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Systems thinking for local food environments: a participatory approach identifying leverage points and actions for healthy and sustainable transformations

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Abstract

Background Current local food environments encourage poor diets, posing a significant threat to public and planetary health. Acknowledging and addressing its inherent complexity is vital to making meaningful improvements to the food environment. Using a participatory approach with local stakeholders, this study aims to gain insight into the factors and mechanisms underlying the local food environment and to identify leverage points and system-based actions to foster healthy and sustainable local food environments.

Methods A systems-thinking approach was used in a Dutch municipality in 2022. Two group model building (GMB) workshops were held with community stakeholders (e.g. local policymakers, retailers and residents). During the first workshop (June 2022), factors and mechanisms influencing the local food environment were identified and visualized through a causal loop diagram (CLD). During the second workshop, leverage points and system-based actions to improve food environments were identified by the stakeholders. Four months after (October 2022), an action-implementation meeting was organized to stimulate the implementation of selected actions. Progress was monitored through brief telephone interviews 6 and 12 months after the second workshop.

Results The CLD visualises the factors and mechanisms influencing the local food environment from the point of view of the community stakeholders. The CLD consists of 46 factors shaping the local food environment, which were categorized into four identified subsystems: societal factors, individual, socio-economic factors, commercial factors and political factors. Eight leverage points were identified within the CLD, for example, 'lobby from food industry', 'governmental food policies' and 'e-commerce and platform economy'. Stakeholders formulated 20 actions targeting the identified leverage points. During the action-implementation meeting, long-term plans were created for five actions. After 1 year, only one participant (policy advisory role) remained actively engaged in three of these actions.

Conclusions This study yields insight into the numerous factors and mechanisms underlying the local food environment and identified system-based actions as perceived by local stakeholders to improve this food environment locally. The CLD offers stakeholders valuable insights on employing a systems approach when enhancing food environments. More research is necessary, especially into the long-term processes and effects of implementing system-oriented actions to improve local food environments.

Keywords Local food environment, Group model building, Health, Systems thinking, Complex

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Background

Over the last decades, food consumption patterns changed in parallel with changes in the (local) food environment [1]. Contemporary local food environments are characterized by the omnipresence of attractive, cheap, energy-dense, and nutrient-poor foods [2]. Such food environments stimulate unhealthy and unsustainable food choices that pose a threat to human and planetary health [2–5]. This builds upon socio-ecological theory and the recognition that food consumption is determined by contextual and environmental factors, including the local food environment [6]. Citizens interact with their local food environment daily where physical (e.g. food presence), economic (e.g. food prices), political (e.g. food regulations) or sociocultural (e.g. food culture) factors shape citizen food choices both directly and indirectly [7]. Via multiple interconnected factors, the local food environment shapes individual food- accessibility, availability, affordability and acceptability, affecting their food consumption and health [8]. The food environment itself is also considered a complex adaptive system due to the multitude of stakeholders and the dynamic influencing factors underlying it [9, 10]. If food environment interventions continue to be developed and implemented without acknowledging these underlying complex dynamics, programs and policies risk targeting the ‘wrong levers’ of the food environment or even yield negative unplanned consequences [9]. Thus, to improve (local) food environments, academics have called for more complex approaches [5, 10–12].

A way to address this complexity in planning programs and policies is through systems thinking, which emphasizes the importance of understanding the factors and mechanisms that shape the local food environment, before formulating actions for change [8, 9], and researchers may engage with local stakeholders who use and influence the system at hand [13, 14]. Municipalities can engage diverse stakeholders [15, 16] shaping the local food environment [17, 18], making municipalities promising settings to improve food environments [15], with some already beginning to prioritize this on their agenda [19]. However, insights into effective ways to improve the local food environment through systems thinking and in collaboration with local stakeholders is lacking [15].

Group model building (GMB) is a participatory method for engaging community stakeholders in the process of understanding and changing systems [13]. The method integrates a variety of exercises that are based on principles of systems thinking, which involves stakeholders in the visualisation of a system, identification of potential leverage points and development of effective and long-lasting solutions for system change [13]. GMB is a distinctive and valuable method in public health research.

GMB has successfully been used to engage local stakeholders in systems thinking to understand and address complex and dynamic causes of health behaviours and outcomes [9, 20–23]. It has also been used to mobilize action in the field of public health [21]. Its participatory design enables stakeholders to collaboratively identify and mobilize action, fostering a deeper understanding and more impactful interventions [21, 24–26]. One of the main benefits of GMB is its strong focus on stakeholder engagement. GMB actively involves stakeholders, ensuring that diverse perspectives are considered, which can lead to more holistic and sustainable solutions. Furthermore, GMB facilitates a systems thinking approach, allowing for the identification of complex inter-dependencies and leverage points within the food environment. Additionally, the method is action-oriented, often resulting in tangible plans and strategies that stakeholders are committed to implementing.

Despite its proven efficacy in other public health domains [21, 27–29] GMB has been underutilized in the context of systems thinking to improve (local) food environments, even as the literature increasingly calls for this application [9, 10]. Applying GMB to understand and improve food environments offers significant opportunities, given the complex and multifaceted nature of the local food environment and GMB’s ability to incorporate multiple viewpoints and to foster collaboration of stakeholders. We assume that insights gained from GMB can specifically address the local food environment in Veenendaal, enhancing the applicability and impact of the systems approach.

Therefore, using a GMB approach with local stakeholders, this study aims to gain insight into the perceived factors and mechanisms underlying the local food environment and to identify potential leverage points and system-based actions for healthy and sustainable local food environments.

Methods

Study design

This study used GMB to engage a broad group of local stakeholders in systems thinking towards healthy and sustainable local food environments during two GMB workshops (June 2022), an action-implementation meeting (October 2022) and an external member-check meeting (November 2022). All workshops and meetings were designed and organized by the research team. Before the GMB workshops, two sessions were held with residents to determine their perspective on the local food environment (outcomes not reported) and to invite two residents who were willing to represent their shared perspectives during the GMB workshops.

All participants were 18 years or older and provided written informed consent for the study. Ethical approval was granted by the Wageningen University and Research Social Sciences Ethics Committee on 8 July 2021. The STROBE checklist was completed for this study (Additional file 1) [30].

Setting

This study took place in the municipality of Veenendaal, the Netherlands. Veenendaal had 67 671 inhabitants in 2022 [31]. A total of 49.1% of its residents aged 18–64 had overweight or obesity in 2020 [32], which corresponds to the country's average. Also, 81% were native Dutch, while 13% had a non-Western migration background and 6% had a Western migration background [33].

As part of the local prevention agreement of Veenendaal [34], the municipality aimed to enhance its local food environment and integrated the present study to support this goal. As a result, the municipality actively participated in the planning, recruitment and organisation of the workshops and allocated time, budget, and materials for the workshops and future implementation of actions [34].

Study procedure and participant recruitment

GMB workshops

To enhance active participation and sufficient interaction between participants, we aimed for 5–17 participants per workshop [13]. Local stakeholders were recruited for the GMB workshops through purposive sampling, via an email from the municipality. Additionally, one of the researchers (T.W.) and a resident personally invited food outlet managers in the centre of Veenendaal. They called those located outside the city centre. Two participants from the residents' sessions volunteered to participate in the GMB workshops. GMB participants were compensated financially for their time. All activities performed during the two GMB workshops were either based on existing GMB scripts, publicly available on the Scriptape-dia website [35, 36] or based on our own scripts, which we developed in advance (Table 1).

The first GMB workshop aimed to gain insight into the factors and mechanisms underlying the healthiness and sustainability of the local food environment using existing GMB exercises (Table 1). For this workshop, each member of the research team had specific tasks, as described in the GMB literature [13]. The tasks were distributed as follows: facilitators (M.P. and C.D.), physical wall builder (M.P.), digital wall builder (T.W.), note takers (F.R. and L.G.) and timekeeper (T.W.). The Systems Thinking In Community Knowledge Exchange (STICKE) software [37, 38] was used to build the CLD during the

GMB workshops, and the CLD was later replicated in the Vensim software [39].

The second GMB workshop aimed to verify and finalize the leverage points and to formulate system-based actions for change, also based on existing (GMB) exercises (Table 1). For workshop 2, the tasks were: facilitators (M.P. and C.D.), modellers (C.D. and T.W.), wall builder (M.P.), note takers (F.R. and J.W.) and timekeeper (T.W.). For both GMB sessions, a municipal stakeholder was the gatekeeper, welcoming everyone at the start of the session.

After the second workshop, the research team grouped the developed actions to improve the local food environment into levels according to the action scales model (ASM) [40]. This model distinguishes four interconnected systems levels, including events, structures, goals and beliefs. Each of these levels influences the way the system operates and its main outcome. Actions targeted at deeper levels (goals or beliefs), hold greater potential to change the functioning of a system. By understanding which systems levels are being addressed by the actions, stakeholders can better assess the scope and scale of changes that are needed to implement these actions [40]. Table 1 describes the scripts used for both GMB workshops and preparatory meetings of the research team.

External member-check meeting

Shortly after the GMB workshops, an external member-check meeting was held with policy stakeholders from the region to verify whether the CLD was clear and complete. The meeting was organized as part of a regular bi-annual meeting between different policy stakeholders involved in health and nutrition in the region. Two researchers (F.R. and M.P.) were present during this meeting. Table 1 describes the scripts used for the meeting.

CLD development

The creation of the CLD was a participatory and iterative process, involving all participating local stakeholders and the research team. Based on the outcomes from the GMB workshops, insights from the external member-check meeting, and evaluations of the research team, a CLD visualizing the factors and mechanisms underlying the local food environment from the point of view of the local stakeholders was developed (Table 1). This included the development of factors, connections and feedback loops within the CLD. Besides, the research team identified subsystems within the CLD, based on clusters of factors that were linked (i.e. through feedback loops) and that represented a common larger theme.

Table 1 Description of scripts for GMB workshops, stakeholder and implementation meetings, and preparatory work

Workshop/meeting/preparatory work	Scriptapedia script title or own script	Aim of script	Adaptations to Scriptapedia script or description of own-script activities
GMB session 1	Own-script	To create a safe space and explain the main terms and goals of the session	Opening, introduction round, presentation: overweight/obesity and role of food environment, residents shared their perspectives of and their vision for local food environment, presentation: systems dynamics, goal of session n/a
	'Hopes and fears'	To determine group expectations for a GMB session at the start of a project	
	'Graphs over time'	To engage participants in a GMB session by framing the problem, initiating mapping, eliciting variables, and gathering input to decide the reference modes for the model to be built	Group size adapted: maximum 4 people per group from different stakeholder groups, to encourage active participation Factors were written on post-its rather than displaying the graphs over time on the wall, to save time
	'Building a causal loop diagram with paper'	To capture the variables and causal structures that arise during a participant discussion early in the GMB process, before any structures or diagrams have been made. This script was used concurrently with the 'graphs over time' script or any discussion during which participants talk about relationships within the system	All factors placed in a large circle on the board. Group was asked, factor per factor, for positive or negative connections between factors Exercise replicated at the same time in Systems Thinking In Community Knowledge Exchange (STICKE) software by digital wall builder
Preparation between GMB 1 and GMB 2	'Next steps and closing'	To identify next steps and close the GMB session	n/a
	Own-script	To complete the CLD based on discussions from GMB 1	CLD completed by research team based on written notes from the session; using STICKE software. Only variables directly influencing local food environment were included in the CLD. Variables considered as part of the food environment were excluded
	Own script	To identify subsystems and leverage points	Based on results and notes from GMB 1, subsystems and leverage points identified by each researcher, then discussed with the team until consensus was reached

Table 1 (continued)

Workshop/meeting/preparatory work	Scriptapedia script title or own script	Aim of script	Adaptations to Scriptapedia script or description of own-script activities
GMB session 2	'Transferring group ownership from one image to another'	To show the group how insights from the first session were incorporated into the CLD, and obtain their feedback on the CLD completed by the research team	CLD projected on screen and printed for each participant
	'Places to intervene'	To identify potential leverage points in the CLD to generate change	Leverage points (identified by the research team) presented to participants. Feedback asked, and adaptations made after consensus was reached among participants
	'Action ideas'	To identify action ideas for system change (in this case, to improve local food environments), and to prioritize them along a matrix according to how easy or hard they are to achieve and how much impact they would yield	Group size modified: maximum 4 participants (from different stakeholder groups) to encourage active participation Action scale model (ASM) presented to participants and used to ensure actions target various levels of the system (Nobles et al., 2021) Matrix exercise not done during the workshop but incorporated in questionnaire sent to stakeholders to prepare action-implementation meeting
	'Next steps and closing'	To identify next steps and close the GMB session	Research team asked permission to contact all participants for an action-implementation meeting, focusing on developing and implementing the actions
Preparation between GMB 2 and external member-check meeting	Own script	Completing CLD after GMB 2	Researchers (T.W., F.R., M.P., J.W. and C.D.) completed the CLD based on feedback obtained from participants during the first GMB exercise of GMB 2
External member-check meeting	Own script	Checking CLD with policy stakeholders from other municipalities	Stakeholders checked the content of the CLD for accuracy and validity in their municipality individually. CLD modified based on discussions with participants, until consensus was reached

Table 1 (continued)

Workshop/meeting/preparatory work	Scriptapedia script title or own script	Aim of script	Adaptations to Scriptapedia script or description of own-script activities
Preparation between external member-check meeting and action-implementation meeting	Own script	Create list of participants for action-implementation meeting	Two researchers (T.W. and F.R.) together with two local policy advisors from the municipality, made a list of local stakeholders needed to implement all actions formulated during GMB workshop 2
Own script	Select actions to further work on and to implement in Veenendaal based on feasibility and urgency	Participants (from the list described above and prior GMB workshops) were sent an invitation for the action-implementation meeting and an online survey in which they were asked to select their top three actions that are most urgent and feasible to implement. Based on this selection, and the stakeholder groups that had not filled in the questionnaire but registered to attend the meeting, two researchers (T.W. and F.R.) identified eight actions most feasible and urgent and divided these over three working groups. The researchers took into account the different levels of the ASM (Nobles et al., 2021) and grouped related actions	
Action-implementation meeting	Own-script	To facilitate and accelerate the implementation of actions by relevant community stakeholders	Participants divided over three working groups ($n = 5-7$). Each group formulated action plans and outcome objectives short- (3 and 6 months), medium- (1 year) and long-term (5 years) and engaged in discussions about potential barriers and strategies to overcome them. After this first round, participants changed groups to exchange feedback on the work proposed by the other working groups. After this feedback round, all participants reconvened with their original working group and adjusted their plans where necessary. Each working group selected a group representative, based on their network, interests and availability

Action-implementation meeting

Four months after the two GMB workshops, an action-implementation meeting was held to encourage the local stakeholders to select and work on the implementation of actions. The participants were sent an invitation by email. These consisted of all participants of the GMB workshops and stakeholders needed to implement all actions formulated during GMB workshop 2. When participants could not attend, they were asked to send a colleague. Four researchers were present during this meeting (F.R., M.P., T.W. and W.H.). Table 1 describes the scripts used for this meeting.

Follow-up on implementation of actions

Six and 12 months after the second GMB workshop, one researcher (T.W.) invited the representatives of the working groups from the action-implementation meeting for a brief telephone interview (20-30 min). One invitation, followed by a reminder invitation 1 week later, was sent by email. During the interview, progress, facilitators and barriers shared by the group representatives were evaluated, addressing three key features for the successful implementation of public health interventions using systems thinking [14]. These include that it is essential to have a 'guide' with the right knowledge and network, a wide group of stakeholders to collaborate with for the implementation of actions and the ability to respond to changes in the local and national context to strategically push the system in the desired direction [14].

Results

Participants

13 community members participated in the first GMB workshop and 12 in the second one. A total of 18 community members attended the action-implementation meeting, of which 6 people had not attended prior GMB workshops but had colleagues who did (due to time restrictions or new jobs) (Table 2). A total of 13 policy stakeholders, including local policy advisors and regional programme managers, attended the external member-check meeting.

Causal loop diagram

Figure 1 shows the final CLD illustrating 46 factors and mechanisms that were perceived to shape a healthy and sustainable local food environment. The research team identified four interrelated subsystems that represent a common larger theme, which are represented by distinct colours in Fig. 1, including (1) societal factors; (2) individual/, socio-economic factors; (3) commercial factors; and (4) political factors. Nine key reinforcing feedback loops were identified within or across these subsystems (represented with an 'R' in Fig. 1, followed by a number).

Societal factors

The first identified subsystem addresses societal factors that were perceived to underlay the local food environment, including aspects such as globalization of the food chain, decreasing prevalence of traditional eating moments and digitalization (Fig. 1).

The participants noticed that modern consumers dedicate less time to preparing and eating meals and prefer convenient and ready-made meals: "Compared to 5 years ago, people are increasingly buying ready-made meals, and often opting for take-out options" (retailer) Participants discussed how the increased consumption of convenient and ready-made meals could be attributed to their greater availability, which allows people to spend less time to prepare and consume a meal: "You also fill up [your agenda] completely. If you knew that [food cannot be obtained so quickly, easily, and at any time] then you would not do that" (retailer).

Next, participants discussed that the increased consumption of convenient and ready-made meals can also be explained by a general lack of time, which has to do with a decrease in traditional working hours and society's 24/7 economy. The 24/7 economy was also perceived as contributing to a decline in traditional eating moments, resulting in people spending less time on their meals. Consequently, there is a growing desire for meals that are easy to prepare and consume (R1, Fig. 1). Participants also discussed how the increased consumer demand for ready-made meals boosts the e-commerce and platform economy but the other way around: a larger e-commerce and platform economy boosts the demand for convenience and ready-made meals (R2, Fig. 1). Additionally, the increasing e-commerce and platform economy, feed back into the growing 24/7 economy, closing R1 (Fig. 1).

Individual, socio-economic factors

The second identified subsystem revolves around individual, socio-economic factors that, according to the participants, create consumer demand that shape local food environments, including factors such as culture, skills, affordability and social norms (Fig. 1).

Participants discussed the role of healthy/sustainable food in today's society, with a focus on social norms and the affordability of food. They argued that eating unhealthy food is often the norm, especially during social gatherings. Participants also discussed how this norm could be reversed through increased knowledge and skills, or by talking more about healthy food to raise awareness: "It is quite hip to talk about food, and the extent to which people think about food also contributes to shaping the social norm" (retailer). The participants hypothesized that if healthy/sustainable food were to become the norm, consumers would be more conscious

Table 2 Description of participants of the group model building (GMB) workshops and action-implementation meeting

Sector	Role	Sex	Attended GMB workshop 1	Attended GMB workshop 2	Attended action-implementation meeting
Community	Resident	F	X	X	
Community	Resident	F	X	X	
Community	Resident	F	X		
Health promotion	Dietitian	F		X	X
Health promotion	Lifestyle coach	M		X	
Health promotion	Lifestyle coach	F	X	X	X
Health promotion	Sports coach	M	X		
Health promotion	Sports coach	M	X	X	
Municipality	Policy advisor	M		X	
Municipality	Policy advisor	M	X	X	
Retail	Restaurant manager and owner	M	X	X	X
Retail	Fast food manager	M	X		
Retail	Lunchroom manager	F	X	X	
Retail	Lunchroom employee	F	X	X	
Retail	Supermarket manager	F	X		
Retail	Supermarket manager	M	X	X	
Retail	Intern	F			X
Municipality	Policy advisor	F			X
Province	Project manager	F			X
Municipality	Neighbourhood manager	M			X
Housing corporation	Neighbourhood manager	F			X
Housing corporation	Neighbourhood manager	M			X
Retail	Owner	F			X
Health promotion	Lifestyle coach	F			X
Municipality	Project manager	F			X
Retail	Owner	F			X
Municipality	Project manager	M			X
Health knowledge institute	Project manager	F			X
Health knowledge institute	Advisor	F			X
Health promotion	Neighbourhood coach	F			X
Municipality	Policy advisor	F			X

of their food, increase their food skills, hence, see it as a priority, and demand more healthy/sustainable food (R3, Fig. 1). However, participants discussed that consumer demand for healthy/sustainable food is also largely influenced by its relative affordability. They noted that having a healthy/sustainable diet is more challenging for people with a low income.

Commercial factors

The third identified subsystem focuses on the commercial factors, linked to the food industry, which were perceived to shape the local food environment. It includes factors such as marketing budget for healthy/sustainable food, lobbying from the food industry, and the food industry's willingness to change (Fig. 1).

The participants discussed the widespread availability, constant advertising and low price of unhealthy food. One participant explained how the food industry is dependent on consumer demand: "As a company, you cannot simply change the supply without there being a demand" (retailer). Also, consumer demand for healthy/sustainable food impacts the food industry's willingness to change, ultimately determining the allocation of staff and resources. The latter also influences production costs, which affect the affordability of food, and as mentioned above, the affordability of healthy/sustainable food impacts consumer demand for it (R5, Fig. 1).

Some participants mentioned the omnipresence of unhealthy food advertisements in the streets and discussed the industry's predominant investment in

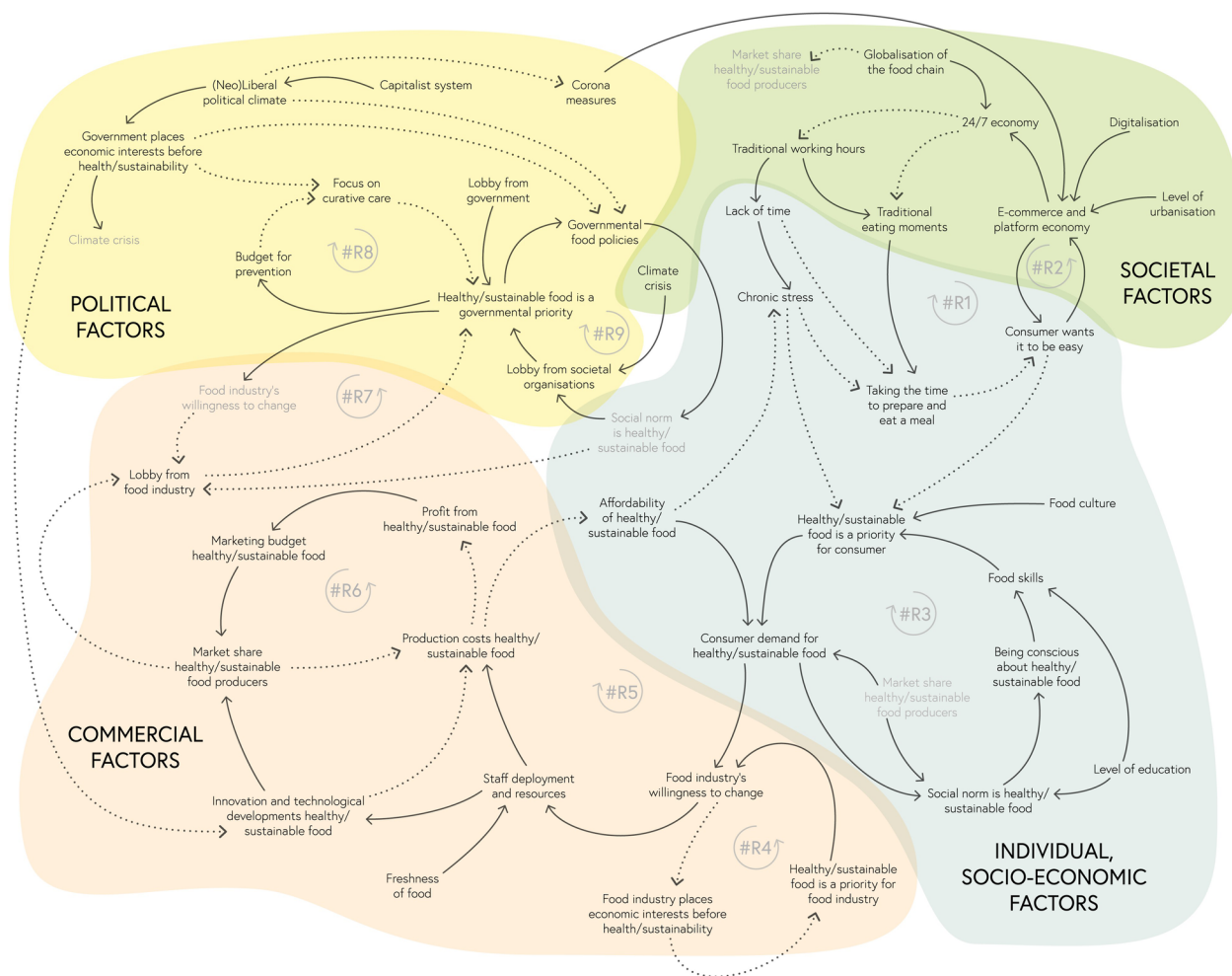


Fig. 1 Causal loop diagram (CLD) of the factors influencing a healthy and sustainable local food environment. Factors written in grey are already mentioned in the CLD but have been rewritten elsewhere to increase readability

unhealthy food marketing. A participant explained: “You prefer to advertise for things that you can sell” (retailer). Thus, the potential profit from (healthy/sustainable) food is a crucial factor in determining what will be advertised. Yet, the participants also discussed other factors influencing the choice of foods offered and promoted by retailers, such as the freshness of food and the number of staff and resources needed to be able to prepare and offer certain foods. They discussed how an increased marketing budget for (healthy/sustainable) food impacts the market share of producers of those foods. In turn, a larger market share leads to reduced production costs, thus yielding higher profits for the producers of (healthy/sustainable) food (R6, Fig. 1).

Participants also discussed how the food industry’s willingness to change is contingent upon the level of priority that is given to healthy/sustainable food. The participants agreed that the food industry often prioritizes

economic interests over public health and sustainability, decreasing the likelihood that healthy/sustainable food takes precedence over unhealthy and less sustainable alternatives (R4, Fig. 1). Participants argued that as long as the food industry is not willing to shift towards more healthy/sustainable food, it will continue its lobbying efforts towards the government, which will reduce the chances that healthy/sustainable food become a governmental priority (R7, Fig. 1).

Political factors

The fourth and final subsystem identified illustrates how political factors, such as governmental priorities, food policies and a capitalist system were perceived to shape the local food environment (Fig. 1).

Participants observed that the current (Dutch) health-care system concentrates on treating diseases, rather than prioritizing prevention efforts: “Our healthcare system is

focused on curing instead of preventing” (lifestyle coach). Participants emphasized that this eventually results in a lack of budget for prevention and healthy and sustainable food environments (R8, Fig. 1).

Participants also observed that various governmental departments may hold divergent interests, which influences the extent to which healthy/sustainable food is a governmental priority. A participant (local policy advisor) explained that colleagues working on the job market would see the opening of a large fast-food chain as a significant asset. On the other hand, another colleague working in the public health domain would perceive this development as unfavourable due to negative health implications. Participants then discussed how the lack of prioritization of public health hampers the implementation of policies in favour of healthy and sustainable food environments: “We really only have few policy tools to keep food outlets out” (local policy advisor). This challenge also was linked to the broader political climate in the Netherlands. Participants further discussed how food policies could, in the long term, support shaping social norms around healthy/sustainable food, which in turn can pave the way for societal organizations to lobby the government to make healthy/sustainable food a governmental priority (R9, Fig. 1).

External member-check meeting

The external stakeholders found the CLD impressive and useful and deemed it applicable to their respective municipalities. Based on the discussions held, minor adaptations were made to the CLD (Fig. 1). Three factors were merged into one overarching factor (‘governmental food policies’), one factor was embedded in the CLD (‘climate crisis’) and one new perceived association was drawn (between ‘globalization of the food chain’ and ‘market share healthy/sustainable food producers’).

Leverage points and system-based actions for change

Eight leverage points were identified based on the first GMB workshop and in consultation with the participants during the second GMB workshop (Fig. 1). Based on these leverage points, participants formulated a total of 20 different actions. Most actions, 11 in total, corresponded to the ‘structures level’ of the ASM model, followed by 7 actions addressing the ‘events level’. The participants formulated one action corresponding to the ‘beliefs level’ and another one corresponding to the ‘goals level’ of the ASM (Table 3) [40].

Selection and implementation of actions

A total of 15 participants shared their top three actions most feasible and urgent to implement. Two of these participants were not able to attend the meeting, and

four participants joined without sharing their top three actions. Based on this list of the top three actions, the stakeholders and the ASM levels of all actions, the researchers selected the eight most relevant actions for the action implementation meeting (Table 3).

Due to a lack of time and preferences of participants, implementation plans were developed by the assigned working groups for only four actions (Table 3). Group A ($n=5$) worked on an implementation plan for action 5 and group B ($n=6$) worked on actions 10 and 17. The group expanded the scope of action 17 to include increasing accessibility to healthy/sustainable food for low-income families by expanding the municipality’s governmental financial support system so the beneficiaries can spend this budget in stores selling healthy/sustainable food. Group C ($n=7$) worked on an implementation plan for action 9 (Table 3). A local policy advisor became the representative for groups A and B, and a lifestyle coach became the representative for group C.

Follow-up on implementation of actions

The group representatives accepted the invitation for the telephone interview. During the first telephone interview, the group representative for groups A and B indicated that there had been occasional communication within the group. However, this participant was mostly establishing new collaborations within the municipality to work on actions 5, 10 and 17 (Table 3).

During the second telephone interview, the representative for groups A and B explained that contact with the group members terminated, but the representative successfully established new connections with colleagues from other departments of the municipality to implement the actions. The representative mentioned that the intrinsic motivation and enthusiasm of colleagues facilitated this progress. However, the representative mentioned the need for continuous follow-up to ensure progress as well as the importance of budget and timing. While this project had secured funding through a public health policy, this was reaching its end [34]. Now the efforts were directed at incorporating actions 5 and 17 in a new policy for long-term funding [41].

Timing played a role too: action 5 could be included in a rewritten event policy; although, action 10 faced challenges as existing contracts for advertisements in bus stops could not be modified (Table 3). Finally, the representative for groups A and B argued that the lack of jurisdictional instruments hindered the implementation of certain policies, such as a policy to restrict the amount of publicity for unhealthy and unsustainable food (action 10). Despite this, the representative was exploring alternative options.

Table 3 Overview and description of actions, leverage points and action scales model (ASM) level

Action number	Title of action	Description of action	Leverage point	ASM level
1	Healthcare cost savings due to healthy diet	Consumer organizations, health insurers and business owners provide insight into healthcare cost savings resulting from a healthy diet	'Healthy/sustainable food is a governmental priority'	Beliefs
2	Reduce unhealthy impulse buying	Supermarkets are researching what healthy or non-food related products can be sold impulsively, and offering that at impulse buying spots	'Governmental food policies'; 'food industry's willingness to change'	Goals
3	Advertising healthy/sustainable food	Supermarkets and restaurants in the municipality have developed and implemented policies to primarily advertise healthy/sustainable food inside and outside the store (e.g., billboards, posters)	'Food industry's willingness to change'	Structures
4 ^B	Fancy ordering healthy food	Restaurants and supermarkets make healthy choices more visible and prominent to consumers on their online platforms (e.g. advertising and offers for healthy food, healthy food at the top)	'E-commerce and platform economy'; 'demand for healthy/sustainable food'	Structures
5 ^{A*}	Healthy/sustainable food at events	The municipality sets conditions for public events to encourage and increase the supply of healthy/sustainable food	'Healthy/sustainable food is a governmental priority'; 'governmental food policies'	Structures
6	Healthy food gets cheaper	The national government lowers the price of healthy food (e.g. reducing value added tax (VAT) or providing subsidies)	'Governmental food policies'	Structures
7	Incentive fund for the production of healthy/sustainable food	Foodvalley region has an incentive fund for the production of healthy/ sustainable food	'Food industry's willingness to change'	Structures
8	Lead by example: healthy and sustainable eating in corporate canteens	Companies and organizations make healthy and sustainable eating easier in their canteens (e.g. make unhealthy food more expensive than healthy food, more healthy options)	'Healthy/sustainable food is a governmental priority'; 'governmental food policies'	Structures
9 ^{C*}	More time and attention for a healthy lifestyle	Lifestyle coaches and neighbourhood coaches support people on behalf of well-being (e.g. assisting with a healthy lifestyle and helping with 'organizational issues' that reduce stress and creating more space for relaxation)	'Taking the time to prepare and eat a meal'	Structures
10 ^{B*}	Outdoor advertising healthy eating	Municipality amends General Local Government Ordinance (APV) boundary conditions to allow signs further from a property on the sidewalk when healthy eating is involved	'Healthy/sustainable food is a governmental priority'; 'governmental food policies'	Structures
11	Shortening the work week	The government shortens the standard work week so that people have more time for healthier lifestyles (e.g. prepare their own meals)	'Taking the time to prepare and eat a meal'	Structures
12 ^A	Sponsoring healthy food	Supermarkets and catering establish a policy of sponsoring only healthy food and communicate this	'Healthy/sustainable food is a governmental priority'; 'governmental food policies'	Structures
13	The Foodvalley Innovation Award	The Foodvalley Innovation Award includes health as a criterion in addition to sustainability	'Food industry's willingness to change'	Structures

Table 3 (continued)

Action number	Title of action	Description of action	Leverage point	ASM level
14	Concept stores for healthy/ sustainable food	The municipality facilitates and encourages the opening of concept stores that offer healthy/ sustainable food	'Demand for healthy/sustainable food'	Events
15	Free fruit at the supermarket	Supermarkets distribute free fruit samples to children	'Demand for healthy/sustainable food'	Events
16	Free fruit picking	The municipality communicates more and better about the fruit trees in the municipality, from which everyone may pick fruit for free	'Demand for healthy/sustainable food'	Events
17 ^{B*}	Part 1: healthy/ sustainable food as a gift Part 2 ^{**} : increased access to healthy/sustainable food for low-income families	Part 1: The municipality's gift card is expanded so it can also be spent in stores selling healthy/ sustainable food (e.g. greengrocer, store selling local produce) Part 2 ^{**} : the municipality's governmental financial support system is expanded so low-income families can spend this budget in stores selling healthy/sustainable food	'Healthy/sustainable food is a governmental priority'	Events
18 ^C	Learning how to cook healthy/ sustainable food	A 'healthy and sustainable cooking workshop' is organized at least twice a year for residents of the municipality, in cooperation with various stakeholders (community centre, lifestyle coach, dietician, supermarket)	'Demand for healthy/sustainable food'; 'taking the time to prepare and eat a meal'	Events
19 ^C	Learning how to cook healthy and fresh products	Supermarkets and market stalls make it easier for consumers to prepare fresh produce by sharing preparation techniques with them (flyers, videos or as part of cooking workshops)	'Demand for healthy/sustainable food'; 'taking the time to prepare and eat a meal'	Events
20	Ordering healthy food online	ICT companies create a mobile app that allows consumers in the municipality to order healthy food	'E-commerce and platform economy'	Events

Superscripts (A, B, C) indicate which group worked on an action implementation plan. A (*) indicates that an implementation plan was developed for the action by the corresponding working group during the action-implementation meeting. A (***) indicates that this action was expanded by the stakeholders during the action-implementation meeting

During the first telephone interview, the representative for group 3 indicated that three participants already quit the group due to lack of time, and three other participants were not responding to emails. The representative declared that due to lack of time, response and motivation from the group, the efforts to implement action 9 were insufficient. No telephone interview was conducted at 12 months.

Discussion

Using a participatory approach, this study identified factors and mechanisms underlying the local food environment and identified leverage points and system-based actions for healthy and sustainable local food environments using systems thinking. The findings from this study provide, to the best of our knowledge, one of the first CLDs that illustrate the factors and mechanisms perceived to underlie the local food environment in terms of health and sustainability, from the perspective of local stakeholders. A total of 42 underlying factors were identified, grouped within four subsystems including societal-, individual, socio-economic, commercial and political factors. The CLD includes nine feedback loops, with multiple factors having a reinforcing relationship in shaping the local food environment. Based on the CLD, local stakeholders developed 20 actions to trigger systems change for a healthier and more sustainable local food environment. According to the ASM, most actions developed targeted the 'structures' ($n=11$) and 'events' ($n=7$) levels, while only two actions addressed the 'beliefs' or 'goal' level [40]. While the CLD offers valuable insights for employing systems thinking as part of a local stakeholder approach to improve food environments, implementing actions requires more intensive input and a longer period, as 1 year after the second GMB workshop, only one participant remained active.

The findings from this study illustrate that local stakeholders grasp the complexity of local food environments and its inter-relatedness with the wider food system. While the study's point of focus was the local food environment, the factors and mechanisms identified extended well beyond the local level, including national factors (e.g. national government priorities) and global developments (e.g. digitalization). These findings are in line with prior GMB studies, which studied factors and mechanisms underlying complex public health problems and also observed a broad range of factors that go beyond local boundaries [22, 42]. Thus, even when taking a local lens, the importance of the national or global food system must be acknowledged [2].

While most of the prior GMB studies addressed the underlying factors of a particular health concern or health outcome, they also identified similar factors and

mechanisms related to the (local) food environment. For instance, prior studies identified factors related to marketing for unhealthy food [9, 22, 42, 43], available time [9, 22, 42] and affordability of healthy food [9, 22, 42, 43]. In contrast, not all CLDs developed in prior studies included political factors related to the food environment, except for a CLD on unhealthy snacking in schools that included the factor 'school food rules' [42]. In addition, a few feedback loops observed in other studies are in line with our findings, for example, reinforcing loop 1 (R1, Fig. 1), addressing trade-offs between available time and convenience of food [9, 42] and reinforcing loop 6 (R6, Fig. 1), concerning the economic and marketing power of the food industry [22]. A more recent study also used a participatory approach to model the food retail environment [44]. This map deviates from our model as it integrates aspects of the food environment within the systems map (e.g. food availability, food marketing, food prices), whereas the CLD developed in this study identifies the factors underlying such food environment characteristics. Nevertheless, both similarities and differences were observed between the maps (e.g. the model of Karapici and Cummins incorporates the 'attractiveness of the neighbourhood', whereas our model included 'lobby from industry' as a variable, while these determinants did not appear in the other CLD. This highlights the notion that different participants in different contexts may reveal different factors and feedback loops, which should be considered when interpreting the outcomes of participatory systems maps.

This study is among the first that used group model building (GMB) as a participatory approach to engaging local stakeholders to understand and improve local food environments. This method fosters community involvement using active participation and collaborative problem-solving. However, GMB also has some limitations. It can be resource intensive in terms of time, personnel and financial costs. The success of GMB heavily depends on skilled facilitation to manage group dynamics and ensure productive sessions. Furthermore, the findings and solutions generated from GMB sessions can be highly context-specific, potentially limiting their generalizability [13]. Yet, GMB holds promise in empowering local stakeholders to take ownership of food environment challenges and work towards a systems-driven decision-making process [25]. The insights gained from the current study can serve as a valuable resource for other research activities seeking to comprehend complex issues involving the local food environment. However, it is essential to keep in mind that the CLD and other findings were developed by a limited group of stakeholders. Therefore, while these insights provide a valuable starting point, the CLD is not exhaustive.

The participants of the GMB workshops formulated actions to improve the local food environment targeting different leverage points and various levels of the ASM [40]. Although actions were formulated for all ASM levels, most actions addressed the events and structures levels of the ASM. In line with prior studies, participants encountered challenges when attempting to generate actions that would alter the goals and beliefs of a system [22]. This may stem from the difficulty of imagining actions that unfold over time (e.g. changing social norms) to conceptualize societal shifts not directly embedded within one's lived experience or that require action that is out of one's control [40]. The last point could be addressed by inviting high-level representatives that have the power to change higher levels in the system. Also, systems thinking itself can be challenging and may require more than two sessions to grasp the concept fully [22]. Therefore, longer-term projects involving a wider range of stakeholders are needed that allow to intensify efforts for actions to result in systems change.

Despite the short duration of this project, the researchers did a 6- and 12-month follow-up on the implementation of actions. After 12 months, only one participant who was also a group representative remained active. Using the river analogy to identify key requirements for the successful implementation of system-based actions, the remaining group representative could be identified as the 'guide' [14]. Indeed, the representative motivated and connected stakeholders and their agendas to change the local food environment. In line with previous studies, the 'guide' had the time to work on the actions because they aligned with the strategic priorities of the guide's organization and professional tasks. This confirms the importance of having a key stakeholder to steer systems change [12, 14]; although, it may also be risky to have all actions depend on just one stakeholder. Finally, quick and strategic responses to changes in the local context to push the system in the desired direction were observed, as the 'guide' seized 'a window of opportunity' to put the topic of healthy/sustainable food provision on the agenda for the new event policy [45]. Also, when a new local policy document was to be developed regarding prevention and health, the guide included actions from the GMB workshops in the policy to secure financing. Embedding actions within a broader policy and securing finance are two elements that have been found to facilitate the success of public health interventions based on systems thinking [12].

Strengths and limitations

This study has notable strengths. First, 1 year before the first GMB workshop, the researchers created a local network with key residents and local stakeholders, with the

municipality's assistance. This enabled the researchers to invite residents living in a lower socio-economic and multicultural neighbourhood to participate in the study, despite this group being usually difficult to recruit for such projects [46]. This local network also enabled collaboration with local stakeholders throughout the project, which can improve the implementation of actions [13] by increasing ownership and addressing competing interests [47, 48]. Second, the commitment from the municipality and the financial contributions for participation convinced a diverse group of stakeholders to actively participate in the study. Third, the active participation of the municipality was essential to structurally incorporate this project in long term municipal plans. Partnering with a local organization is crucial to gain sufficient knowledge of the community and build a network. It also makes it possible to ensure that outputs continue to be implemented after the departure of the research team [21]. Fourth, all sessions, workshops and meetings for this study were hosted by the municipality. Last, this study went beyond the 'usual' steps of GMB, which is the formulation of actions. An action-implementation meeting was organized with relevant stakeholders to stimulate lasting systems change in the local food environment, as recommended by prior GMB studies [21].

This study also has limitations. Although the participants represented a wide variety of stakeholder groups, we cannot guarantee that all perspectives were represented. Besides, not all participants participated in all steps of the process, and some were occasionally replaced by a colleague. Choosing whom to include and defining the boundaries of a community is an acknowledged challenge in community-based research [46]. Also, the research team that guided the workshops and built the CLD may have affected the outcome. On the other hand, the goal of the workshops was not to create 'the best' CLD, in terms of reflection of reality; rather the CLD is a visual tool that can support stakeholders in systems thinking and the development of system-based actions for change. Next, when formulating actions for systems change, we did not consider existing initiatives that may already target certain factors or mechanisms of the CLD (whether based on systems thinking or not). We did ask the participants to discuss existing initiatives they were familiar with, that could be built upon when aiming for healthier and more sustainable food environments. Moreover, examples of a variety of wider actions to improve food environments can be found elsewhere [49, 50]. The last limitation of this study relates to time. We only had a limited amount of time during the workshops, which combined with the diversity in backgrounds of participants; required simplifications of the scripts. Besides, as observed by Gerritsen et al. (2020), the two

GMB sessions were not sufficient to implement the actions. We, therefore, organized an action-implementation meeting focusing on developing a long-term plan to implement certain actions from the GMB workshops. On the other hand, this fixed and limited amount of time may have encouraged local stakeholders to participate, given busy schedules. Besides, the short amount of time dedicated to each script serves the purpose of making the best use of time with the group and enables the overall process to move forward in an organized way, ultimately resulting in useful outputs for the stakeholders [36].

Recommendations for practice

The CLD of the local food environment may guide local policy advisors to improve their food environment. In addition, municipalities may use a systems approach to develop, implement, or strengthen ongoing efforts to improve their food environment. Also, this study illustrates the crucial role of leaders or 'guides', which have the time, capacity and motivation to push for the implementation of actions. Ideally, a small group of stakeholders should intensively work together to implement actions that target different leverage points and levels in the system. Also, national, and global organizations, governmental institutions and food industries are crucial to have on board when seeking to long-lastingly change the system [51, 52]. Local public officials rarely exchange with higher levels of governance [15], so engaging with different levels of governance should be an aim in itself.

Recommendations for research

Future research should determine if systems thinking leads to different and more effective interventions compared with traditional linear and single-component interventions. Long-term process and effect evaluations of interventions based on principles of system-thinking are needed, which take into account both intended and unintended consequences of interventions, and measure the smaller, often less tangible changes in the system (i.e. change in mindset) [53]. Frameworks have been developed to evaluate public health projects based on principles of systems thinking, but their application remains limited [53–55]. Another way could be to evaluate food environment interventions using quantitative models based on systems thinking, such as agent-based modelling [56]. Besides, future research could prioritize the system-based actions (i.e. using a choice model) presented here based on estimated impact and easiness to implement, as the GMB 'matrix' script was not performed. Also, there is a need to determine how actions targeting the 'goals' and 'beliefs level' of the system

can be developed and implemented successfully for public health interventions. Finally, quantitative studies and literature reviews could further strengthen our systemic understanding of local food environments, extending beyond the stakeholder perspectives identified in the current study.

Conclusions

This study yields insights into the factors and mechanisms underlying the local food environment, as perceived by local stakeholders and system-based solutions to make it healthier and more sustainable. It also reveals the need for a long-term systems approach, with a group of key stakeholders from diverse fields and governance levels, which have the time, capacity and motivation, to jointly implement system-based actions for healthy and sustainable local food environments.

Abbreviations

CLD	Causal loop diagram
GMB	Group model building
NCDs	Noncommunicable diseases
STICKE	Systems Thinking In Community Knowledge Exchange

Supplementary Information

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Supplementary Material 1. STROBE Statement – checklist of items that should be included in reports of observational studies – completed for the study entitled: 'Systems Thinking for Local Food Environments: Identifying leverage points and actions for Healthy and Sustainable Transformations'. STROBE Statement filled in for the manuscript entitled: 'Systems Thinking for Local Food Environments: Identifying leverage points and actions for Healthy and Sustainable Transformations'.

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Author contributions

T.W., M.P. and C.D. designed the study. T.W. and J.W. drafted the scripts for the workshops and all authors provided feedback until agreement was reached. T.W. and F.R. organized the workshops, and all authors were present during the first two workshops whereas T.W., F.R. and M.P. were present during the action-implementation workshop. T.W. wrote the draft manuscript. M.P. and C.D. were the main reviewers and editors of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All participants were aged 18 years or over and provided written informed consent to participate in the study. Ethical approval for the study was granted by the Wageningen University and Research Social Sciences Ethics Committee on July 8, 2021.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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