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Sustainable food posts on social media: an exploratory study on X using hashtags

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ABSTRACT

Social media is considered a powerful tool to spread information about sustainable food, with both positive and negative impacts on sustainable food behavior. Thus, this exploratory study aimed to investigate the topics related to the hashtag #sustainablefood and their sources on “X.” Posts in English containing the hashtag #sustainablefood, between June 1st, 2021 and May 30th, 2022, were retrieved using a combination of the Twitter API and the social networking scraper SNS in Python. Characteristics of users generating the posts were retrieved from their profiles and analyzed using content analysis. Results indicated that companies and media organizations led the communications related to #sustainablefood, whereas regular consumers were a minority of the users posting content on the topic. In addition, associations between hashtags were analyzed with network analysis and using hierarchical cluster analysis, nine main topics were identified: *agriculture*, *climateaction*, *climatechange*, *environmental*, *farm*, *plantbased*, *vegan*, *innovation*, and *foodtech*. Hashtags on each topic varied by source, producing different messages. *Plantbased* and *climatechange* were identified as key bridging hashtags via betweenness centrality. This study contributes to understanding how sources use hashtags differently regarding sustainable food on social media and highlights the importance of analyzing post sources to avoid misattributing content to regular users.

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Introduction

Two of the Sustainable Development Goals (SDGs) of the “2030 Agenda for Sustainable Development” are sustainable consumption and production (SDG 12) and good health and well-being (SDG 3) (UN 2015, 2020). Achieving these and other food-related goals requires ensuring access to healthy diets derived from sustainable food systems (Willett et al. 2019). The European Commission defines a “sustainable” food system as one that encompasses “a range of issues such as security of the supply of food, health, safety, affordability, quality, a strong food industry in terms of jobs and growth and, at the same

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time, environmental sustainability, in terms of issues such as climate change, biodiversity, water, and soil quality” (EC 2019).

Sustainable food consumption encompasses environmental, social, economic, and health dimensions. It refers to dietary patterns that promote sustainable production, human and planetary health, social equity, environmental protection, biodiversity, animal welfare, responsible consumer behavior, cultural acceptability, economic accessibility, individual and collective well-being, and the needs of future generations (Mensah, Wieck, and Rudloff 2024). In this regard, the EAT-Lancet Commission has outlined the features of a healthy and sustainable diet, one that is mainly composed of plant-based foods and includes limited amounts of animal-source foods (Willett et al. 2019).

Social media could play a fundamental role in spreading information about the SDGs and encouraging sustainable food consumption patterns (UNSDG 2017). It has been shown that consumers seek and use sustainable food information on social media (Rini et al. 2024) and that they trust information from social media more than the information delivered by other media (Ardèvol-Abreu and de Zúñiga 2017; Håkansson and Witmer 2015; Turcotte et al. 2015).

However, studies have shown that social media can have both positive and negative effects on consumer knowledge and sustainable food habits (Simeone and Scarpato 2020). Social media functions as a tool for cultural exchange and sharing information about sustainable food habits across different groups (Choudhary et al. 2019), and serves as a network-building platform for developing sustainable food consumption within communities (Campos and Zapata 2017). In the context of sustainable food consumption patterns, social media can encourage uniform consumption behaviors that move consumers away from sustainable food practices, such as eating locally or organically or reducing meat consumption; for example, people tend to prefer well-known fish species over local ones, which can cause overfishing and damage local culinary traditions (Simeone and Scarpato 2020). Conversely, it has also been reported to promote sustainable practices by endorsing zero-mile products and encouraging participation through food reviews and online communities (Simeone and Scarpato 2020).

Social media is used to spread information about sustainable food consumption patterns by consumers (Seyfang 2006), nonprofit organizations (Campos and Zapata 2017), local food farmers (Kummer and Milestad 2020), and food industry corporations, among others. In particular, social media has become one of the most important components of the marketing mix of food companies (Felix, Rauschnabel, and Hinsch 2017; Nielsen 2022; Vollero and Chiara 2021), and has been regarded as an effective advertising medium for green food advertisers since consumers seek sustainable food information in social media (Minton et al. 2012).

Moreover, studies have shown that different types of users share distinct kinds of information about sustainable food consumption on social media. Food retailers posting about sustainability refer to general issues to minimize controversies (Samoggia, Bertazzoli, and Ruggeri 2019). For example, palm oil agri-food producers have adopted a multi-dimensional outlook communicating sustainability issues about the product, while retailers avoid engaging in sensitive issues regarding palm oil production (Ruggeri and Samoggia 2018). Therefore, it remains relevant to study the sources of the messages when analyzing social media posts regarding sustainable food on social media.

Nevertheless, research on sustainable food in social media remains limited, and existing studies analyzing posts about sustainable food have not comprehensively considered the different sources of these messages. Some have excluded commercial marketing content (e.g., Davis and Papiés 2022), others have omitted user identification to preserve their anonymity (e.g., Laakso et al. 2022), while others have regarded all posts as expressions of public opinion (e.g., Aleixo et al. 2021). Studies addressing the sources of social media content have mainly focused on specific groups, such as activists (e.g., Small and Warn 2020), influencers (Friedlander and Riedy 2018), or agri-food chain producers (Ruggeri and Samoggia 2018). Only a few have provided a more comprehensive analysis that includes user classification (e.g., Maye et al. 2021).

The present study addresses the topic by focusing on the hashtag #sustainablefood. This term has been reported to be frequently used by a wide range of users, including international organizations (e.g., UN 2024), governments (e.g., RIVM 2024), retailers (Zwart and Wertheim-Heck 2021), consumers (Ran et al. 2022), and in policy development (Ammann et al. 2023), among other contexts. Specifically, this study aimed to analyze the topics related to the hashtag #sustainablefood on X (aka Twitter), and the users posting those messages by using content and network analysis. Through this approach, we seek to determine what the main topics related to sustainable food are on X, and what users are setting the agenda regarding those topics on X.

Literature review

Agenda setting and social media

The agenda-setting theory is one of the most widely applied frameworks in the study of media effects. It postulates that mass media shape public perceptions of reality by influencing which issues audiences consider important, which is largely determined by the amount of coverage an issue receives and the prominence of its placement (M. E. McCombs and Shaw 1972). Recently, a reverse agenda-setting process has been proposed, suggesting that media organizations also respond to audience feedback by prioritizing topics of public interest (M. McCombs 2005). In the context of social media, users actively contribute to this dynamic by posting their opinions and engaging in discussions that can later be reflected or amplified in different media outlets (Zhou and Moy 2007).

In July 2024, 5.17 billion consumers, 63.7% of the world's population, were active users of social media (Statista 2024b). Only in 2023, users spent, on average, 151 minutes per day using social media platforms (Statista 2024a). People use social media as a communication utility for entertainment and relaxation, as well as for social interaction, to express opinions, and to seek and share information, among others (Whiting and Williams 2013).

Recent studies on social media have found a reciprocal interaction between news media accounts and individual users, suggesting that both influence each other in shaping agenda attributes (X. Wang et al. 2023). However, social media content does not only reflect public opinion (McGregor 2019). Companies use social media to communicate with consumers and promote their products and services, building brand loyalty, raising awareness, and influencing consumer opinion, evaluation, attitudes,

and purchasing behavior (Mangold and David 2009; Kim and Ko 2012). Likewise, nonprofit organizations also use social media as a tool to build community, share information, and call for action (Lovejoy and Saxton 2012). Consequently, the public agenda is shaped not only by individuals and media outlets but also by a range of other actors (X. Wang et al. 2023). Therefore, when analyzing social media messages, it is essential to identify the sources of those messages in order to understand both what is being communicated and by whom. In this regard, the use of hashtags and network analysis has proven to be an effective approach for studying social media content (Karami et al. 2020; La Rocca and Boccia Artieri 2022).

Hashtags and network analysis

Hashtags are an integral part of social media, as they serve as tools to organize and steer conversations on social media. They function as topics to distribute information about relevant themes (Uhl, Kolleck, and Schiebel 2016), as keywords to label and promote content, ideas and conversations (Kotsakos et al. 2015), to seek attention, localize, organize, or contribute to an information stream (Abenavoli et al. 2021; Bennett and Segerberg 2012), structure and spread content, summarize, endorse, bond, inspire, reach, and amuse, among others (Rauschnabel, Sheldon, and Herzfeldt 2019), and when linked with other hashtags to tell a story (Yang 2016). In addition, they are used to reach other persons with the same interests regarding a specific topic (Bennett and Segerberg 2011), to build communities (Kwon and Ha 2022), to reach supporters and raise public attention (R. Wang, Liu, and Gao 2016), as an instrument for protest and activism (Clark 2016), or to communicate clear political positions (Recuero, Zago, and Soares 2019).

Companies use hashtags as a way for two-way communication with their consumers as well as to promote (Martín, Lavesson, and Doroud 2016) and raise awareness and interest in their brands (Shin, Chae, and Ko 2018). They profit from the use of hashtags because they are easy to use for searching and collecting information to determine the attention and the active participation of consumers producing electronic word of mouth (Shin, Chae, and Ko 2018).

The study of hashtags has grown considerably in the last 20 years (La Rocca and Boccia Artieri 2022). Different studies have used hashtags and network analysis to study different topics on Twitter (Karami et al. 2020). Social Network Analysis (SNA) has been considered an appropriate method for analyzing discourses on digital spaces (Eddington 2018). The discourses on social media can be studied by identifying the associations between words and concepts shared in posts (Lambert 2017). By using SNA, word associations in text words' frequencies and associations are analyzed to determine the meaning inherent to the data, by identifying the network structures of nodes and edges, where nodes can be words or hashtags, and edges represent their relationship or co-occurrences (Siew et al. 2019).

In particular, the study of sustainable food topics using hashtags and network analysis has received limited attention. Studies using hashtags have focused especially on events in news and politics (Bruns et al. 2016). Moreover, the analysis of users is usually not considered and the content of the messages is either attributed to public opinion or omitted to protect the identity of users. In particular, few studies have used hashtag network analysis to study different sustainable food related topics on Twitter.

For example, a study found six communities around the hashtag #sustainability (i.e., Environmental sustainability, Sustainability awareness, Renewable energy and Climate Change, Innovative technology, Green architecture, and Food sustainability (Pilař et al. 2019). Regarding the hashtag #healthyfood, the most associated words were healthy *lifestyle*, *diet*, and *fitness*, as well as *vegan*, *homemade*, and *organic* (Pilař, Kvasničková Stanislavská, and Kvasnička 2021). Nevertheless, none of these studies offered a classification of communities or topics by type of users. One of the few hashtag network analyses offering a classification of users found a high quantity of users using Twitter for marketing purposes when investigating the narratives around “sustainable meat.” In this study, #sustainablemeat tweets were used to promote a business or the production of meat, and #eatlessmeat tweets were associated with planetary issues and an evolution of the “vegan” narrative (Maye et al. 2021).

Therefore, this paper aimed to investigate the topics related to the hashtag #sustainablefood and their sources on “X” (aka Twitter). It relied on a combination of content and network analysis of hashtags. The following research questions were addressed.

RQ1: What are the main topics related to sustainable food communicated on X?

RQ2: How do different types of users differ in the themes they emphasize when communicating about sustainable food?

RQ3: How are sustainable food-related communications interconnected, and which hashtags occupy central or bridging positions in the online discourse on sustainable food?

Materials and methods

Retrieval and cleaning of data

Original tweets in English containing the hashtag #sustainablefood, posted between 1 June 2021 and 30 May 2022, were retrieved using a combination of the official Twitter API and the social networking scraper SNS in Python. Snsrape was used because it enables comprehensive data collection from social networking services beyond standard API limits and can export the retrieved posts in an Excel sheet if needed. The search was limited to English since it is the most common language used on Twitter (Alshaabi et al. 2021). Once all posts were compiled into an Excel sheet, retweets were removed to avoid duplicate information, resulting in 2813 original tweets. Since this study aimed to analyze the hashtags related to #sustainablefood, tweets containing only the #sustainablefood hashtag were discarded ($n = 205$). The remaining 2608 tweets were cleaned by removing unreadable characters within the posts. Finally, all posts were converted to lowercase.

Text analysis

Tweets were analyzed using the text-analysis software KHCoder (<https://khcoder.net/en/>). The hashtags *sustainablefood*, *sustainability*, *food*, *sustainable*, and *foodsustainability* were ignored for the network analysis since they represented different versions of the main hashtag. A first analysis revealed 1399 users and 3764 different hashtags with 10,950 mentions. Nevertheless, in order to include the most representative hashtags, only 318 hashtags with 6 or more mentions each were considered for further study, representing 50% of the total mentions. Next, to avoid analyzing separate hashtags with the same meaning, the 318 hashtags were converted into 293 code words. Using “codewords,” KHCoder identifies different words as the same word (e.g., *biotechnology* = *biotechnology* or *biotech*). Posts not containing any of the 293 codes were discarded and 1965 posts were used for further analysis. Then, a matrix of 1965 documents and the 293 codes was developed using the same program. In this matrix, every time a code appeared in a post, it received a 1 whereas 0 was used to indicate that it was not included in the post. As the codes were developed from the initial hashtags, for clarity, the word “hashtag” is used in the following sections.

Analysis of users

The name of the 1399 users who generated each post was extracted. Then, the information publicly available on the profile of each of the users was used to identify groups of users using content analysis. The coding was manually performed using an inductive approach. One of the authors performed an initial coding, which was subsequently revised by a second author. The number and percentage of users and posts were then calculated for each group of users.

Network analysis

Later, using this matrix, a “one-mode” or “adjacency” matrix containing the 293 hashtags \times 293 hashtags matrix was developed for network analysis using the program UCINET 6 (S. P. Borgatti, Everett, and Freeman 2002). Using the same program, node centrality measures such as degree centrality, eigenvector centrality, and betweenness centrality were performed. Centrality measures and cluster analysis have been used effectively to classify topic networks on Twitter (Himmelboim et al. 2017). Degree centrality scores show how many other nodes or actors are adjacent to a determined node. The degree is the connection of one node with other nodes, determining how many other actors a node is adjacent to (Scott 2017). Eigenvector centrality determines how central a hashtag is based on the largest eigenvector of the network matrix. Instead of just awarding one point for every network neighbor a node has, as in the degree centrality, eigenvector centrality awards a number of points proportional to the centrality scores of the neighbors, determining the centrality of a node based on the largest eigenvector of the network matrix (Newman 2018). A hashtag with a small degree could have a higher eigenvector centrality score than a hashtag with a high degree if the first hashtag is connected to more popular hashtags while the second hashtag isn't. This measure is often interpreted as a measure of popularity since a node with high eigenvector centrality is connected to other nodes that are themselves well-connected (S. Borgatti, Everett, and Johnson 2017).

Betweenness centrality indicates how often a node appears on the shortest paths connecting other nodes. It acts as a guide to understand the influence of certain nodes on the flow of information or resources between others (Newman 2018). Consequently, nodes with higher betweenness scores function as intermediaries, brokers, and gatekeepers among communities (Scott 2017).

Then, hierarchical cluster analysis was used to group hashtags with similar centrality measures. Hierarchical cluster analysis is one of the most used methods for community detection (Newman 2018). Based on a network of nodes or actors, and a defined measure of similarity or connection strength between nodes, the program joins together the most similar words to form groups (Newman 2018). The analysis was performed based on the previously developed centrality measures, considering Euclidean distances and Ward's aggregation criterion. The final dendrogram enabled the identification of groups of hashtags with similar centrality for the definition of the main group of topics (Figure A1).

Graphs showing the words associated with the different topics were developed using the visualization software Gephi 0.10 (<https://gephi.org/>).

Results

Analysis of users

A total of 1399 different users were identified, and 80 of them were no longer available at the time of the analysis. The remaining 1319 users were classified into 15 categories based on the information publicly available on their profiles. Table 1 shows the number and percentage of users and posts within each of the categories. "Regular users" without any specific affiliation were only 73 (5.22%) and generated 92 posts (6.77%). Conversely, the great majority of the users corresponded to a wide range of institutions or were affiliated with several different types of institutions. "Companies" were the biggest group of users (15%) and posted the majority of tweets (23.66%). The group "Consultant/Academic/Policy makers/Activists" (14.08%) followed in the number of users, but only posted

Table 1. Number of users and posts by classification of users.

Users classification	No of users	%	No of posts	%
CEO/Company relevant position	39	2.79	59	3.00
Communication/Journal/Radios/Magazine/Podcast/Publishers	147	10.51	231	11.76
Companies	210	15.01	465	23.66
Consultancy agencies/Marketing/Finance/Real estate/Communication agencies	127	9.08	163	8.30
Consultant/Academic/Policy makers/Activist	197	14.08	154	7.84
Farms/Grocery stores/Butchers/Shops	33	2.36	26	1.32
Governmental agencies/Embassies/International organizations	33	2.36	23	1.17
Network/Associations/Commerce Chamber	92	6.58	139	7.07
NGO/Foundations	150	10.72	194	9.87
Political parties	6	0.43	11	0.56
Politician	10	0.71	6	0.31
Regular user	73	5.22	92	4.68
Restaurant/Hotel/Resort/Parks/Reserves	33	2.36	43	2.19
University/Research project/Consortium	109	7.79	177	9.01
Writer/Journalist/Reporter/Artist	60	4.29	49	2.49
No longer available	80	5.72	133	6.77
Total	1399	100.00	1965	100.00

7.84% of the tweets (Table 1). Other groups of users with a relevant contribution to the analyzed posts were “Communication/Journal/Radios/Magazine/Podcast/Publishers,” “Consultancy agencies/Marketing/Finance/Real estate/Communication agencies,” “NGO/Foundations,” and “University/Research project/Consortium.”

Content of the posts

The analyzed posts included a total of 3764 hashtags related to a great diversity of topics. Nevertheless, only 318 of the hashtags had six or more mentions, representing 50% of the total mentions. These hashtags were selected for further analysis. As explained in the method, they were converted into 293 codes. From these 293 hashtags, the top 10 hashtags by frequency were *plantbased* ($f = 127, 2.58\%$), *climatechange* ($f = 120, 2.43\%$), *aquaculture* ($f = 94, 1.91\%$), *climateaction* ($f = 93, 1.89\%$), *foodtech* ($f = 89, 1.80\%$), *vegan* ($f = 83, 1.68\%$), *foodsystem* ($f = 80, 1.62\%$), *foodwaste* ($f = 77, 1.56\%$), *agriculture* ($f = 65, 1.32\%$), and *regenerativeagriculture* ($f = 64, 1.30\%$). The complete list of hashtags by frequency can be found in the Appendix (Table A1)

Network and hierarchical cluster analysis

The 293 hashtags were analyzed using network analysis (Figure 1). The analysis of the network and the degree centrality scores revealed that *plantbased*, *climatechange*, and *vegan* were the most connected hashtags, whereas *plantbased*, *climatechange*, and

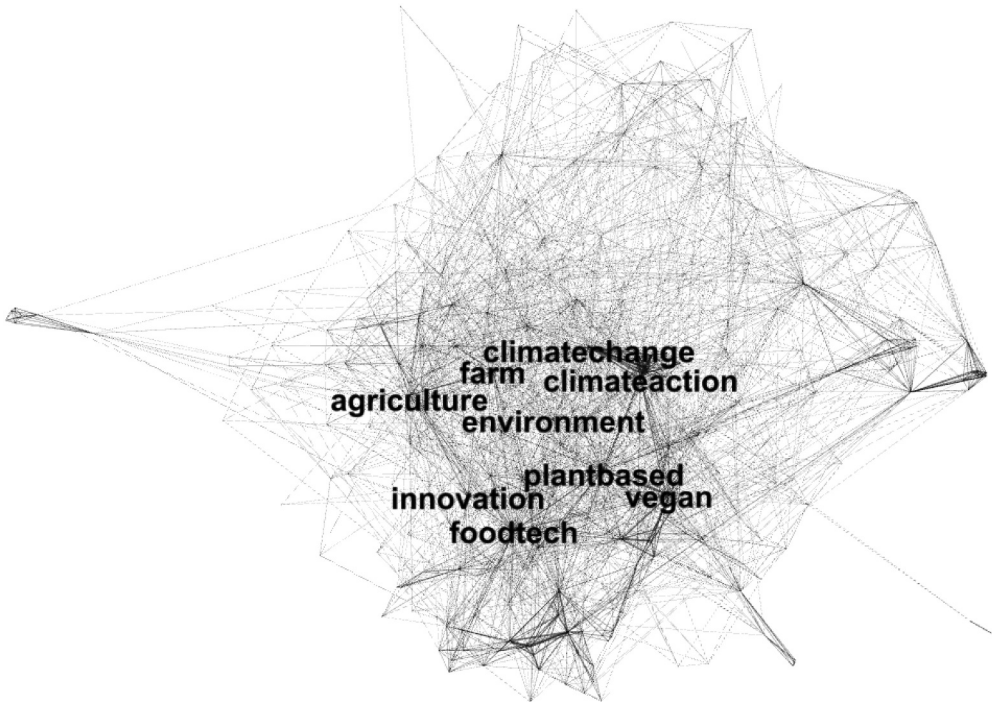


Figure 1. Network of the 293 hashtags and the 9 main hashtags.

Table 2. Top 20 hashtags by frequency, degree, and eigenvector centrality scores.

Hashtag	Frequency	%	Degree	Eigenvector
plantbased	127	2.58	100	0.25
Climatechange	120	2.43	88	0.23
foodtech	89	1.80	72	0.21
vegan	83	1.68	74	0.19
agriculture	65	1.32	63	0.17
climateaction	93	1.89	68	0.17
innovation	37	0.75	59	0.16
farm	59	1.20	63	0.16
environment	33	0.67	55	0.15
foodinnovation	45	0.91	47	0.13
sustainableagriculture	46	0.93	43	0.13
foodsecurity	54	1.09	47	0.13
foodwaste	77	1.56	52	0.12
protein	38	0.77	42	0.12
foodbusiness	17	0.34	40	0.12
futureoffood	36	0.73	37	0.12
plantbasedfood	27	0.55	44	0.12
zerowaste	23	0.47	41	0.12
foodsystem	80	1.62	42	0.12
climate	21	0.43	39	0.12

foodtech were the most central hashtags in the network in terms of eigenvector centrality scores (Table 2).

Hierarchical cluster analysis was performed on the centrality measures of all the identified hashtags to identify the most central to the conversation on sustainable food. Seven groups of hashtags were identified (Table 3). The dendrogram that resulted from the cluster analysis and the complete list of words by groups and frequencies can be seen in the supplementary material (Figure A1, Table A1).

Group 2 was selected as the group containing the main topics since this group showed the highest centrality scores. Although group 5 had the highest number of hashtags, on average, these were not the most frequently posted and showed lower centrality scores. Group 6 followed group 2 in eigenvector centrality scores, but the topics were very dispersed.

Table 4 shows the number of posts and their main sources for the 9 hashtags identified as the main topics related to the conversation about sustainable foods on X.

Figure 2 shows the linkages among the different top ten hashtags per topic, where the thickness of the lines represents the frequency with which every pair of hashtags appeared together. In the following, the nine different topics related to the hashtag #sustainablefood, the top ten hashtags related to them, and the two main groups of users posting about these topics will be explained in detail.

Table 3. Cluster groups and centrality scores.

Groups	No of hashtags	Frequency (M)	Degree	Eigenvector
1	67	9.52	11.40	0.02
2	9	78.44	71.33	0.19
3	49	13.57	15.90	0.04
4	25	40.64	40.92	0.11
5	84	9.07	6.93	0.01
6	27	24.41	25.93	0.08
7	32	15.19	19.59	0.05

Table 4. Number of posts by topics and users.

Users group	agriculture	%	climateaction	%	climatechange	%	environment	%	farm	%	plantbased	%	vegan	%	innovation	%	foodtech	%
CEO/Company relevant position	1	1.54	2	2.15	1	0.83	0	0.00	0	0.00	1	0.79	0	0.00	0	0.00	3	3.37
Communication/Journal/Radios/ Magazine/Podcast/Publishers	14	21.54	3	3.23	10	8.33	4	12.12	15	25.42	28	22.05	15	18.07	0	0.00	24	26.97
Companies	9	13.85	19	20.43	17	14.17	11	33.33	16	27.12	33	25.98	40	48.19	17	45.95	38	42.70
Consultancy agencies/Marketing/ Finance/Real estate/ Communication agencies Consultant/Academic/Policy makers/Activist	6	9.23	4	4.30	10	8.33	3	9.09	4	6.78	16	12.60	6	7.23	1	2.70	2	2.25
Farms/Grocery stores/Butchers/ Shops	7	10.77	4	4.30	10	8.33	6	18.18	4	6.78	4	3.15	3	3.61	1	2.70	3	3.37
Governmental agencies/ Embassies/International organizations	1	1.54	0	0.00	0	0.00	0	0.00	2	3.39	2	1.57	1	1.20	0	0.00	0	0.00
Governmental agencies/ Embassies/International organizations	0	0.00	1	1.08	0	0.00	1	3.03	1	1.69	1	0.79	0	0.00	0	0.00	0	0.00
Network/Associations/Commerce Chamber	6	9.23	30	32.26	34	28.33	3	9.09	2	3.39	13	10.24	2	2.41	3	8.11	10	11.24
NGO/Foundations	7	10.77	9	9.68	9	7.50	1	3.03	3	5.08	5	3.94	1	1.20	1	2.70	1	1.12
Political parties	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Politician	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.20	1	2.70	0	0.00
Regular user	3	4.62	5	5.38	4	3.33	1	3.03	1	1.69	5	3.94	2	2.41	1	2.70	0	0.00
Restaurant/Hotel/Resort/Parks/ Reserves	0	0.00	0	0.00	3	2.50	0	0.00	0	0.00	3	2.36	0	0.00	0	0.00	0	0.00
University/Research project/ Consortium	5	7.69	6	6.45	9	7.50	1	3.03	3	5.08	3	2.36	2	2.41	8	21.62	7	7.87
Writer/Journalist/Reporter/Artist	2	3.08	3	3.23	3	2.50	0	0.00	3	5.08	5	3.94	4	4.82	2	5.41	1	1.12
No longer available	4	6.15	7	7.53	10	8.33	2	6.06	5	8.47	8	6.30	6	7.23	2	5.41	0	0.00
Total	65	100	93	100	120	100	33	100	59	100	127	100	83	100	37	100	89	100

Plantbased and vegan

Although *plantbased* was the most posted hashtag (127), it was frequently posted with the hashtag *vegan* (83) and vice versa. The two groups dominating the communication of these two topics were “Companies” (25.98%) and “Communication/Radio/Journals/Magazines/Podcasts” (22.05%) (Table 5).

“Companies” (25.98%) dominated the communication of the *plantbased* topic promoting products for *vegan* or *vegetarian* consumers mainly. Among the main products advertised were *alternative protein* products such as high in protein pasta, plant-based milk, and meat. Unlike the “Companies” group, the “Communication/Radio/Journals/Magazines/Podcasts” (22.05%) group posted information about the production of *plant-based* and *alternative protein* products highlighting the food technology (*foodtech*), and *foodinnovation* of *foodbusinesses* and *startups* in the production of such products (Table 5).

In the case of the topic *vegan*, “Companies” (48.19%) promoted *plantbased*, *meatalternative* or *alternativeprotein* products for *vegan*, *vegetarian*, and *flexitarian* consumers. Some hashtags represent names, either of companies (e.g., *nextmeat*), or others such as the case of *seaspiracy*, a movement (and a documentary) that seeks to expose how the fishing industries impact the oceans (www.seaspiracy.org). The *seaspiracy* hashtag is used by companies to remind consumers that fishing affects the oceans, and promote the consumption of algae as an *alternativeseafood* or *sustainableseafood*. “Communication/Radio/Journals/Magazines/Podcasts” (18.07%) promote the themes addressed in their media, such as *plantbased* or *meatalternative* recipes, or ingredients for *vegan*, *vegetarian*, and *flexitarian* consumers (Table 5).

Climatechange and climateaction

Although mostly used together, *climatechange* (120) was used in more posts than *climateaction* (93). The main source of both topics was the group “Network/Associations/Commerce Chamber” (*climatechange* = 28.33%, *climateaction* = 32.26%). While the most related hashtag for *climatechange* was *climateaction*, *impactinvesting* was the main hashtag related to *climateaction*. As Table 6 shows, they share 9 of the main 10 hashtags because these two hashtags were used mostly simultaneously. In particular, the main source was an organization bringing together investors (*impactinvesting*, *foodfund*) and *foodentrepreneurs* to catalyze the flow of capital to social enterprises (*socent*), or *foodstartups* working on *regenerativeagriculture*, and other food businesses.

“Companies” were the second group leading these topics (*climatechange* = 14.17%, *climateaction* = 20.43%). Nevertheless, here the related hashtags were, among others, words used in slogans, characteristics of the production, or the philosophy of the company (e.g., organic legumes grown in *healthysoil* for *sustainableliving*) (Table 6).

Agriculture and farm

While *farm* was the most related hashtag for *agriculture*, *agriculture* was the most related hashtag for *farm*.

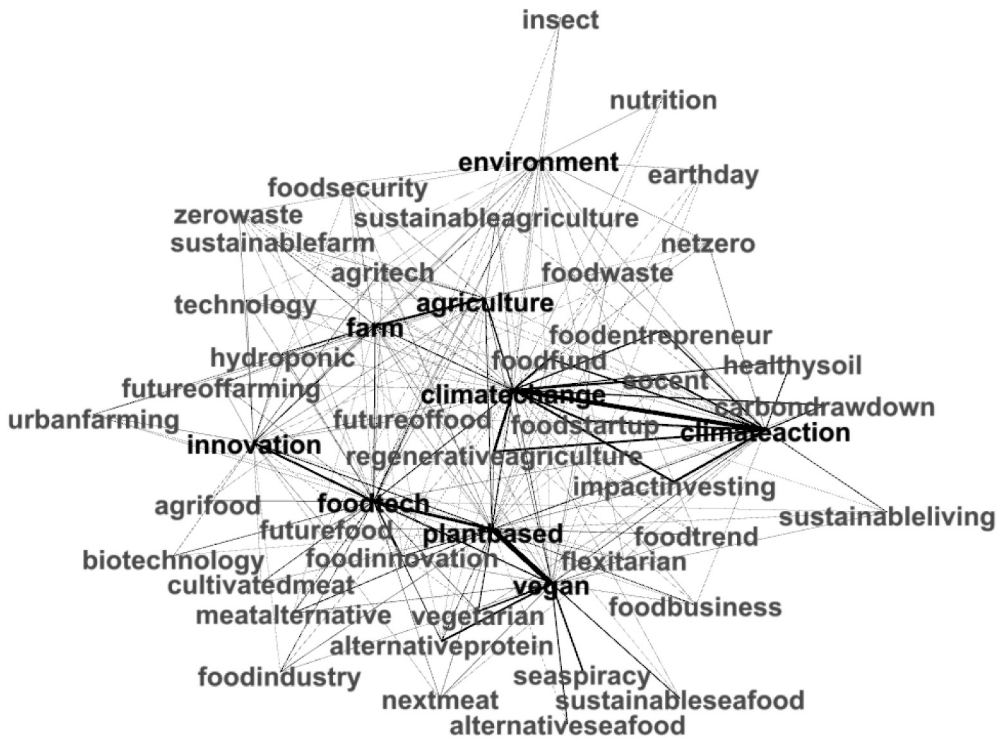


Figure 2. Main 9 topics and their top 10 related hashtags.

The topic *agriculture* was led by “Communication/Radio/Journals/Magazines/Podcasts” (21.54%) that promoted themes such as *sustainablefarming*, *sustainableagriculture*, *hydroponics*, etc., followed by “Companies” (13.85%) that promoted *plantbased* products for *vegan* consumers, or technology (*agritech*) for *sustainableagriculture* or *sustainablefarming*. Regarding *foodsecurity*, some companies emphasize that their *sustainableagriculture* such as *hydroponic* fights against *foodwaste* and therefore *climatechange* (Table 7).

Regarding the *farm* topic, “Companies” (27.12%) promote products produced with innovative (*innovation*) technology (*foodtech*) such as *hydroponic* for *sustainablefarming*/*sustainableagriculture* underlining their concern for *foodsecurity* and *climatechange*. “Communication/Radio/Journals/Magazines/Podcasts” (25.42%) promoted the information in their media such as *sustainableagriculture*, *sustainablefarming*, *agriculture*, etc.

Foodtech and innovation

Foodtech (food technology) and *innovation* were topics led by “Companies.” *Plantbased* was the most related hashtag for *foodtech*, and *foodtech* was the most related hashtag *innovation*.

In the case of *foodtech*, “Companies” (42.70%) used hashtags to describe their products or highlight their characteristics (e.g., *cultivatedmeat*, *plantbased* proteins, *alternativeprotein*). In general, they are products or services related to *plantbased* ingredients.

Table 5. Associated hashtags to *plantbased* and *vegan* topics.

plantbased			vegan		
Associated hashtag	Frequency	%	Associated hashtag	Frequency	%
vegan	31	9.81	plantbased	31	11.88
foodtech	18	5.70	alternativeprotein	24	9.20
vegetarian	13	4.11	seaspiracy	21	8.05
foodinnovation	12	3.80	vegetarian	20	7.66
Meatalternative	11	3.48	alternativeseafood	14	5.36
foodbusiness	8	2.53	sustainableseafood	13	4.98
alternativeprotein	7	2.22	foodtech	8	3.07
regenerativeagriculture	6	1.90	nextmeat	6	2.30
foodindustry	6	1.90	flexitarian	6	2.30
foodtrend	6	1.90	meatalternative	5	1.92
Other 89 hashtags	198	62.66	Other 63 hashtags	113	43.30
Total	316	100	Total	261	100

Table 6. Associated hashtags to *climateaction* and *climatechange* topics.

climateaction			climatechange		
Associated hashtag	Frequency	%	Associated hashtag	Frequency	%
impactinvesting	29	8.38	regenerativeagriculture	32	8.40
climatechange	26	7.51	impactinvesting	27	7.09
Regenerativeagriculture	25	7.23	foodstartup	26	6.82
foodstartup	23	6.65	socent	26	6.82
socent	22	6.36	climateaction	26	6.82
foodfund	20	5.78	foodfund	24	6.30
carbondrawdown	16	4.62	foodentrepreneur	18	4.72
foodentrepreneur	16	4.62	carbondrawdown	17	4.46
healthysoil	13	3.76	healthysoil	14	3.67
sustainableliving	9	2.60	agriculture	9	2.36
Other 57 hashtags	147	42.49	Other 77 hashtags	162	42.52
Total	346	100	Total	381	100

Table 7. Associated hashtags to *agriculture* and *farm* topics.

agriculture			farm		
Associated hashtag	Frequency	%	Associated hashtag	Frequency	%
farm	13	10.08	agriculture	13	8.78
climatechange	9	6.98	hydroponic	10	6.76
Sustainableagriculture	6	4.65	sustainablefarm	7	4.73
agritech	6	4.65	climatechange	6	4.05
plantbased	5	3.88	futureoffarming	6	4.05
foodwaste	5	3.88	sustainableagriculture	5	3.38
sustainablefarm	4	3.10	urbanfarming	5	3.38
foodsecurity	4	3.10	foodtech	5	3.38
vegan	3	2.33	innovation	5	3.38
hydroponic	3	2.33	foodsecurity	4	2.70
Other 52 hashtags	71	55.04	Other 52 hashtags	82	55.41
Total	129	100	Total	148	100

The second group by the number of posts was “Communication/Radio/Journals/Magazines/Podcasts” (26.97%), which used hashtags to inform about the topics they were presenting in their media (e.g., *foodinnovation*, *alternativeprotein*, *meatalternative*, *biotechnology*, etc.). (Table 8).

Table 8. Associated hashtags to *foodtech* and *innovation* topics.

foodtech			innovation		
Associated hashtag	Frequency	%	Associated hashtag	Frequency	%
plantbased	18	6.08	foodtech	13	9.70
foodinnovation	16	5.41	hydroponic	7	5.22
innovation	13	4.39	plantbased	6	4.48
futureoffood	10	3.38	agritech	6	4.48
Alternativeprotein	10	3.38	farm	5	3.73
cultivatedmeat	9	3.04	futurefood	4	2.99
vegan	8	2.70	technology	4	2.99
meatalternative	8	2.70	zerowaste	4	2.99
biotechnology	8	2.70	urbanfarming	4	2.99
agrifood	7	2.36	futureoffood	3	2.24
Other 61 hashtags	189	63.85	Other 48 hashtags	78	58.21
Total	296	100	Total	134	100

Regarding *innovation*, “Companies” (27.12%) that call themselves food-tech companies promote products related to the *technology* used in farming (*farm*) and *agriculture*, for the *futureoffood* and *zerowaste* (e.g., ultra-high protein crops). The communication of “University/Research project/Consortium” (21.62%) was different. Although using the same hashtags, they communicated the result of their research projects funded by the Horizon European grants mainly (e.g., for the production of functional bio-based ingredients (*biotechnology*), or to help *farmers* adopt new *technology* and ideas for sustainable food production).

Environment

The most related hashtag for the topic *environment* was *foodtech*. Here, besides promoting products, “Companies” (33.33%) led the communication offering services such as training and capacity-building for the development of agriculture systems for *sustainableagriculture* highlighting technology (*foodtech*), *innovation*, and *nutrition* among others. “Consultant/Academic/Policy makers/Activists” (18.18%) led the conversation in second place promoting ideas about the *earthday*, *nutrition*, *insect* consumption, *climateaction*, or *netzero* issues, among others (Table 9).

Table 9. Associated hashtags to *environment* topic.

environment		
Associated hashtag	Frequency	%
foodtech	4	4.94
innovation	3	3.70
Climateaction	3	3.70
foodwaste	3	3.70
netzero	3	3.70
nutrition	3	3.70
earthday	3	3.70
insect	3	3.70
climatechange	2	2.47
sustainableagriculture	2	2.47
Other 44 hashtags	52	64.20
Total	81	100

Regarding the interconnection of sustainable food-related hashtags, an analysis of the top ten hashtags with the highest betweenness centrality scores showed that seven main topics overlap with those exhibiting the highest betweenness centrality (i.e., *plantbased*, *climatechange*, *vegan*, *climateaction*, *agriculture*, *farm*, and *foodtech*). Additionally, three hashtags also appeared to have high betweenness centrality scores, although they did not represent main topics (i.e., *organic*, *sustainableliving*, and *sustainablefarm*) (Table 10). The hashtag *plantbased* was the most relevant among these since it had the highest betweenness centrality score, indicating that it acted as a bridge linking different thematic communities within the network.

Discussion

This exploratory study aimed to analyze posts about sustainable foods on X by identifying the key topics discussed, examining which topics are emphasized by different user groups, and exploring the hashtags that act as bridges between communication communities. The nine main hashtags related to sustainable foods included in the posts were *agriculture*, *climatechange*, *climateaction*, *plantbased*, *vegan*, *farm*, *environment*, *innovation*, and *foodtech*. These topics broadly align with the European Commission’s definition of a “sustainable” food system (EC 2019). However, issues such as food safety, affordability, employment, and food security were rarely present.

The analysis revealed that companies and media organizations dominate most of the communication, where “dominate” or “lead” refer to producing the highest volume of posts on specific topics. Companies mainly focused on *plantbased*, *vegan*, *farm*, *environment*, *innovation*, and *foodtech* content, while media organizations primarily concentrated on *agriculture*. These findings suggest that online narratives about sustainable food are largely shaped by commercial and media organizations promoting plant-based products and innovative farming technologies, often emphasizing product marketing, technological progress, and lifestyle branding. In contrast, social and policy dimensions of sustainability, such as affordability, equity, and food security, tend to be neglected. This imbalance indicates that social media discussions on sustainable food reflect a narrow and commercially driven interpretation of what the term truly entails.

Plantbased was the most frequently used hashtag and showed the highest eigenvector and betweenness centrality scores, indicating its dominant role as a topic and as a hashtag

Table 10. Top 10 hashtags with the highest betweenness centrality scores.

Hashtag	Score
<i>plantbased</i>	3928.04
<i>climatechange</i>	3196.98
<i>vegan</i>	2070.38
<i>Climateaction</i>	1977.56
<i>agriculture</i>	1817.43
<i>farm</i>	1748.08
<i>organic</i>	1593.55
<i>sustainableliving</i>	1572.65
<i>foodtech</i>	1476.61
<i>sustainablefarm</i>	1389.65

that connects related communications. *Vegan* was the hashtag most closely connected with *plantbased*. The prominence of *plantbased* and *vegan* hashtags, driven primarily by company accounts, suggests that sustainable food is being framed as a market opportunity and a marker of responsible consumption. This finding aligns with prior research indicating that sustainability communication in digital media often merges environmental responsibility with lifestyle marketing (Vermeir et al. 2020). While this framing may increase public engagement, it also risks reducing sustainability to a matter of personal environmental choices rather than collective efforts within the food system.

Results showed that references to plant-based were more frequent than references to vegan or vegetarian, which may be related to general associations with these terms and market dynamics. Consumers identified as “vegetarian” or “vegan” are stigmatized (Markowski and Roxburgh 2019) and often seen as a minority group (i.e., vegans) (Davis and Papies 2022). On the contrary, on social media, plant-based eating is typically portrayed as modern, relaxed, a lifestyle suitable for all consumers (Jallinoja, Markus, and Mari 2019). Differences in the associations of plant-based and vegan or vegetarian products have also been reported by studies analyzing labels. Products labeled as plant-based are generally perceived as more appealing than those labeled as “vegetarian” and “vegan” (Ruby, Graça, and Olli 2024), as the term plant-based conveys inclusivity and avoids association with a minoritarian group (Ruby, Graça, and Olli 2024). In contrast, vegan labeling can negatively affect perceptions of taste and healthiness (Demartini et al. 2022). Moreover, while “vegetarianism” is declining in some traditional vegetarian countries (WEF 2022), plant-based products continue to make up a significant portion of the market, although their growth appears to be stabilizing. According to the Good Food Institute (GFI 2024), the U.S. plant-based retail market was valued at \$8.1 billion in 2023, but in 2024, performance varied across different segments. Staple foods declined, while tofu, protein powders, beverages, and desserts experienced growth (GFI 2024). This highlights the importance of understanding not only how plant-based products are labeled and marketed but also how this term is communicated by different users on X.

The close connection between *climatechange* and *climateaction* reflects how networks, associations, and chambers of commerce frequently use these topics, and their related hashtags, to legitimize entrepreneurship, investment, and innovation. Posts using these hashtags often highlighted initiatives such as funding for regenerative agriculture, impact investing, and engagement in social enterprises as signs of civic engagement. This suggests that climate narratives are being used to promote the idea that technological and entrepreneurial progress are effective responses to climate challenges.

Although both hashtags were central to the sustainability discourse, they differed in the degree of emphasis and influence users attribute to them. Regular users did not frequently rely to these terms. People generally care about climate change and are motivated to engage in climate action (Steg 2023), whether by contributing personal income, endorsing pro-climate social norms, or demanding increased political action (Andre et al. 2024). However, research has shown that concerns about climate change can produce anxiety and distress. Taking action can serve as a coping mechanism, as activism reinforces a sense of connection and can be seen as an expression of care (Budziszewska and Jonsson, 2021). Moreover, the framing of climate messages shapes public responses. Messages that emphasize losses, such as climate change, tend to evoke anger, negative feelings, and distrust (Jenkins et al. 2023), while messages focusing on how consumers

can do more for the world or highlighting potential benefits of sustainable actions (i.e., *climateaction*) (Balaji, Jiang, and Jha 2021) foster positive attitudes, increase environmental concern, and boost the intention to adopt recommended behaviors (Bhatnagar and McKay-Nesbitt 2016). However, while climate action can inspire optimism, it may also distract from addressing the deeper structural causes of unsustainable food production and consumption.

Regarding *agriculture* and *farm* topics, media organizations focused on *agriculture*, while companies led the *farm* communication. Agriculture broadly includes all aspects of crop production and animal domestication, whereas farming specifically involves land cultivation and livestock raising (Gamage et al. 2023). This study found that the media associated agriculture with the production of plant-based and vegan products, while companies linked farming to innovation, food technology, and sustainable practices aimed at the future. This difference reveals two conflicting frames: one promoting sustainable agriculture as an ecological practice, and another connecting sustainable farming with technological modernization. Both frames associate sustainability with progress in food production through technological advances. Although this aligns with Goal 2 Zero Hunger of the SDGs, which calls for promoting sustainable agriculture with modern technologies (UN 2023), these framings overlook participatory or systemic approaches and fail to address that, although industrialized farming produces low-cost food, it pollutes water, air, and soil (UN 2021). Biotechnology and technological advancements are likely to continue this trend (Johnson 2006), even though the main aim of sustainable agriculture should be to ensure profitability, environmental health, and social and economic well-being by using techniques that mimic natural processes, preserve soil fertility, and prevent water pollution (UN 2021).

The *environment* topic also demonstrated how sustainable food communication differentiates between technology and food sustainability issues. Companies often associated environmental responsibility with *innovation*, using hashtags like *foodtech* and *nutrition* to highlight products and services that aim to improve agricultural efficiency and sustainability. The use of hashtags related to *foodtech* and *innovation* by companies further supports this, indicating that social media communication about sustainable food by companies favors technological progress for agriculture and farming, as well as the production of *cultivatedmeat* or *alternativeproteins*. In contrast, posts from consultants, academics, and activists frame environmental issues within broader sustainability challenges such as *netzero*, *insect-based nutrition*, and planetary health.

Across all themes, the network structure revealed that a few highly visible hashtags act as bridges connecting different sustainable food conversations, while others remain isolated. Hashtags like *plantbased* and *climatechange* link separate communities, serving as discursive hubs, indicating that public discourse emphasizes certain aspects of sustainable food while sidelining others, especially social and ethical dimensions. Understanding these structural imbalances is vital because the narratives dominating online platforms influence how citizens, consumers, and policymakers define what sustainable food means and which actions are considered legitimate or desirable.

The prominence of themes like plant-based diets and technological advances shows that other equally important issues, such as food justice, affordability, cultural heritage, or systemic inequalities, might be overlooked in online communications over time. This narrow focus risks skewing public understanding of what truly defines sustainable food.

To fix this, stakeholders, including marketers, communication experts, and advocacy groups, should actively expand the narrative to include less marketable but essential issues. They can do this by intentionally adding neglected topics to online campaigns, encouraging user-generated content on diverse issues, and working across sectors to amplify voices, especially those outside large corporations. Since public conversations influence perceptions and policies, we recommend calls to action that broaden the scope of sustainability to include resilience, fairness, and shared responsibility. Future discussions should move beyond plant-based foods and highlight areas like regenerative agriculture, circular food systems, and indigenous and local knowledge, capturing the complexity of sustainable food challenges and solutions.

The dominance of commercial and media actors raises questions about how these communication patterns affect public understanding of sustainability, especially among those aged 18 to 34, who make up around 70% of X users (Statista 2025). When companies lead the conversation, sustainable food is often framed through narratives of branding, innovation, and market-based solutions. Companies use social media to influence consumer behavior toward sustainable practices (Vladimirova et al. 2024), showcase their corporate responsibility efforts, and promote their products and services (Araujo and Kollat 2018; Maye et al. 2021; Paliwoda-Matiolańska and Nakayama 2024). Indeed, eco-labels and green advertising have been shown to significantly and positively impact green purchase intentions (Nguyen-Viet 2022). While such strategies can raise awareness and normalize sustainable consumption, they also risk reinforcing the commodification of sustainability, turning complex social issues into marketable environmental goals. Therefore, to expand their storytelling to include trade-offs, challenges, and long-term commitments related to sustainable food systems, companies could integrate environmental, social, and ethical sustainability issues into their messaging. This can be achieved by partnering with third-party organizations, researchers, and civil society, which can enhance credibility and encourage genuine dialogue. For example, supporting campaigns or initiatives that raise awareness about often overlooked aspects of sustainable food, such as supply chain labor, community access to food, or biodiversity. However, companies must also stay alert to consumer skepticism about greenwashing and focus on authenticity, transparency, and ongoing communication.

Conversely, the limited participation of research institutions and civil society organizations in discussions about sustainable food diminishes opportunities to share nuanced, evidence-based perspectives. This lack of social media engagement may stem from disinterest, concerns about misinterpretation, reputational risks, difficulty translating scientific evidence into accessible formats, lack of institutional incentives, or resource constraints. To tackle these issues, universities, NGOs, and policymakers could take a more proactive role in disseminating accessible, evidence-based insights on sustainable food systems. For example, universities could focus on making research more accessible via social media and provide training and support for researchers in effective digital science communication. Additionally, while social media can rapidly boost research visibility among broader and younger audiences, its fast-paced and often polarized environment may not always foster nuanced discussions with different groups. Therefore, universities could adopt a diversified communication approach that combines traditional outreach with digital engagement to broaden reach, influence, and credibility. As a result, traditional methods such as policy briefs, public events, or community

engagement could be complemented with collaborations involving established science communicators or influencers. This could counterbalance commercially driven narratives and promote more informed public debates of what truly constitutes sustainable food systems, illuminating complex trade-offs involved in sustainable food transitions, such as food security vs. sustainable use of resources, dietary shifts vs. cultural traditions and preferences, or environmental sustainability vs. economic goals.

This study did not examine potential greenwashing or how audiences interpret, share, and challenge sustainability narratives. Social media environments are inherently participatory; messages can be challenged, reinterpreted, contested, or distorted by users. Consumers, for instance, often avoid products or brands they suspect are greenwashing if they perceive environmental claims as false or misleading (Isac et al. 2024). Thus, while companies may lead the creation of sustainability-related content, they do not fully control how audiences receive, reinterpret, or contest these messages. Research shows that meaning-making around food often reflects the interplay of identities, values, and tensions between cultural traditions and advocacy (Riley and Donaldson 2024). On social media, messages evolve dynamically as they are reframed by diverse users (Molder et al. 2022; Mundt, Ross, and Burnett 2018), and coexist with misinformation, distortion, and competing interpretations (Aïmeur, Amri, and Brassard 2023; Kidd and McIntosh 2016). By mapping who drives particular narratives and how topics interconnect, this study lays the groundwork for exploring how digital communication shapes public literacy about sustainable food. However, fully understanding this discursive process, from content production to reinterpretation and influence across contexts, requires an interdisciplinary approach that integrates communication studies, food systems research, and social psychology. Understanding these interpretive dynamics is essential for designing communication strategies that foster trust, promote transparency, and counter misinformation.

Implications

The findings of this study have significant implications for practice and policy. The limited communication about sustainable food topics such as social equity, affordability, and food security, along with the prominence of communication by fewer stakeholders, highlights the need for collaboration among communication experts, policymakers, and companies. This collaboration should aim to rebalance the conversation through evidence-based storytelling and participatory efforts that inform, inspire, and mobilize a broader audience, helping to develop inclusive communication strategies that promote a more comprehensive public understanding of sustainable food systems. Companies can incorporate social and systemic sustainability issues, like affordability, food justice, and indigenous knowledge, to craft a more complete sustainability narrative. They could also work with third-party organizations, researchers, and civil society to reduce perceptions of greenwashing and increase transparency by balancing marketing with honest communication about real challenges, trade-offs, and ongoing sustainability efforts. Media and policymakers could also emphasize these overlooked topics, fostering policy debates and public campaigns that advocate participatory and systemic approaches to sustainability. Researchers and universities can boost their visibility by strategically using social media to share accessible, evidence-based research, making scientific insights more

relatable to the public. Partnering with science communicators and digital influencers can help attract younger audiences and combat misinformation. Additionally, blending traditional methods like policy briefs and events with digital campaigns can foster a balanced and credible discussion of complex issues. Civil society and advocacy groups can use social media to raise awareness about social justice, equity, and local or traditional knowledge related to sustainable food issues. This multi-stakeholder approach can bridge the gap between commercial narratives, presenting a comprehensive understanding of sustainable food systems through interdisciplinary strategies that craft messages that resonate, educate, and mobilize different audiences.

Limitations and future research

As with any other research, this study has limitations. First, the analysis covers only one year of posts on X and focuses exclusively on the hashtags, which may not fully capture the broader or evolving discussions about sustainable food on the platforms. Other hashtags could reveal different patterns regarding which groups post and lead conversations, and the analysis of the full content of posts could provide a more comprehensive understanding of what topics are being discussed, their emphasis, and framing. Extending the timeframe or comparing multiple periods could provide a more detailed picture. Additionally, many accounts were no longer active at the time of the analysis, which may have influenced the results.

This study also did not examine sentiment or valence, as the focus was on hashtag relationships rather than the tone or context of the posts. Future research could combine a wider range of hashtags with sentiment analysis and user characteristics to gain a deeper understanding of online conversations about sustainable food. Similarly, this research did not consider how users interacted with posts through likes, retweets, or replies, limiting the understanding of how sustainable food messages resonate with audiences. Incorporating engagement metrics could help identify which types of content generate higher interaction and influence visibility on social media.

To address the former, future research could employ mixed-methods approaches. For example, qualitative methods like interviews, focus groups, or digital ethnography could reveal how users interpret, resist, or negotiate the meaning of sustainability in food, especially around contested narratives such as skepticism toward corporate sustainability or the lived experience of affordability constraints in sustainable food consumption. Additionally, expanding quantitative analysis could track how key topics change over time, sentiment analysis could measure emotional responses to different sustainable food topics, and engagement metrics such as likes, shares, or comments could compare engagement patterns across platforms and audiences. These studies would offer a more comprehensive and actionable understanding of how online platforms both reflect and influence sustainable food systems.

The findings reflect only users active on X and do not account for those engaging with sustainable food offline or on other platforms. Future research could use qualitative methods, such as interviews with social media users or ethnographic observation, to examine how audiences engage with, negotiate, or resist these narratives. This would help bridge the gap between message production and socialization, offering a more complete understanding of the impact of social media communication on sustainable food behaviors.

Conclusions

The findings of this study indicate that content about sustainable food on X is predominantly produced by companies and media organizations. In contrast, universities, researchers, NGOs, activists, and ordinary users play a much less prominent role, suggesting that the discourse on sustainable food is largely shaped by actors with commercial interests. This imbalance in who disseminates information and how they frame sustainable food may influence the variety and type of content that consumers encounter. It is important, however, to recognize that social media, particularly X, represents only one of many channels through which consumers can access information about sustainable food.

Many studies assume that general users generate most social media content. Yet, this analysis reveals that unaffiliated users did not lead discussions about sustainable food on X, challenging the common assumption that consumers are the primary voices in online discourse. Accordingly, caution is needed when interpreting social media content, as not all posts can be assumed to reflect consumer perspectives. At the same time, the limited visibility of consumer-generated content does not necessarily indicate a lack of engagement or understanding, as audiences may participate in more passive ways, such as reading, liking, or sharing posts.

The results also show that the main topics associated with the hashtag #sustainable-food are communicated differently depending on the source. This highlights the importance of identifying and distinguishing message sources in social media analyses. Future research should classify messages according to their origin to better differentiate between regular users and other actors, enabling more precise insights into how various groups discuss sustainable food topics online.

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Appendix

Table A1. List of hashtags by group and frequency.

Hashtag	Group	Frequency	Hashtag	Group	Frequency
aeroponic	1	8	urbanfarming	4	27
agroecology	1	14	vegetarian	4	22
Allotment	1	9	zerowaste	4	23
alternativeseafood	1	28	alga	5	9
animalwelfare	1	9	alternativefarming	5	7
australium	1	6	bioreactor	5	6
bluegrowth	1	6	blockchain	5	7
bristol	1	7	buffalofoodie	5	15
cea	1	6	buffalosmallbusiness	5	17
cellbased	1	9	buylocal	5	6
cleanfood	1	7	cambridge	5	18
computermodeling	1	12	canadaagriculture	5	7
eathealthy	1	10	choosepackaging	5	7
edibleinsect	1	13	cleanketo	5	6
edinburgh	1	6	communityfood	5	7
ethical	1	10	computationalbiology	5	10
eu	1	8	costoflivingcrisis	5	24
farmersmarket	1	8	cowsmilk	5	7
farminguk	1	8	dairyfarming	5	7
fishfarmer	1	6	ddpyoga	5	8
fishfarming	1	18	ecoagrifoodchallenge	5	9
fishgeek	1	6	ecommerce	5	14
foodloss	1	22	ecopreneur	5	7
foodlover	1	14	environmentalbusiness	5	7
foodpolicy	1	7	ethicalmeat	5	7
foodprocessing	1	6	eugreendeal	5	6
foodstudy	1	6	failsworth	5	6
foodsupply	1	9	feedingthecity	5	7
fresh	1	7	finland	5	6
fruit	1	9	foodchain	5	6
glasgowdeclaration	1	7	foodforthought	5	8
goodfood	1	12	foodpartnership	5	17
grocery	1	7	foodprint	5	7
healthydiet	1	7	freightfarm	5	8
healthysoil	1	14	getoldhamgrowing	5	11
homemade	1	7	gfsi22	5	7
hospitality	1	7	globalhunger	5	7
insectprotein	1	6	growarow	5	6
instafood	1	9	healthyliving	5	8
lamb	1	6	icymi	5	6
locallygrown	1	8	impact	5	9
microalga	1	8	irishfood	5	14
oldham	1	11	issbethechange	5	9
onehealth	1	9	knowyourfish	5	15
organicfarming	1	9	knowyourfisherman	5	13
palmoil	1	7	lambtastic	5	7

(Continued)

Table A1. (Continued).

Hashtag	Group	Frequency	Hashtag	Group	Frequency
pasta	1	8	lchfdiet	5	6
podcast	1	8	letstalkaboutfood	5	15
pulse	1	5	maternalhealth	5	6
ras	1	13	mediketo	5	6
recirculatingaquaculture	1	9	micronutrient	5	7
reducefoodwaste	1	15	migrantworker	5	11
reducewaste	1	9	mussel	5	6
regenerativefarming	1	6	nextgenerationip	5	6
science	1	6	noplastic	5	11
seasonal	1	10	nordiccountry	5	6
seaweed	1	13	nosingleuse	5	10
sheffield	1	13	onlyeg	5	6
soilhealth	1	6	ontag	5	7
sustainablediet	1	7	optimenergy	5	7
thepentairlife	1	6	pacificcloudseafood	5	20
trubeef	1	11	packaging	5	7
vegetarianfood	1	11	patent	5	6
veggie	1	8	plantmilk	5	7
wildabout	1	14	publichealth	5	8
yummy	1	7	repurposeyoursurplus	5	7
zerofoodwaste	1	25	safefood	5	6
agriculture	2	65	seasonalfood	5	6
climateaction	2	93	seaspiracy	5	24
climatechange	2	120	servingbetter	5	11
environment	2	33	shopnow	5	10
farm	2	59	stopfoodwaste	5	9
foodtech	2	89	superfood	5	5
innovation	2	37	sustainablebusiness	5	9
plantbased	2	127	sustainableenergy	5	8
vegan	2	83	sustainablelifestyle	5	31
agrifood	3	22	sustainablemilk	5	7
altprotein	3	9	thepossible	5	8
aquaponic	3	9	turtletree	5	6
bakery	3	6	ukharvest	5	7
beef	3	9	urbangarden	5	6
biobased	3	9	veganfoodie	5	7
biodiversity	3	20	volunteer	5	7
biomass	3	14	wholefood	5	5
blueeconomy	3	6	wildfood	5	8
carbondrawdown	3	20	zerowasteliving	5	11
cleanmeat	3	16	zerowastetakeout	5	11
climateemergency	3	11	aquaculture	6	94
coffee	3	6	biotechnology	6	28
delicious	3	10	carbonfootprint	6	27
earthday	3	16	circulareconomy	6	53
farmer	3	11	climatecrisis	6	25
farmlife	3	10	community	6	19
fishery	3	20	cultivatedmeat	6	37
foodentrepreneur	3	21	dairy	6	16

(Continued)

Table A1. (Continued).

Hashtag	Group	Frequency	Hashtag	Group	Frequency
foodjustice	3	10	ecofriendly	6	13
foodproduction	3	12	flexitarian	6	18
foodsafety	3	24	foodscience	6	18
gardening	3	10	foodstartup	6	35
growyourown	3	26	foodtrend	6	17
healthylifestyle	3	7	futurefood	6	16
indium	3	7	gogreen	6	9
insect	3	8	health	6	23
lowcarb	3	6	healthyeat	6	21
milk	3	6	impactinvesting	6	54
nutraceutical	3	6	meat	6	14
ocean	3	7	meatalternative	6	23
organicfood	3	22	meatfree	6	8
plantbaseddiet	3	9	plantbasedprotein	6	25
recipe	3	7	supermarket	6	9
research	3	8	sustainablefoodsystem	6	14
retail	3	6	technology	6	9
seafood	3	42	veganfood	6	12
shoplocal	3	19	verticalfarm	6	22
sidestream	3	34	byproduct	7	11
supplychain	3	17	cellularagriculture	7	11
supportlocal	3	12	dairyfree	7	12
sustainabledevelopmentgoal	3	13	diversity	7	13
sustainablepackage	3	15	eatlocal	7	27
sustainableseafood	3	41	esg	7	21
tasty	3	6	farmtofork	7	29
upcycling	3	7	farmtotable	7	19
veganuary	3	10	fish	7	21
wheat	3	6	foodfund	7	32
worldfoodday	3	17	foodie	7	15
agritech	4	47	foodnew	7	10
alternativeprotein	4	63	foodservice	7	7
climate	4	21	foodsovereignty	7	9
foodbusiness	4	17	futureoffarming	7	7
foodindustry	4	33	greenhouse	7	6
foodinnovation	4	45	growyourownfood	7	25
foodsecurity	4	54	healthy	7	14
foodsystem	4	80	highprotein	7	5
foodwaste	4	77	horizoneu	7	34
futureoffood	4	36	indoorfarm	7	7
healthyfood	4	28	japan	7	6
hydroponic	4	21	keto	7	13
localfood	4	50	local	7	13
nutrition	4	42	netzero	7	19
organic	4	46	nextmeat	7	7
plantbasedfood	4	27	nongmo	7	15
protein	4	38	racialequity	7	8
regenerativeagriculture	4	64	savetheplanet	7	7
startup	4	23	socent	7	34

(Continued)

Table A1. (Continued).

Hashtag	Group	Frequency	Hashtag	Group	Frequency
sustainableagriculture	4	46	socialenterprise	7	15
sustainablefarm	4	41	socialjustice	7	14
sustainableliving	4	45			

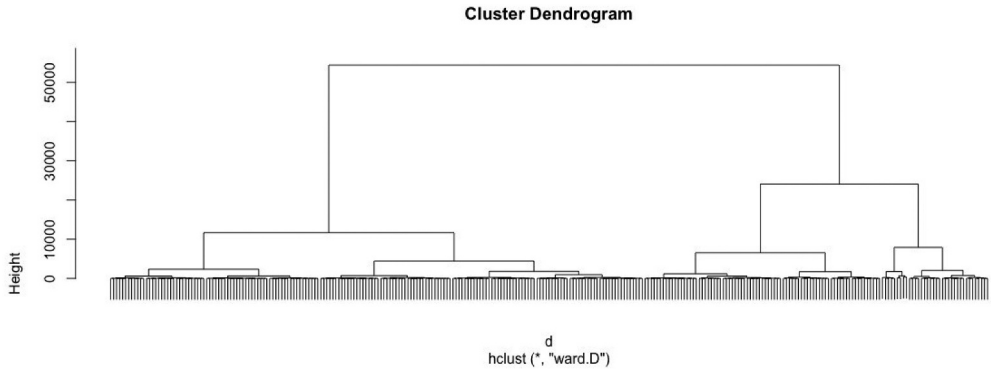


Figure A1. Dendrogram of cluster analysis.