloaded as reference files and assembled as a final library using the desktop version of Endnote X9. Duplicates were removed, first for results within each database and then across databases. The remaining results were screened via the three-stage screening process following ROSES (Haddaway et al., 2017a), first at title and abstract level and then at full text level. The screening process is depicted in Fig. 2.

For the title screening, a web-based reference management system was used (EndNote Web). Title and abstract screenings were conducted by two members of the team independently. When conducting the title screening, we manually removed any duplicates that were not identified by Endnote X9's duplicate removal. This screening phase entailed careful reading of each individual title and abstract, and then, based on predetermined inclusion and exclusion criteria, the decision whether to include a study or not was made. For the final stage of full text screening, all remaining search results were divided and among three co-authors for independent screening. In case of uncertainty, full texts were read and screened by more than one author. If no full text was available, even after contacting authors, trying to retrieve the article via social media or through inter-library loans, the respective article was excluded from analysis but was included in a list of unobtainable articles (see Supplementary Material 5).

To ensure high interrater consistency in screening for eligibility, we conducted consistency checks with a subset of 10% of the identified articles at each screening level (613/12,262 articles at full text, 170/1662 at abstract and 29/285 at full text level). We performed a trial screening at each of these levels respectively before conducting the consistency checks. At title level, deviations were discussed among raters; at abstract and full text level, all disagreements were discussed in team meetings. Based on these discussions, inclusion/exclusion criteria were refined where necessary. To measure how well our decisions were aligned, we used Cohen's Kappa for the decisions on title and abstract level (with two raters reading each article) and Fleiss' Kappa for the decisions based on full texts (with three raters reading each article). For the consistency check at full text level, we conducted one trial round with 28 articles and a second round with 29 articles. After the second round, we received an acceptable Fleiss Kappa (see Supplementary Material 6 for further information on the consistency checks).

In a few cases, eligibility could be assessed only with an extra step: Although the eligibility screening process took place at the *article* level, eligibility decisions eventually were made at the level of each individual *study*. In twelve cases, after duplicate removal, more than one article presented results from the same study. These linked articles were grouped together and screened for eligibility as a single unit so that all available data pertinent to the study could

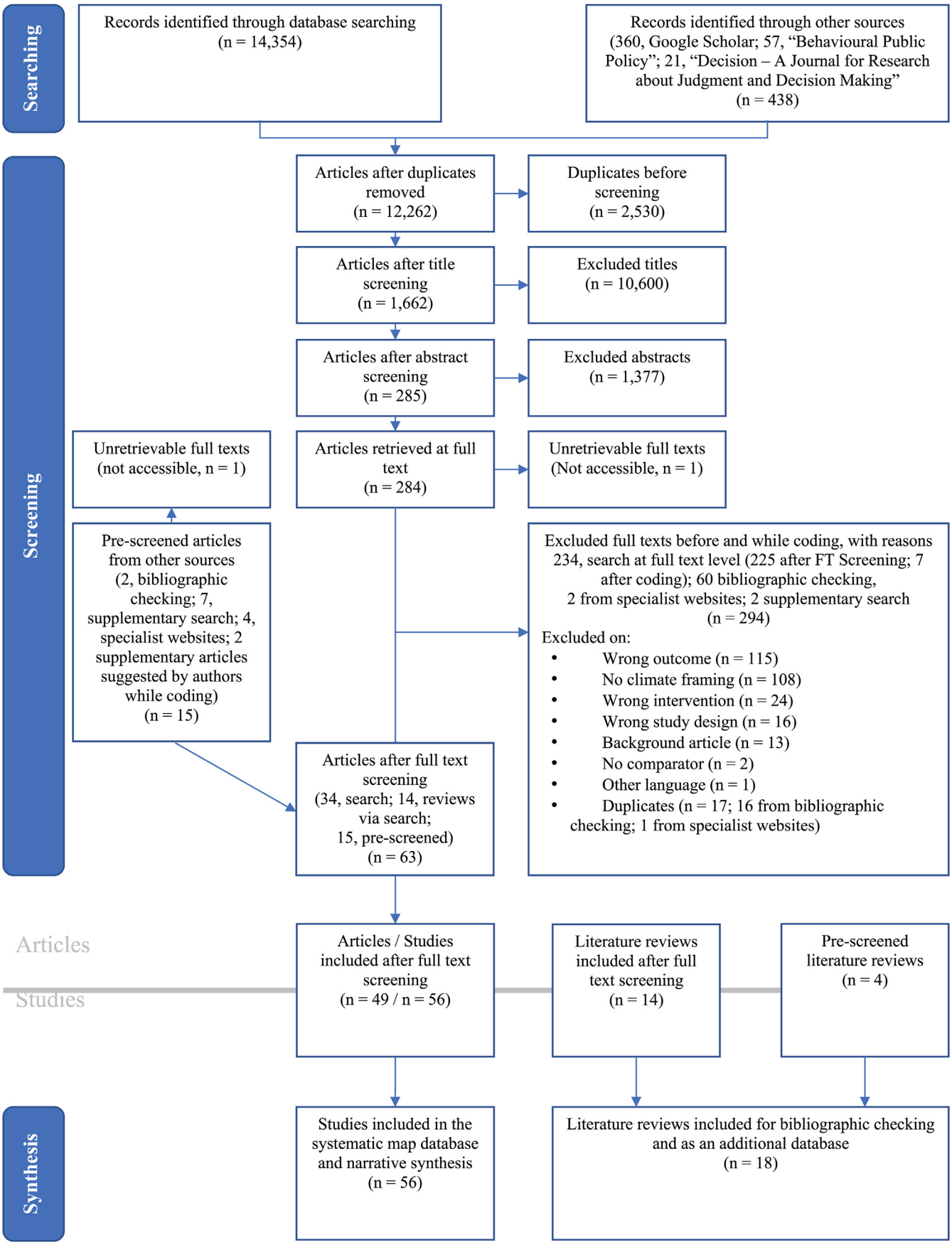

Fig. 2. Flow diagram for systematic maps.

be considered when making eligibility decisions. If there was any doubt about eligibility, the study was included in the next step. If after the screening process the eligibility of certain studies remained unclear, then further information was sought, in some cases directly from the study authors (see also Fig. 2).

2.3.2. Inclusion and exclusion criteria

In general, we aimed to include all types of empirical studies, quantitative and qualitative, using different methods (experimental and others), describing some form of behaviorally informed policy intervention that aims at mitigating climate change and measuring changes in food consumption (animal protein or substitutes) or consumer food waste (and thereby indirectly measuring GHG emissions). While we excluded overview reports, commentaries and conceptual pieces, we collected relevant literature reviews as part of the three-stage screening process in a separate file to be used later for a manual supplementary search we refer to as 'bibliographic checking' (see above).

Specifically, we defined our inclusion and exclusion criteria in line with our so-called PICO-FS elements (CEE, 2018) as described above as well as in Table 3 below.

2.4. Analysis

2.4.1. Metadata extraction

We coded and analyzed full texts using a coding scheme developed iteratively during screening and planning. The coding categories outlined in Supplementary Material 3 were used for extracting relevant metadata, which include descriptive information about the article. The data-extraction form was pretested after screening at the full text level. Moreover, we undertook consistency checks of a subset of 5% of the articles before extracting data to minimize extraction errors and to ensure consistency across reviewers. The coding team discussed all discrepancies in detail.

2.4.2. Coding

In our coding scheme, each line of the extraction form represents one study and not one article (that can contain multiple intervention studies with different observations). As part of extracting data, we made use of supplementary files of the articles and of linked studies if available. If vital information was lacking, we attempted to contact the respective authors directly for clarification. If the relevant information could not be identified, the field was tagged as "unreported". Gap filling (i.e., extracting metadata from other publications describing the same study) was used in one case to retrieve vital information that was not available otherwise. Upon completion of the data extraction, extracted material was double-checked by another author to reduce typographical and other errors.

We have not critically appraised each study for its internal and external validity, since this is not standard practice for systematic maps. However, some of the metadata relevant to study validity has been extracted, and potential future systematic reviews can use this as a basis for full critical appraisal prior to synthesis. Here, following strictly the methodology of systematic mapping, we provide only a basic critical appraisal by extracting general information on study design and experimental procedures relevant to internal and external validity.

3. Results

3.1. Summary of the evidence

Fig. 2 illustrates all steps in evidence identification and screening, along with the numbers of included and excluded studies at different stages of the mapping process. Our search between January 2019 and June 2019 identified in total 14,792 articles, most of which were found by the database search (14,354). After having removed duplicates (2,530), we screened 12,262 unique articles for inclusion according to our defined criteria presented in Table 3. The number of duplicates (2,530) is higher than the difference between records identified through database searching and records after duplicate removal from this search, because we also included duplicates from supplementary searches.

Of the screened articles, we identified 49 that met the inclusion criteria and were subsequently included in the systematic map database. In addition, we found 18 literature reviews, which we included for bibliographic checking and as an additional database (see Supplementary Material 2). The vast majority of the articles are traditional academic articles; only the minority are grey literature and there is one academic book. The 49 articles correspond in total to 56 independent studies. Generally, each article contained one study, but several articles investigated two or more studies. In the systematic map database each row details one study, with each column providing additional metadata, for example the study ID, the bibliographic references, the outcome variable, and the study location (see Supplementary Material 7).

3.2. Key findings of the systematic map

If we look at the publication dates of the studies (Fig. 3), we can see that this is a fairly young research topic, which, however, has attracted great interest in recent years. Up to the year 2010, we found only two studies on this topic overall. Since then, the number of studies has risen markedly, and especially since 2016 there has been a further sharp increase. While between 2010 and 2015 about three studies per year were published, at least nine relevant studies have been published annually on average since 2016. As we have identified six studies for 2019 already in June, it can be assumed that research will continue to grow in the near future.

So far, almost all investigations have been carried out in Europe and North America, with Australia being the only outlier. Fig. 4 shows a map of study locations and illustrates the concentration of research in a few regions of the world – mostly the Anglo-Saxon world and Europe. Specifically, research was conducted in 14 countries worldwide with a strong concentration (about 40% of the studies) carried out in the United States (US) and the UK. In addition, four or more studies were conducted in Belgium, Sweden, Canada, and Germany (more details are provided in Supplementary Material 8). None of our included studies has been conducted in Africa, Asia, or South America.

Regarding sample size, we find considerable variations between the studies, with 18 individuals being the smallest sample and 64,284 households the highest (Fig. 5). In most studies, the sample size does not exceed $n = 5{,}000$, with the majority of the studies with a sample size between $n = 100$ and 500. In the qualitative studies, sample sizes were expectedly lower. Since systematic maps do not include information on effectiveness of the respective intervention, we also do not provide information on effect size and statistical power (which is also rarely provided in the studies we coded).

As this systematic map synthesizes evidence for various behavioral interventions targeting GHG intensive food consumption and food waste, it is interesting to analyze which behavioral interventions are in the focus of research. Fig. 6 shows how often the 13 considered intervention categories have been examined without considering whether the intervention has been combined with other interventions in a study (for a detailed overview of all combinations of the interventions see Supplementary Material 9). Although all interventions considered were investigated in at least

Table 3
Eligibility (PICO-FS).

Screening Criteria	Relevant - included	Irrelevant - excluded	Examples of inclusion
Population	Included are individual consumers, private households and large households (such as public or corporate cafeterias) that consume food (animal protein or substitutes) or that produce food waste.	Excluded are: self-production, cooperatives, and forms of alternative agriculture.	Consumers in a supermarket or restaurant.
Interventions	Included are interventions by public or private (or public-private) actors that use behavioral insight-based policies such as nudges or indirectly by improving *another* policy (e.g., a label) designed on the base of behavioral insights, but only if the effect of the behaviorally informed intervention was reported.	Excluded are: command-and-control regulation, market-based policies such as trading schemes, taxes and subsidies; purely informational and educational interventions that do not make use of behavioral insights.	1) Defaults, 2) Simplification, 3) Use of social norms, 4) Increase in ease and convenience, 5) Disclosure, 6) Warnings, graphic or otherwise, 7) Pre-commitment strategies, 8) Reminders, 9) Eliciting implementation intentions, 10) Informing people of the nature of their own past choices, 11) Priming; 12) Physical or digital micro-environment changes; 13) Other.
Comparator	Included are studies that compare levels of food consumption (animal protein or substitutes) and/or consumer food waste with a) those that did not receive an intervention (control group in an experimental setting), or b) those that received a different intervention, or c) with the level of food consumption and food waste before the intervention was put in place. This might include time series studies that track emissions over time following an intervention.	Excluded are: studies without reported changes in the populations' behavior.	Studies reporting changes on meat consumption after a text message reminder intervention.
Outcomes	Included are studies reporting on changes in actual consumption of animal protein or substitutes and/or consumer food waste. Regarding waste, we did not differentiate between types of food waste, i.e., all types were included.	Excluded are: studies on pre-behavior variables such as values, intentions, attitudes, or willingness to pay; studies on food unrelated to animal protein or food waste from packaging, as well as food waste and losses incurred in the course of production and transportation.	Ideally, the study reports on the reduction in consumption/food waste and what this implies for GHG emissions. Since this was rarely the case, we included "climate framing" as additional screening category.
Framing	Included are studies that use some sort of climate framing, i.e., that embed or motivate the study as contributing to the discourses on climate change, global warming, greenhouse gas emissions (e.g., carbon dioxide/CO2, methane/CH4 or GHG equivalent), sustainable or green consumption or similar.	Excluded are: studies framed as tackling climate change adaptation, water use, pollution; studies motivated to improve public health or social issues – unless combined with climate change; marketing studies with largely commercial purposes (e.g., promoting a climate-friendly product).	Quantitative intervention studies measuring changes in GHG emissions, but also intervention studies targeted at changing food consumption (animal protein or substitutes) and/or consumer food waste in line with our outcome criteria, as long as these refer to climate change, for example by mentioning that the intervention's outcomes help mitigate climate change.
Relevant Study Type	Included are all types of empirical studies that provided primary data, both quantitative (e.g., experimental studies, panel studies, regressions) or qualitative (e.g., self-reports in an interview study). Included (but separated) are all types of academic literature reviews (qualitative, quantitative, systematic, non-systematic, critical/umbrella reviews etc.), serving for completeness checks for our search of core articles.	Excluded are: studies that do not have an empirical design and that do not provide primary data; commentaries, conceptual pieces; studies on other interventions outside our focus; also excluded are overview studies that are not academic literature (e.g., summaries, policy reports).	Experimental studies, panel studies, interview studies, observational studies.

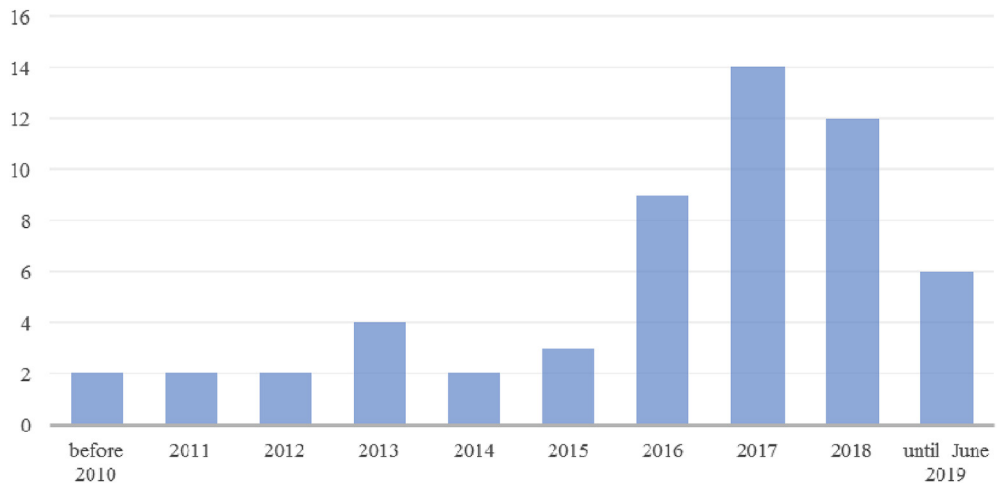

Fig. 3. Year of publication.

Fig. 4. Map of the study locations.
Note: Red dots are specified in terms of city or neighborhood. Grey dots only identify the respective country, region, or continent, such as North America, Scandinavia, and the Baltic states. The map can be found in EviAtlas (www.nudgeforgoodfood.github.io/). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

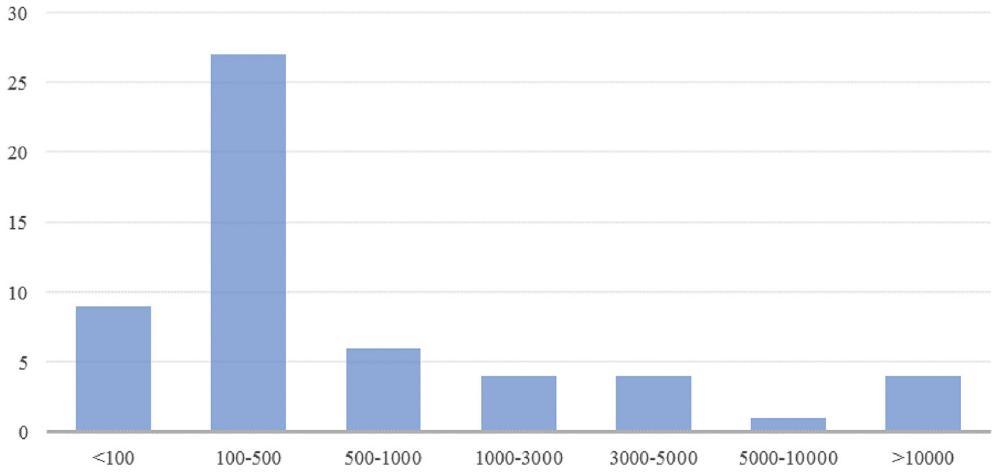

Fig. 5. Sample sizes.
Note: One study is not considered in the figure because of missing information (Spaargaren et al., 2013).

one study, their use differs markedly: The four most frequently analyzed interventions are priming (21 studies), disclosure (17), norms (15), and defaults (15). In contrast, few studies in our search sample have analyzed simplification, intentions, pre-commitment, and past choices.

Often, combinations of several interventions were tested in the studies. Fig. 7 gives an overview of how many interventions were applied in one study. Although there have been many different combinations of interventions, only five out of our 56 studies apply more than three interventions. Most studies analyze either two (24 studies) or three combined interventions (19 studies). Only eight studies solely focus on one intervention; however, only those are able to study the pure effect of a single intervention.

Fig. 8 focuses on the studies that investigate the effects of only one intervention and shows the number of studies per intervention. With three and two studies, respectively, defaults and reminders are the interventions for which there is evidence of the pure effect of the respective intervention, since they are focusing only on one specific intervention instead of combining several ones. None of our included studies focused exclusively on the interventions of pre-commitment, simplification, ease, disclosure, warnings, past choices, priming, and micro-environment change.

Regarding outcome, 36 studies solely focus on food consumption, while 18 studies investigate the effects of behavioral interventions on food waste (Fig. 9). Two studies analyse both outcome variables, i.e., the impact on food consumption and the amount of waste (Lorenz-Walther et al., 2019; Reid et al., 2009).

Fig. 10 shows the outcome mode of the included studies, i.e., whether the outcome variable considered is actual behavior, self-reported actual behavior, or a hypothetical decision.

Regarding the food consumption studies, we noticed that while there are several studies on meat and meat products, there is little

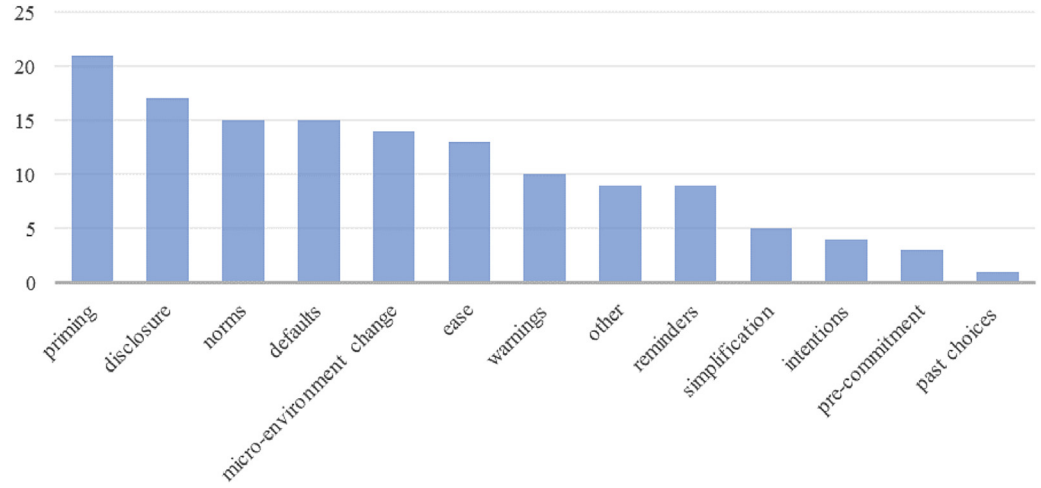

Fig. 6. Interventions: number of studies per intervention.
Note: Number of interventions used in total.

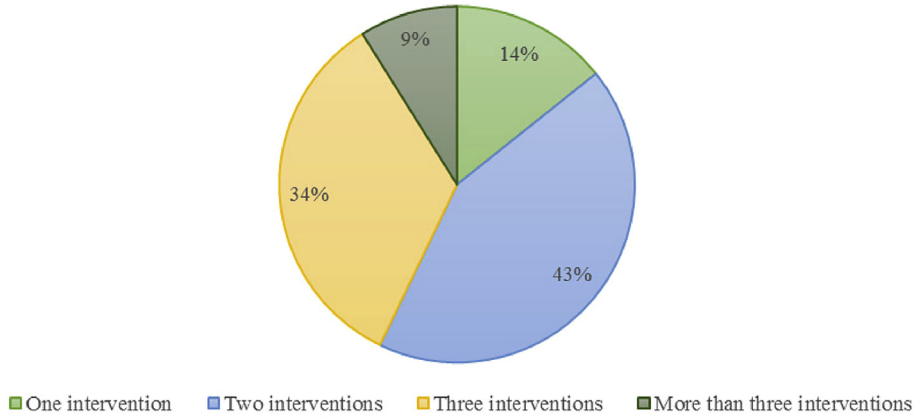

Fig. 7. Number of interventions used in one study.

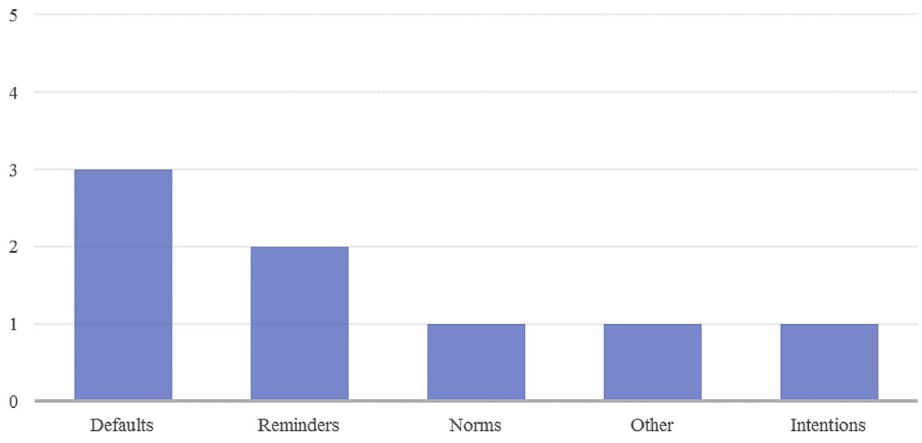

Fig. 8. Number of studies focusing only on one intervention.
Note: Only studies (n = 8) that focus on one intervention alone.

research on dairy products. Fig. 11 illustrates that there is not a single study solely focused on dairy products, and only a few studies (18%) that include dairy products (equally, fish and eggs were targeted so little that we excluded them from the results analysis).

Fig. 12 demonstrates the relationship between interventions and outcomes. It illustrates which interventions have been mostly used to steer food consumption and which ones to change food waste behavior. There are considerable differences between the interventions. With 15 studies overall, the use of social norms is

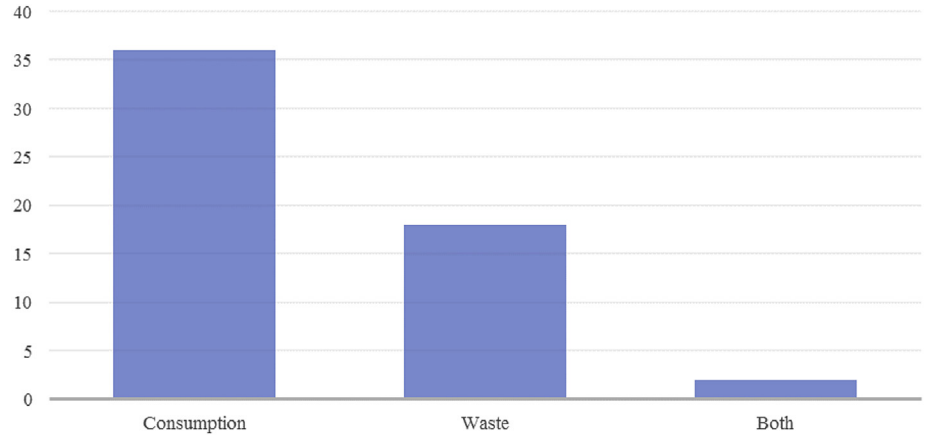

Fig. 9. Number of outcomes.

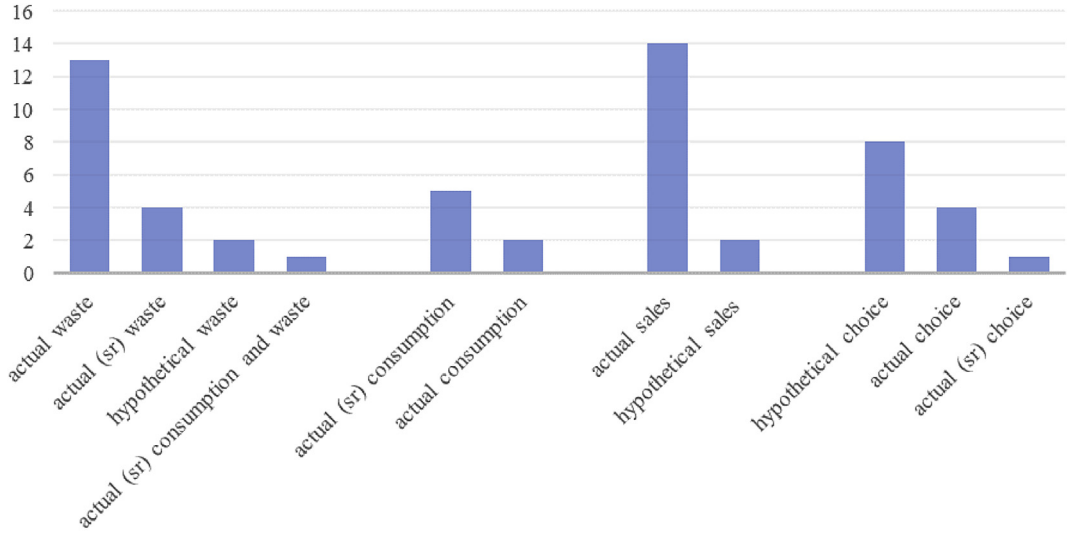

Fig. 10. Outcome mode.
Note: Outcome mode grouped by outcome.
sr: self-reported.

among the most frequent interventions triggering behavioral change. Interestingly, social norms are rarely used to influence food consumption, but are frequently applied to change food waste behavior.

4. Discussion

4.1. Review of results and suggestions for further analysis

The aim of this systematic map was to find and collate evidence on the use of behavioral informed policies in the form of interventions aiming at steering individual's food choice towards less animal protein heavy diets as well as towards changing food waste behavior. Both behaviors – consuming less animal protein and wasting less food – have been singled out as important policy areas for demand-side climate change mitigation. After having presented the key results in Section 3, we now discuss these findings in more detail and add limitations to our approach.

4.1.1. Quality of studies

Due to very specific inclusion criteria, we identified 49 relevant articles including 56 separate studies. In addition, we identified 18 literature reviews relevant to our research topic. Recall that by far the most of these publications are peer-reviewed work; very few are grey literature. Moreover, most of the quantitative studies use quite a substantial sample size (on average 100–500). As can be seen in the Supplementary Material 7, many studies are canteen studies that took place in universities with student samples. Due to this specific environment and specific sample type, external validity of the results of those studies might be limited. Yet, there is also a substantial group of studies with restaurant customers, retail shoppers, individual and large households. While we cannot say anything about the statistical power of the studies (which is typically not accounted for in systematic maps) the general impression is that overall, the design of many of the studies is of high quality. One reason for the relatively high quality might be that most studies have been published in recent years.

The publication dates of the articles span ten years, with a very strong recent increase of published studies after 2016. This is a finding in line with other policy areas where behavioral informed regulation is increasingly applied and investigated, with a marked increase in the mid 2010 years (Hummel and Maedche, 2019) and

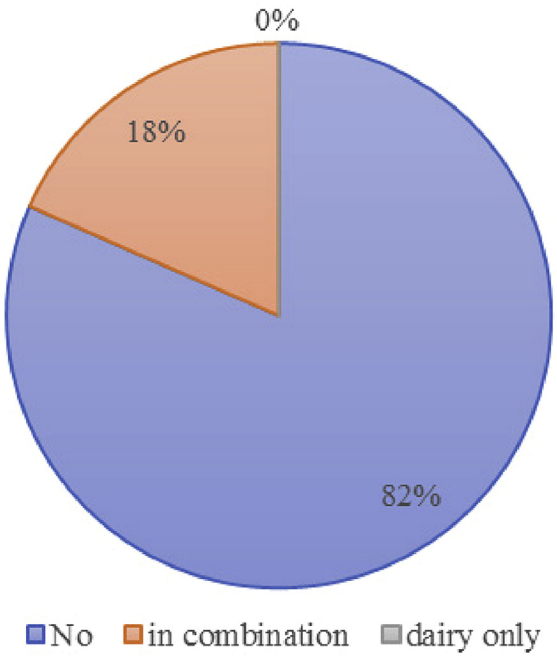

Fig. 11. Studies addressing changes in food consumption with a focus on dairy products.
Note: 100% are all food consumption studies (n = 38).

almost no studies before 2008 (Thaler and Sunstein, 2008).

4.1.2. Geographical spread of research

Regarding location of studies and research groups, we found an unsurprising concentration in the Anglo-Saxon world (the US, the UK, Canada) where Behavioral Public Policy has been implemented first and plays a large role in today's policy making. We also find some active research groups in the nudge-friendly Nordic countries Sweden and Norway as well as in Germany, Belgium, and Italy. Almost all of these countries have or had a government with strong interest in Behavioral Public Policy (OECD, 2017). Moreover, in most of these countries, meat consumption has been on the climate policy agenda for a while (see e.g., FAO n.d.). Also, it is quite intuitive that study countries are clustered in the wealthy "Global North" (including South America and Australia) where consumers factually consume lots of animal protein in general and red meat in specific (OECD & FAO, 2018). In the "Global South" with a largely plant-based diet, the societal and nutritional issues are simply different and rather focus on malnutrition. Too much meat is an issue for the local elites, only.

However, recent statistics (OECD, 2020) suggest that meat demand and animal protein consumption is dramatically increasing in the BRICS countries, particularly in China. Even in India, there are signs of increasing meat consumption driven by an increasingly affluent middle class. The sheer volume of additional meat demand stemming from the two most populated countries of the world is likely to have a serious adverse effect on greenhouse gas emissions. Hence, it would be most interesting and relevant to see more of this type of research in and on these two countries. While public approval of health and environmental nudges overall seems to be quite high in most of the world - and particularly high in China (Sunstein and Reisch, 2019) – it would be valuable to investigate the possibility of cultural differences with respect to the impact (and hence cost-effectiveness) of behavioral policies in countries worldwide. India is recently focusing on the use of behavioral insights for various policy goals, including sustainability, and its policies will undoubtedly reflect distinctly Indian culture and policy priorities (Government of India, 2020).

Following the methodological standards of systematic maps, we did not look into the effectiveness of the described interventions; hence, an especially valuable next step would be to study the effectiveness of the interventions in a systematic review or meta-analysis. One focus could be on defaults, since it is generally believed that default rules are especially effective in the environmental setting (Sunstein and Reisch, 2014). A more general call would be to intensify research in those countries where meat consumption is now increasing with their growing middle classes.

4.1.3. Study designs

Only eight studies focused on one type of intervention, most of the studies combined two or even three types of behavioral interventions. However, to investigate the pure effect (and effect size) of a specific intervention, more studies with single interventions would be welcome to provide a better evidence base for policy-makers. This conclusion is in line with reviews on other areas in which behavioral interventions have been applied for climate change mitigation (see for energy conservation, e.g., Andor and

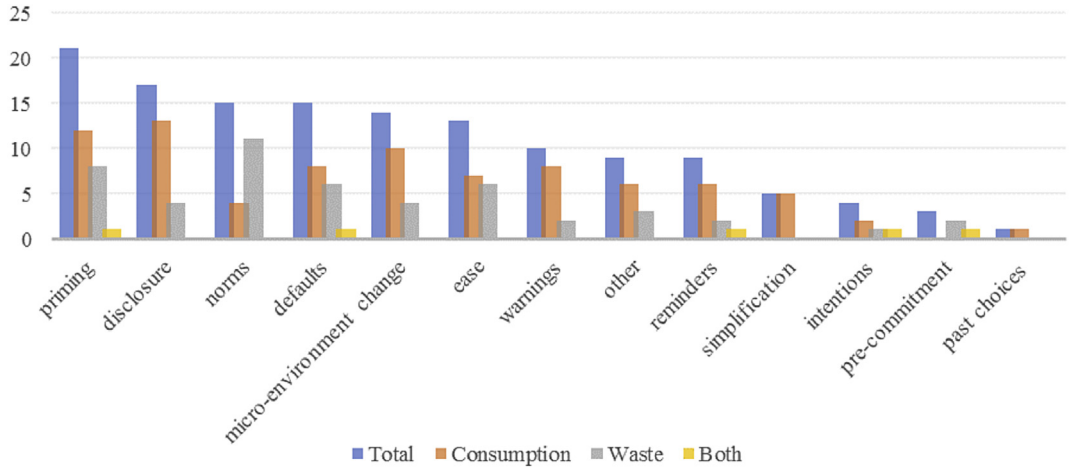

Fig. 12. Number of studies per intervention and their outcome.
Note: For example, priming was used 21 times in all of the studies. Twelve priming studies focused on the outcome food consumption, eight on food waste, and one study focused on both outcomes.

Fels, 2018). Also, from a research perspective, multi-intervention studies often bear the risk of unintended (and unchecked) spill-over effects between the interventions. Singling out interventions might seem a rather artificial academic exercise, but it would have a great deal of practical relevance.

Regarding intervention type, there is a clear focus on a few widely used and much debated nudges: priming (21 studies), disclosure (17), social norms (15), defaults (15), micro-environment change (14), and ease (13) are studied most often. Interestingly, social norms are rarely used to influence food consumption, but are frequently applied to nudge food waste behavior. The growing evidence clusters developing around these interventions seem to be potential candidates for future systematic reviews analysing their effectiveness. Then, there is a second group of almost equally often applied nudges consisting of warnings and reminders. The last group - implementation intentions, pre-commitment, simplification, and past choices - was studied much less as regards animal protein consumption and food waste. Much more empirical evidence is needed for these interventions before conducting a systematic review that could inform future policy making.

4.1.4. Reported outcome types

Regarding the outcome of the intervention, most studies (n = 36) solely focus on consumption behavior, much fewer on waste (n = 18), and only two consider both. Most studies observe the effects on actual behavior, either directly measured (mostly in field experiments) or self-reported. This adds to the relevance of this research since real behavior tends to be much more reliable than hypothetical decisions; in other consumption areas, the latter constitutes the majority of studies (e.g., Andor and Fels, 2018 for energy labelling). What is striking is the scarcity of studies that focus on dairy, but also on fish and eggs. The strong majority of studies look at different types of meat or their plant-based substitutes. We can only speculate why. One possibility is that meat consumption and production have several negative impacts besides the climate effect, most prominently on animal rights and animal welfare (e.g., cattle transport to the slaughterhouses) as well as human health. Consumption of (red and processed) meat has been correlated with developing certain types of cancer (Bouvard et al., 2015), dairy much less so. Moreover, in the communication towards consumers, it seems easier and more promising to advocate a reduction of meat consumption than reducing dairy. Dairy products seem to be difficult to replace from a nutritional point of view (Fulgoni et al., 2011), and one could also speculate that because people start consuming these foods in infancy, the taste preference is deeply ingrained. However, due to the emission reduction potential of decreasing dairy consumption (e.g., Poore and Nemecek, 2018), this field should receive more attention in research and policy practice.

4.2. Limitations of the methodology and the searches

Systematic maps are useful to compile an overview over the knowledge gaps and cluster in a specific field of research by providing an evidence synthesis related to a particular research question. They are particularly valuable due to their broad approach that allows including different types of interventions, multiple outcomes, and multiple study types – both quantitative and qualitative (McKinnon et al., 2015). They are also particularly well suited to minimize publication bias, since also studies with null results and grey literature are included. Yet, they do not – by design and intention – provide an assessment of a specific intervention's effectiveness and cost-effectiveness. In practice, the latter is, however, a key indicator and important guide for policy makers. Hence, a systematic map can serve as the first step to identify those knowledge clusters that are ready for systematic reviews and meta-analyses (and hence, estimates on effectiveness) and those areas that deserve more research attention before a further synthesis in form of systematic reviews could be insightful.

Another feature that readers might find missing is a critical appraisal of each individual study. However, as explained above, this is not a common standard for systematic maps. Readers interested in the individual studies are welcome to dig deeper into the supplementary online materials that contain a wealth of data not reported in the text.

As only articles in English and German were included, we cannot exclude a bias to those studies from English or German speaking countries. While titles and abstracts of publications in other languages are often published in English, including more languages might have helped to find more studies from regions other than Europe and Anglo-Saxon countries (see Fig. 4) and thus increased the accuracy of our map. However, limited time and funding meant that we had to limit ourselves to the languages we speak as mother tongue (a limitation that is also common for systematic maps and reviews, see e.g. Cresswell et al., 2018). We therefore acknowledge a certain risk of evidence omission. Moreover, the comparator element of the PICO–F criteria has led to the exclusion of certain study types, particularly more qualitative research, which might have limited the breadth of our search. Also, in many cases, the GHG emissions were not provided or quantified as direct outcome, but we had to use the existence of an explicit climate or environment frame as substitute.

Finally, we focused on studies with a climate or environment frame and thus did not include studies that analyzed the effect of the considered behavioral interventions on food consumption or food waste solely due to other motivations, for example, a healthy diet or animal welfare. Yet, those studies could also reveal interesting information as the motivation to apply an intervention does not necessarily have an influence on the effect. Therefore, we would like to recommend researchers and policymakers interested in one specific intervention to review these other strands of the literature in addition to our systematic map.

5. Conclusions

This systematic map identified and coded 49 articles that could answer our key research question: "Which behaviorally informed demand-side interventions and demand-side policies have been implemented and studied that target individual consumers as well as private and large households with the aim to reduce their GHG emissions resulting from food (animal protein and substitutes) consumption and consumer food waste?"

5.1. Implications for research

As outlined above, the map identified knowledge clusters amenable to full synthesis via systematic review, namely the six well-studied intervention types: priming, disclosure, defaults, social norms, micro-environment change, and ease. A review of the study findings from the articles in this map could promote the understanding of many issues, above all the effectiveness of these nudges. It is recommended that more primary research is undertaken on the less well-studied interventions as well as on interventions to reduce food waste beyond social norms. The research should aim to test those interventions that have hardly been applied, to develop the evidence base for full appraisal.

It would be valuable to test individual interventions to obtain more clarity on their effectiveness. Unfortunately, 70% of the studies combine two or three nudge interventions. More attention should be given to the intended and unintended spill-over and

side-effects of the combinations. Related, research on how to design effective combinations of nudges might be useful. Finally, more primary research in and on countries that are currently increasing their animal protein demand (mainly China and India), published in an internationally accessible language such as English, are recommended. Ideally, such studies should be conducted by interdisciplinary and international research teams.

5.2. Implications for policy

Today, systematic maps are accepted as being useful for decision-makers (Haddaway et al., 2016): first, they highlight knowledge gaps, where more primary research is needed and evidence cannot support policy; second, maps identify knowledge clusters, where sufficient studies exist but there is a lack of clarity over effectiveness, and so full synthesis can be conducted rapidly by taking studies directly from the map into quantitative/qualitative synthesis; and third, they show patterns in research methods that can highlight best practices and issues with methodology that can support the improvement of primary evidence production and mitigation of research waste. The present mapping study shows all three benefits.

In light of substantial effects in multiple domains of public policy, behaviorally informed approaches have a great deal of promise for reducing greenhouse gas emissions in connection with food consumption and food waste. The evidence collated in this map could ultimately inform policymakers and retailers, as well as those responsible for canteens and large households, on the design of food choice architectures favouring a diet with less animal protein and less food waste. While the efficacy, welfare effects (cost-benefit analysis), and cost-effectiveness of the different interventions were not investigated in our study, the breadth of approaches, and at least some of the outcomes, suggest that behaviorally informed policies are highly promising in this domain.

It might be useful to note that the policies mapped in the present study seem to be more acceptable and easier to implement than more robust policy measures, such as taxes or bans (Sunstein and Reisch, 2019). Closing the research gaps and extending this type of research particularly to other parts of the world is a worthwhile investment.

To date, the pressure to act quickly upon climate change is growing sharply, and food consumption and waste are in the spotlight. There is increasing agreement that one answer is to steer the food system in general and animal protein consumption in specific into more sustainable pathways (Allievi et al., 2015). With the tailwind of the youth climate movement and a new appreciation of resilient food systems in the light of the current pandemic, there might be a window of opportunity for evidence-based policy.

Data availability

The data that support the findings of this study are included within the supplementary information.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.123717.

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