Applying Digital Technology to Understand Human Experiences of Climate Change on Food Security and Mental Health: A Scoping Review

Jasmin Bhawra, Nadine Elsahli, Jamin Patel

Submitted to: JMIR Public Health and Surveillance
on: October 28, 2023

Table of Contents

Applying Digital Technology to Understand Human Experiences of Climate Change on Food Security and Mental Health: A Scoping Review

Jasmin Bhawra[1]; Nadine Elsahli[2]; Jamin Patel[2]

[1]School of Occupational and Public Health Faculty of Community Services Toronto Metropolitan University Toronto CA
[2]Faculty of Health Sciences School of Health Studies Western University London CA

Corresponding Author:
Jasmin Bhawra
School of Occupational and Public Health
Faculty of Community Services
Toronto Metropolitan University
288 Church St., Suite 300 Toronto, Ontario
Toronto
CA

Abstract

Background: The global impact of climate change ranges from extreme heat and poor air quality, to extreme weather events that endanger entire ecosystems and our way of life. Increasing climate events place undue stress on communities, both indirectly via their impact on food security, as well as increasing ecoanxiety. Ubiquitous digital devices have the potential to connect community members to effectively monitor existing and emerging climate-related crises due to their ability to enable rapid response, instant communication, and knowledge sharing.

Objective: This scoping review aims to identify digital apps used to capture climate change impacts on both food security and mental health to inform necessary development of digital climate change initiatives.

Methods: The search strategy included review of PubMed and Web of Science databases, as well as manual grey literature searches on Google Scholar and relevant organizational (i.e., governmental, non-profit) websites to identify articles and reports published over the past decade (January 2012 to July 2023). Three separate searches were conducted to identify apps focused on climate change and: 1) food security; 2) mental health; 3) food security and mental health. Initial screening was conducted of article titles and abstracts for inclusion of key search terms, i.e., digital platforms, applications, or tools. Articles focused on climate change impacts on wildlife or agriculture (i.e., not on human food security) were excluded. Full-text screening was conducted by two reviewers to generate a final list for data abstraction to a summary table.

Results: A total of 14 digital apps were shortlisted, including 8 articles and 6 applications found through grey literature searches. A total of 7 apps focused on climate change and food security, while 7 focused on climate change and mental health. No platforms examined the intersection of climate change, food security, and mental health. The final shortlist included studies conducted across three continents: Europe (n=3), Africa (n=1), Asia (n=1), with three studies not reporting the geographic region. Several apps were designed to enable user-user communication (n=5), build a knowledge database (n=5), collect and analyze data to generate insights (n = 3), and/or serve as educational tools (n=2).

Conclusions: While some apps focused on food security or mental health, there were no apps identified which took a holistic approach to assessing food systems and health outcomes associated with experiences of climate change. Given the frequency of adverse climate change-related events globally, there is an urgent need for work focused on minimizing food insecurity and mental distress. By harnessing the power of digital apps, we can empower communities to effectively respond to and navigate climate change impacts on both food security and mental health.

(JMIR Preprints 28/10/2023:54064)
DOI: https://doi.org/10.2196/preprints.54064

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Review Article

Applying Digital Technology to Understand Human Experiences of Climate Change on Food Security and Mental Health: A Scoping Review

Authors: Jasmin Bhawra, PhD[1],* Nadine Elsahli[2], Jamin Patel[2]
Affiliations:
1. CHANGE Research Lab, School of Occupational and Public Health, Faculty of Community Services, Toronto Metropolitan University, Toronto, ON, Canada
2. School of Health Studies, Faculty of Health Sciences, Western University, London, ON, Canada

***Corresponding Author**:
Jasmin Bhawra, PhD

350 Victoria St., Daphne Cockwell Health Sciences Complex,
School of Occupational and Public Health, Faculty of Community Services,
Toronto Metropolitan University,
Toronto, ON, M5B 2K3

Email: jasmin.bhawra@torontomu.ca
Phone: 416-979-5000 x553466

Abstract

Background: The global impact of climate change ranges from intense heatwaves and poor air quality, to extreme weather events that endanger entire ecosystems and our way of life. Adverse climate change events place undue stress on food and health systems, with consequences for human food security and mental health status. Ubiquitous digital devices, i.e., smartphones, have the potential to manage existing and emerging climate-related crises given their ability to enable rapid response, instant communication, and knowledge sharing.

Objective: This scoping review aims to identify digital applications (apps) being used to capture or

address climate change impacts on food security and mental health to inform the development of a digital citizen science initiative.

Methods: A scoping review was conducted using three peer-reviewed databases (PubMed, IEEE Xplore, Web of Science), as well as manual grey literature searches of relevant organizational (i.e., governmental, non-profit) websites to identify articles and reports published between January 2012 and July 2023. Three separate searches were conducted in each database to identify digital apps focused on climate change and: 1) food security; 2) mental health; and 3) food security and mental health. Two reviewers conducted initial screening, with a third reviewer resolving any discrepancies. Articles focused on climate change impacts on wildlife or agriculture (i.e., not human food security) were excluded. Full-text screening was conducted for shortlisted articles, and a final data abstraction table was generated summarizing key app features, contextual factors, and participant involvement.

Results: From 656 records screened, 14 digital apps met inclusion criteria. The food security apps (n=7) aimed to capture traditional knowledge to preserve food systems, conduct food security assessments, and aid users in decreasing food insecurity risk while promoting food sustainability. The mental health apps (n=7) assessed climate change-related stress and provided users with coping strategies following adverse weather events. No digital apps examined the intersection of climate change, food security, and mental health. Key app features included user-to-user communication (n=5), knowledge databases (n=5), data collection and analysis (n=3), gamification (n=1), and/or educational resources (n=2) to address climate change impacts on food security or mental health. Three approaches to participant involvement were used across studies, including contributory (n=1), collaborative (n=1), and co-creative (n=1) to ensure relevance and use of digital apps.

Conclusions: The majority of digital apps identified provided a service to citizens to either prevent adverse climate change-related health impacts or manage these effects following an acute event or natural disaster. The capacity of ubiquitous digital tools to enable near real-time communication, involvement of various stakeholder groups, as well as their ability to share relevant educational resources in a timely manner, are important for developing tailored climate change adaptation and mitigation strategies across jurisdictions.

Keywords: Climate change; digital health; ecoanxiety; environmental hazards; food security; mental health; scoping review; smartphone apps; digital apps; mobile health

Introduction

Climate change has been identified as one of the biggest health crises of our time [1–3]. Numerous countries and governmental agencies have committed to various targets to combat climate change as part of the Paris Agreement amidst profound global impacts – ranging from intense heat and poor air quality, to extreme weather events that endanger entire ecosystems and our way of life [4–10]. Research has identified a myriad of direct and indirect risks that climate change has posed to human health, wellbeing, and ultimately survival in the 21st century [2,5,8,10–12].

Among the many impacted systems, evidence clearly demonstrates the effects of climate change on food systems given the sensitivity of agriculture to weather conditions. Climate change has not only impacted the frequency and severity of extreme weather events, but also the timing and length of seasons, precipitation, and temperature [7,9,13,14]. These weather conditions have a direct relationship with growing seasons, soil fertility, nutrient bioavailability, pest resistance, and crop yield, i.e., food supply [13–15]. As a result, human food security is directly connected to climactic conditions and the global food supply, with people living in geographically vulnerable areas (i.e., rural, remote, coastal or northern arctic regions) [16–18] and those whose livelihoods are closely connected to the land (i.e., farmers, Indigenous communities) experiencing the greatest risks to their food security [9,14,19,20]. The Coronavirus pandemic reminded the world of the global

interconnectedness of its food supply [21], as it affected all populations – and not only those previously deemed to be living in areas geographically vulnerable to adverse climate change events [22–24]. Increasing frequency of extreme weather events [24]also directly affects mental health [21,22], with the term ‘solastalgia’ coined to refer to the specific mental distress caused by environmental degradation and climate change [25]. Solastalgia has become increasingly prevalent in regions experiencing adverse weather events, especially where there is a lack of support or dedicated adaptation strategies [8].

The specific mechanisms linking climate change and mental health are still being explored[26]; however, the occurrence of specific climate change-related events (i.e., extreme heat waves, flooding) have been found to increase stress, headaches, psychiatric hospitalizations, post-traumatic stress disorder, and suicide rates – particularly among patients with pre-existing mental health conditions, and among climate refugees who have been displaced [26–33]. In addition to the direct impacts of climate change on mental health, studies have also shown indirect impacts of climate-related events such as heatwaves on human behaviour, including increased aggression and criminal activity [34–36], as well as low mood and impaired cognitive functioning resulting from heat stress [34,37,38]. Overall, adverse mental health impacts are worse among populations experiencing vulnerability, as they often lack control over climate change adaptation and mitigation strategies [39,40]. Other indirect effects of climate change and mental health could potentially result from experiences of climate change-related food insecurity [25,41,42]. Food insecurity research to date describes the experience as not just a physical health issue (i.e., increasing the risk of malnutrition and nutrient deficiencies), but also a significant mental health challenge [17,41–44]. Families struggling with food security commonly report stigma, with significant shame, anxiety, stress, and even depression associated with not being able to access or afford adequate amounts of food [45–47]. Thus, in the current global scenario of exacerbated food insecurity connected to climate change, we must consider the combined experience of mental distress from both direct and indirect climate change impacts. Several studies have emerged exploring this important connection [48,49] however, there is still a significant dearth of evidence in terms of the long-term effects of climate change on mental health through its detrimental impact on human food security.

Capturing the intersection of these complex global health issues requires leveraging existing and emerging technology [50–52]. Digital applications (apps) have long been used to track changing weather patterns and climate events [40,53] but the increasing frequency and severity of climate change warrants citizen engagement and participation to better understand both specific impacts, as well as targeted solutions in the age of climate emergency [1,5,12]. Citizen science has a longstanding history of citizen engagement to capture local environmental impacts. It has proven to be particularly useful in tracking biodiversity loss [54,55], monitoring marine litter [56,57], and measuring air pollution levels across jurisdictions [58,59] for a deeper understanding of our ecological landscape.

Research has shown that digital technology can enhance early warning and emergency response systems while fostering citizen engagement for community health issues [35]. For instance, research-based digital apps such as ‘Siaga Bencana’ and the ‘Kanazawa and Kochi Disaster Preparedness System’ leverage technology to assist individuals in areas prone to natural disasters [36,37]. Moreover, apps like ‘InaRisk Personal’ use innovative tools such as cartographic visualization to help improve knowledge of environmental hazards among youth [38] Despite these advances, there is limited evidence of mobile apps focusing on food insecurity or mental health in a climate emergency.

Over the past decade, there has been an influx of digital apps focused on addressing mental health

disorders in general [60–64] or household food security [26] which include a variety of interactive features such as gamification [63] and digital chatbots [64] to manage anxiety and [26] connect users to food assistance programs [65]. The rapid advancements in the field of mobile apps show the prominence of ubiquitous digital devices for addressing a range of issues requiring effective monitoring and management, i.e., climate change or health-related crises [50,52,66].

However, a key gap persists when we consider digital resource access issues among vulnerable communities, particularly in the global south, which are also facing the brunt of adverse climate change impacts [23,40,66–68]. This gap – referred to as the global digital divide – is characterized by the 'first-level' digital divide (i.e., differences in digital access among citizens), as well as the 'second-level' digital divide (i.e., differences in citizens' usage of computers and the internet) [69]. The global digital divide can be attributed to various factors. First, smartphone penetration varies across the global south. Smartphone ownership in countries such as India, South Africa, Ghana, and Nigeria is very high [70], whereas there is relatively low access in Tanzania [71] and the Central African Republic [72]. Hence, the issue with access to digital apps is not simply a factor of smartphone affordability, as the majority of the global population owns smartphones. Instead, the issue of *Internet inequity* [73,74] plays a larger role, as not all populations have affordable or easy access to Internet. Lack of internet access may thereby prevent citizens' participation in digital research or global climate change initiatives. Moreover, differences in digital literacy levels among vulnerable sociodemographic groups can further the second-level digital divide and potentially deepen existing inequalities [75]. For instance, older individuals [76] and people with cognitive disabilities or communication challenges [77] often face barriers to utilizing digital technologies effectively. Limited digital literacy skills among these groups can hinder their ability to fully participate in the digital economy, access essential services, and engage with digital tools for addressing pressing challenges like climate change [75,76,78].

Despite advances in citizen science [79–81] and the application of digital technologies globally, no study to date has examined how or if digital tools are addressing the intersection of climate change, food security, and mental health. Thus, this scoping review aims to identify digital apps being used to capture and address human experiences of climate change on both food security and mental health to inform the development of a digital citizen science initiative.

Methods

Search Strategy

This scoping review followed the PRISMA for Scoping Reviews (PRISMA-ScR) guidelines. The search strategy included a search of peer-reviewed and grey literature to answer the following research questions: 1) What digital applications are being used to capture human experiences of climate change impacts on food security? 2) What digital applications are available to capture and understand climate change-related impacts on mental health? 3) What digital applications are available to capture and understand climate change impacts on both human experiences of food security and mental health? Three peer-reviewed databases were searched, including PubMed – a health and medical database, Web of Science – a sciences, social sciences, arts and humanities database, and IEEE Xplore – an established computer science and engineering research database to capture a broad range of studies involving digital technologies. The search strategy was developed in consultation with a university librarian and tailored for each database. Searches were organized into theme categories, including: 1) climate change + food security (CC+FS); 2) climate change + mental health (CC+MH); 3) climate change + food security + mental health (CC+FS+MH), with all topic categories searched alongside terms for 'digital apps' (see **Table 1**). Various combinations of these search terms were used to conduct manual grey literature searches on Google and relevant organizational websites (i.e., governmental and non-profit organizations focused on climate change,

public health, and digital health) to identify organizational reports and/or webpages not published in the peer-reviewed literature. All searches were conducted between 7 November 2022 and 22 January 2024. The search was limited to the past 10 years because while digital technology existed prior to 2012, the field of digital apps is rapidly evolving. For instance, many sensors that are commonplace in smartphones now were not available 10 years ago – including environment temperature and humidity sensors – which were released in 2013 and 2015, respectively [82].

Table 1. Comprehensive list of search terms used in the scoping review literature search process

Topic	Search Terms
Climate Change	Climate change, climate crisis, environment, global warming, heatwave, biodiversity loss, greenhouse effect, flood, drought, natural disaster, emergency weather
Food Security	Food security, food insecurity, food sovereignty, food supply, food shortage, food vulnerability, food scarcity, food system
Mental Health	Mental health, mental disorder, mental illness, depression, anxiety, ecoanxiety, solastalgia, stress
Digital Applications	App, web app, web application, mobile application, mobile app, phone application, phone app, digital platform, smartphone app, smartphone application, digital app, digital application

Inclusion Criteria

The inclusion and exclusion criteria are shown in Table 2. Peer-reviewed literature from all fields and/or disciplines covered by PubMed were included in the search. Web of Science searches were limited to the Science, Social Sciences, and Arts & Humanities Citation Indexes. IEEE Xplore searches were limited to journal articles. Titles and abstracts were shortlisted if they included search term(s) from each search topic category, and mentioned the design, development or use of digital platforms, applications, or tools. Only relevant articles published in 2012 or later (i.e., over the past decade) were included since technology has rapidly evolved in this sector. This time filter was also used in the grey literature searches.

Exclusion Criteria

Literature reviews and protocol papers were excluded, as well as articles not published in English or earlier than 2012. Articles that did not focus on the impacts of climate change on human food security experiences or mental health were excluded. For food security-specific searches, articles which focused on climate change impacts on agriculture in general (i.e., not human food security) as well as farming practices or wildlife were excluded. For mental health-specific searches, digital platforms that focused on mental health impacts of the built environment (i.e., neighborhood design, greenspaces) rather than impacts of climate change-related events were excluded.

Table 2. Inclusion and exclusion criteria used in the scoping review literature search process.

Inclusion Criteria	Exclusion Criteria
Article Type	
• Peer-reviewed journal articles	• Literature reviews • Protocol papers
Language	

• English	• Any language other than English
Publication Year	
• January 2012 to July 2023	• 2011 or earlier • July 2023 onward
Study Discipline	
• Science • Social sciences • Arts and humanities • Computer sciences • Engineering	• Not applicable
Study Focus	
• Studies focusing on both climate change and mental health, climate change and food security, or a combination of all three • Studies focusing on the design, development, or use of digital platforms, applications, or tools	• Articles that did not focus on the impacts of climate change on human food security experiences or mental health • Articles which focused on climate change impacts on agriculture or farming practices • Articles that focused on mental health impacts of the built environment (i.e., neighborhood design, greenspaces) rather than impacts of climate change-related events

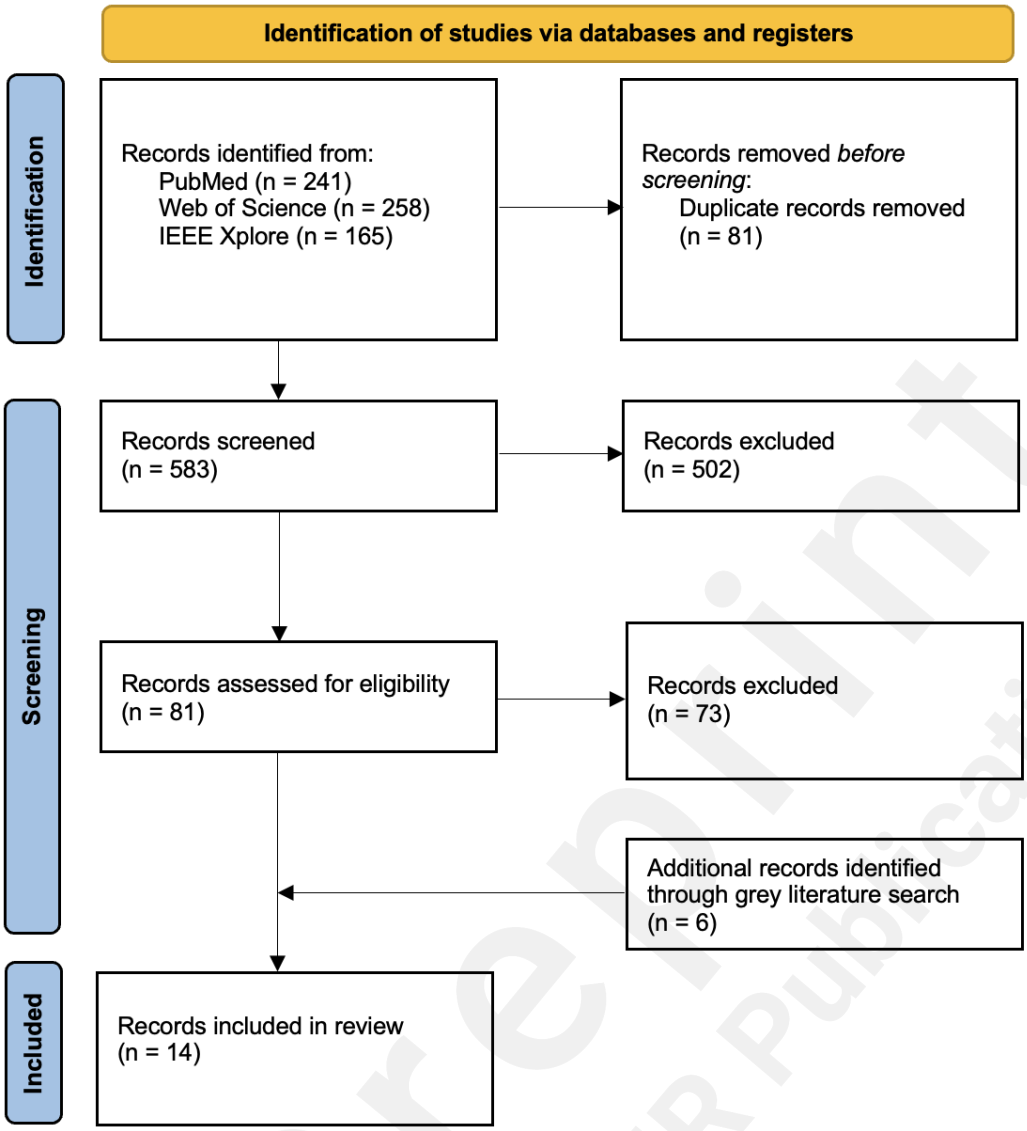
Data Extraction and Appraisal

Two reviewers (NE, JP) conducted a total of three searches corresponding with each research question. All citations were uploaded to Zotero Reference Management Software, and titles and abstracts were screened for relevance and fit with the inclusion criteria. A third reviewer (JB) helped to resolve any discrepancies, with online meetings held to reach consensus on article alignment with initial research questions and inclusion criteria. A consensus was reached on the final article shortlist (by JB, NE, JP) after reviewing the full-text articles. A data summary table was created by extracting relevant data from the shortlisted articles and grey literature, including authors, year of publication, study objective, digital app features, and areas of focus, and equity-related considerations.

Results

As shown in **Figure 1**, 656 citations were identified from three databases (CC+FS=393; CC+MH=233; CC+FS+MH=30). After removing duplicate records (n=81) and results which did not meet inclusion criteria at the title and abstract screening stage (n=394), 81 full text records were reviewed. A total of 14 articles were selected, including 8 peer-reviewed articles (CC+FS=3; CC+MH=5; CC+FS+MH=0) and 6 documents identified through grey literature searches.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) flow diagram of the search and study selection process.



The majority of articles identified focused on the development and evaluation of digital health platforms for addressing various challenges and opportunities related to climate change. The studies consisted of various study designs including observational cross-sectional studies (n=3), experimental studies (n=2), a development and validation study (n=1), a prospective cohort study (n=1), and an ethnographic study (n=1). Only one of the studies involved a mixed methods approach, while the other studies used only qualitative methods (n=3) or quantitative methods (n=4). Studies were conducted in various countries across three continents, including Europe (n=3), Asia (n=1), and Africa (n=1). Five out of the 14 apps were web-based, six were available on both iOS and Android, one was available on Android only, and there was insufficient information provided by two studies to determine the operating system of the digital platform. The majority of digital apps (78.6%) were publicly available and provided access links. The full data summary table is presented in **Appendix A**.

Climate Change and Food Security Apps

A total of 3 articles and 4 grey literature sources were identified in this scoping review that captured climate change impacts on human food security. In a study by Calvet-Mir et al. (2018), an app called the CONECT-e platform was used to enable documentation, sharing and exchange of traditional agroecological knowledge (TAeK) in Spain. By storing TAeK, the platform aimed to preserve culturally sensitive food systems to address food insecurity issues [83]. This process involved

building a TAeK database and enabling communication within the app to facilitate collaborative discussions between knowledge users. Another study by Enenkel et al. (2015) used a smartphone-based digital app that conducted food security assessments in 101 households in the Central African Republic, and shared findings with local aid organizations such as Doctors Without Borders [84]. The app utilized climate-focused features, including remote sensing of droughts, to determine the risk and prevalence of food insecurity in specific communities [84]. Another study conducted by Ramos et al. (2016) developed a web-based tool for food industry professionals to calculate the environmental impact of food production, and to promote sustainable practices for the long-term stability of food supply chains [85]. This involved creating a standardized data gathering system, selecting key environmental indicators, and establishing a methodology for a life cycle impact assessment.

From the grey literature sources, the following apps explored the impacts of climate change-related effects on human food security: Your Virtual Cold Chain Assistant, Good Empire, Floop, and Olio [86–89]. Good Empire, Floop, and Olio emphasized personal ownership and empowered users to make incremental behavioural adjustments to tackle climate change and food insecurity simultaneously [87–89]. These apps included features that allowed users to monitor and share their progress with others to highlight the positive changes they are making. In particular, Olio aimed to reduce food waste and curb overconsumption [89]. Good Empire and Floop primarily focused on the food-carbon footprint, guiding users to make decisions based on their environmental implications [87,88]. Good Empire aimed to free communities from hunger [87], whereas Floop promoted reducing food waste by outlining climate-friendly recipes and meal plans [88]. Unlike the other three apps which focus on individual empowerment and behaviour change, Virtual Cold Chain Assistant focused on providing a tool for farmers to address food sustainability and security while reducing carbon emissions in real-time [86].

Climate Change and Mental Health Apps

This scoping review identified five articles and two grey literature sources examining climate change impacts on mental health. Three articles focused on adults [90–92], one on children and youth [93], and one on a specific adult population of behavioural health responders – professionals that help individuals with mental and behavioural health conditions [94]. Most studies aimed to provide tangible mental health resources, including tips for managing mental health, links to best practice guidelines for healthcare providers, as well as information on nearby mental health treatment facilities or strategies to help those who may be struggling with their mental wellbeing due to climate change events [92–94]. Other apps assessed user behaviour, feelings, and overall wellbeing following the delivery of climate-related warning messages (e.g., “Warning: Thunderstorms with hurricane winds up to 120 km/h, as well as heavy rain with precipitation amounts around 35 l/m² will occur quickly”) [90] or self-reported data on their user wellbeing in relation to temperature changes [91].

The grey literature sources identified two apps that addressed both climate change and mental health – Eco-Anxious and Climate Awakening [95,96]. These apps not only have a shared focus on creating a sense of community for sharing emotions elicited by climate change, but they also focused on transforming these emotions into meaningful connections and learning how to have better climate-related conversations. For example, these apps included narrative storytelling, small group sharing, and listening sessions which enable users to connect, share experiences, and learn how to better manage climate-related emotions together.

Climate Change, Food Security, and Mental Health Apps

There were no peer-reviewed articles or grey literature identified which addressed the third research

question focused on digital apps that capture concurrent climate change impacts on food security and mental health.

Features of Climate Change Apps Platforms

Common features of digital apps were identified (see **Table 3**), with some apps having up to three features simultaneously. Across the 14 digital apps identified within this scoping review, the most common feature seen in six platforms was the ability to track user perceptions, feelings, or health impacts related to climate change (**Figure 2**). Several digital apps prioritized user-to-user communication within the platform (n=5), while others built a knowledge database (n=5) related to the topic of climate change and food security, or climate change and mental health. A few digital apps (n=3) analyzed the collected data to inform evidence-based findings, and two digital apps acted as educational platforms consisting of guides or learning modules. Only one app (Good Empire) uniquely had the feature of gamification, with user contributions to the Sustainable Development Goals (SDGs) being animated through a gamified process of unlocking statuses, achievements, and real-world rewards [87].

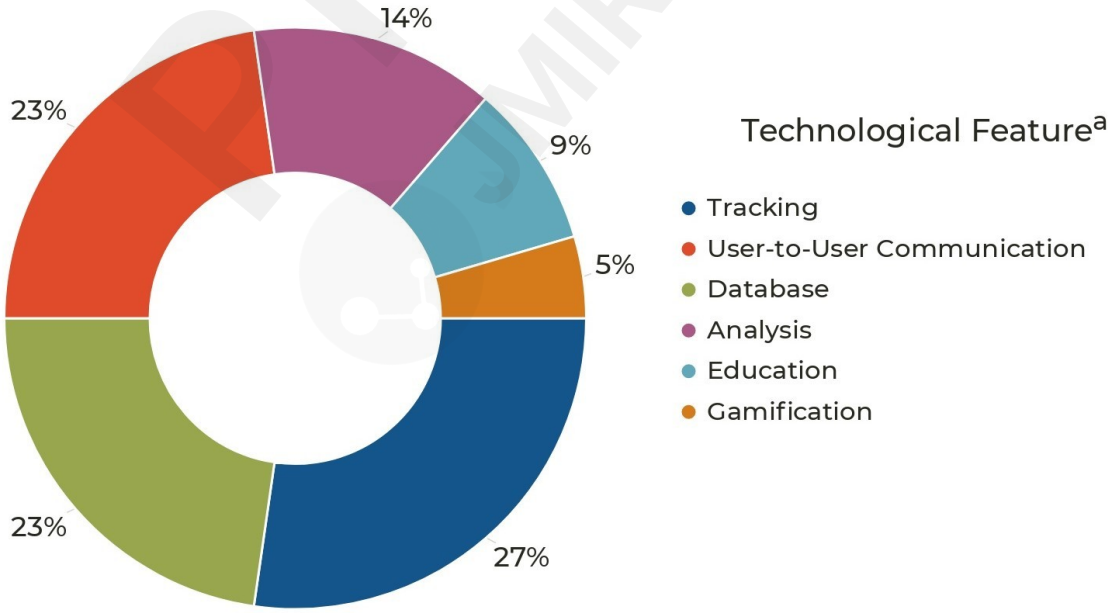
Table 3. Summary of technological features used across climate change digital apps identified in the scoping review (January 2015 - July 2023; N=14).

	Technological Feature[a]					
Study Author (Year)	Tracking	User-to-User Communication	Data base	Analysis	Education	Gamification
Calvet-Mir et al. (2018) [83]		X	X			
Enenkel et al. (2015) [84]	X					
Ramos et al. (2016) [85]				X		
Seligman et al. (2015) [94]			X		X	
Tomczyk et al. (2021) [90]			X			
Price et al. (2015) [93]					X	
Bundo et al. (2023) [91]	X					
Joshi et al. (2023) [92]	X					
Your Virtual Cold Chain Assistant [86]	X		X	X		

Good Empire [87]	X	X				X
Floop [88]	X	X		X		
Olio [89]		X				
Eco-Anxious [95]			X			
Climate Awakening [96]		X				

[a]Features include tracking (monitoring and recording climate-related data), user-to-user communication (facilitating interactions and knowledge exchange), database (storage of climate-related information and resources), analysis (tools for data analysis and generating insights), education (offering climate change learning resources), and gamification (using interactive elements, i.e., rewards and challenges to engage users).

Figure 2. Distribution of technological feature frequencies across climate change digital apps identified from scoping review.



[a]Features include tracking (monitoring and recording climate-related data), user-to-user communication (facilitating interactions and knowledge exchange), database (storage of climate-

related information and resources), analysis (tools for data analysis and generating insights), education (offering climate change learning resources), and gamification (using interactive elements, i.e., rewards and challenges to engage users).

Objectives and Uses of Climate Change Apps Across Contexts

All identified studies and grey literature sources addressed different aspects of climate change, food security, and mental health through their digital platforms. Namely, eight digital platforms focused on providing services to citizens experiencing climate-related food insecurity [85–89] or mental health issues [94–96]. Other studies focused on collecting data related to the usability of a developed platform (n=3) [83,84,93], or understanding of relationships between climate change and mental health (n=3) [90–92].

Various digital platforms were created and used within different contexts related to climate change. While some digital platforms (29%) were developed to be used during or following natural disaster events [84,90,93,94], most identified digital platforms (71%) were developed to be used as an ongoing preventative tool for climate-related food insecurity [83,85–89] or climate change-related mental health issues [91,92,95,96].

Three distinct approaches to citizen participation were observed in this review: contributory, collaborative, and co-creative [83,84,92,97]. In the contributory approach used by Enenkel et al., (2015), local community health workers contributed to food security assessments after undergoing a training session [84]. The local community health workers collected food security data, which was used to assess the feasibility of data collection on socio-economic vulnerabilities related to malnutrition, resource accessibility, and coping capacities across communities in the Central African Republic. In contrast, Calvet-Mir et al., (2018) utilized a collaborative approach to citizen science, which involved societal participation in the documentation and sharing of traditional ecological information and practices. In this study, the CONECT-e platform was used to capture TAeK and enable knowledge exchange between researchers and local community members [83]. In a study by Joshi et al., (2023), a co-creative approach to citizen science was employed, in which experiences shared by local community members were used to co-design a research framework. Researchers and citizen scientists both participated in co-analysis of research data in this study [92]. Each citizen engagement approach, from data collection assistance (contributory), to participation in information sharing (collaborative), to active involvement in research design and analysis (co-creation), was utilized to complement specific study objectives and engage at different stages. Shortlisted articles were reviewed to identify whether digital apps considered equity as part of their app development or implementation process. Equity considerations could include mention of specific population groups (i.e., disadvantaged in the context of climate change impacts), access issues (i.e., smartphone, internet), or digital literacy concerns. Onlythree out of the eight peer-reviewed studies mentioned equity-related considerations. For example, Joshi et al., (2023) examined power dynamics related to socioeconomic status and social identity in their sampling approach by taking proactive measures to represent marginalized castes in India [92]. Additionally, they employed both male and female data collectors to mitigate socio-cultural barriers to female participation in their study. Enenkel et al., (2015) examined climate change impacts on food security in Kabo, Central African Republic, one of the world's most vulnerable regions in the global south in terms of poverty, violent conflicts, and weak disaster resilience [84]. Lastly, Bundo et al., (2023) examined how individuals with psychiatric disorders may be differentially impacted by climate change in Switzerland [91].

Discussion

Connecting climate change with food security and mental health impacts

This scoping review is the first to explore the use of digital apps for understanding the relationships

between climate change, food security, and mental health. While one scoping review by Martin et al., (2022) was identified summarizing the use of digital platforms for food security [65], the current review uniquely captured global advancements in digital apps for climate change impacts on human experiences of both food security and mental health.

Climate change is significantly impacting food systems globally, ranging from adverse effects of extreme weather events [34,98,99] to positive effectssuch as longer growing seasons [100,101] in some regions. Climate change has contributed to lower crop yields and food shortages in regions across Africa and Southeast Asia [18,41,102], while also impacting human food security in vulnerable arctic and coastal regions in the global north [34,99]. While no apps concurrently capturing climate change-related food security and mental health issues were identified in this review, research has shown that experiences of food insecurity are linked to stress, anxiety, and poor mental health outcomes in general [90,91,103–106] and can be exacerbated during climate emergencies [107,108]. In many instances, communities that are vulnerable to adverse climate change events are also disproportionately affected by food insecurity [34,109,110]. Consistent with existing literature [40,50–53], this review found that digital apps, particularly those which provide real-time alerts, information, and communication, can not only ensure that solutions are catered to communities' specific needs, but also foster a sense of empowerment among community members [83,84,92].

The use of digital apps for climate change-related food insecurity

This scoping review uncovered a few digital apps focused on climate change impacts on human food security [83–89]. These apps assessed food security status and food acquisition patterns to support users in engaging sustainable food practices. There was a large focus on individual or community behaviour change to enhance food security, with one app focused on exchanging traditional cultural knowledge to preserve food systems [83]. Food security involves not only access to and affordability of adequate food, but importantly, culturally appropriate food and acquisition practices – particularly in Indigenous and ethnic communities [67,111]. Thus, the availability of digital tools to capture and share traditional ecological knowledge is an important aspect of inclusive and user-centered climate change apps, as cultural aspects are often not captured in many food security assessments [68]. Given their focus on behaviour change, the majority of digital apps identified were designed for use within communities (i.e., user-to-user interaction), and therefore had limited connection to other stakeholder groups (i.e., decision-makers, food assistance programs, etc.).

Many food security-focused digital apps identified in this scoping review relied on user input and activity to understand specific climate change impacts. These platforms often used crowd-sourced data, where users contributed information and shared experiences. In one study by Enenkel et al., (2015) which implemented a digital app in communities within the Central African Republic – one of the most vulnerable regions in the global south [84] – user contributions enabled a better understanding of food security in 101 households. This user-driven approach increased the diversity and potential accuracy of data, enhancing the digital platform's ability to address local challenges effectively. Moreover, the digital apps identified in this scoping review empowered users by implementing citizen-based data collection and data-driven output to users, including offering advice and suggestions for sustainable alternatives to food consumption and production. For example, Calvet-Mir et al., (2018) and Ramos et al., (2016) examined climate change and food security apps focused on empowering farmers and food producers to make informed decisions to address adverse climate change impacts [83,85]. By collecting and analyzing data on farming and food production practices, these digital platforms provided content personalized to their industries and geographic locations. Similarly, other climate change and food security apps which focused on behaviour change included features such as progress monitoring to empower users to engage in more sustainable

practices that address food security [87–89]. These approaches prioritized local knowledge, empowerment, and user control in shaping their own food systems [111,112].

While digital apps can provide near real-time information about food insecurity risk, our scoping review found limited evidence of the evaluation of these apps. Similarly, a previous scoping review examining the use of digital platforms to provide food assistance found a gap in the evidence on the effectiveness and impact of these tools [113]. In the current review, we found only one study by Enenkel et al. (2015) which conducted an evaluation to assess app usability following a food security intervention where the authors calculated the number of smartphone-based food security assessments that could be performed within a six-hour working day [84]. The lack of evaluation activities can be attributed, in part, to the fact that many apps are created in the commercial rather than research domain [113]. Moreover, existing platforms are still in the early stages of implementation due to the relative recency of their development between 2015 and 2023 [113].

Despite the limited number of apps focused on human food security, there are promising advances in the use of digital technology and tools to assess and manage climate change impacts on agriculture and food security from a land management perspective [114–116]. Overall, there is potential to not only capture food security status using digital apps, but to also actively deploy targeted digital health interventions connecting communities with relevant organizations or decision-makers to address existing food security issues [115].

Connecting climate change to mental health outcomes

In addition to examining the role of digital apps for climate change-related impacts on food security, this review also examined its role in mental health. These apps focused on providing users with mental health resources and strategies to cope with solastalgia. Some apps assessed user feelings following the delivery of climate change warnings or messages, while others focused on connecting users to each other to engage in climate-related conversations as a part of managing emotions or stress.

In the current review, studies found that while adults experienced anxiety or stress related to climate change events [90–94], those experiencing greater vulnerability from various social factors, including age, gender, and socioeconomic status, were disproportionately excluded from climate change initiatives [92]. The majority of recent research in this area has shown that in addition to greater climate change activism [117,118], children and youth are particularly vulnerable to both climate change impacts [119–122] as well as mental health challenges [121]. A study conducted by Hickman et al., (2021) across ten countries found that 45% of children and youth report that climate change-related anxiety negatively affected their daily life and functioning [121].

EcoAnxious and Climate Awakening were digital apps identified in the current review which included features for users of all ages to connect with others to share their mental health status. These apps aimed to improve mental health and foster meaningful connections with other app users by improving climate awareness, promoting conversations about climate-related emotions, and online storytelling using guided frameworks and exercises [95], as well as climate-related prompts through small-group listening sessions [96]. Evidence has shown that sharing concerns about climate change can potentially reduce feelings of stress and anxiety, even in the absence of a specific intervention [123]. The majority of digital apps identified did not collect mental health data from users, but instead addressed mental health concerns by providing resources and opportunities for users to connect. The studies that collected mental health data were designed to explore the intersection of climate change and mental health rather than improving mental health outcomes. For instance, Climate Awakening and EcoAnxious [95,96] both used innovative approaches, including features for

online storytelling and small-group sessions, to provide users with a sense of community by allowing them to share how climate change is impacting their mental health.

Similar to the apps uncovered for climate change and food insecurity, no studies identified in this review evaluated the impact of these digital platforms on mental health. This may be due to the relative recency of digital platforms examining both climate change and mental health [84]. Future studies should not only examine the impact of digital apps on addressing climate change impacts on mental health, but also compare their effectiveness across age groups and other sociodemographic groups to understand potential differences in uptake and use.

Gaps in addressing the intersection of climate change, food security, and mental health

This scoping review did not identify any digital apps which simultaneously connected the concepts of climate change to both food security and mental health; however key features identified in the shortlisted digital apps could be considered for this purpose. Given the interconnected and cumulative impacts of climate change on food systems and mental wellbeing [103–106], there is immense potential to address numerous SDGs (SDG 1: Zero Hunger; SDG 2: Good Health and Well-being; SDG 13: Climate Action) with this holistic lens [124]. Specific app features described in this scoping review, including the use of adverse weather event tracking, alerts, educational resources and support, as well as user-to-user communication can importantly be used to promote rapid responses to direct of effects of climate change on i) food insecurity, ii)mental health issues, and ii) the indirect effects of climate change-related food insecurity on mental health across sectors. In particular, addressing the SDGs requires a concerted effort whereby citizens (i.e., app users) track local impacts, decision-makers provide citizens with timely information and resources, and globally there is an effort to share knowledge and resources towards these goals.

Our search uncovered one study protocol for the Food Equity and Environmental Data Sovereignty (FEEDS) project which was the only example of a digital app which aimed to address climate change, food security, and mental health concurrently [125]. The FEEDS project involves a smartphone-based digital app to monitor, mitigate, and manage adverse impacts of climate change on food security and mental health among vulnerable communities. The project takes a digital citizen science approach to co-create and share knowledge among user groups to enable near real-time monitoring, communication, and response to the interconnected issues of climate change, food security, and mental health [125]. Specific app features such as time and location-stamped environmental hazards or adverse weather events, citizen reporting of perceived impacts of climate change on local food systems and indicators of mental health (i.e., stress, anxiety), and a digital dashboard aim to connect citizens to community decision-makers.

Another key gap identified through this review was the lack of discussion of either access or equity-related issues in digital app design. The global digital divide, which includes unequal access to digital tools (i.e., smartphones) and the internet, is necessary to factor into digital app development and deployment for disadvantaged populations [69,73,74]. Out of the 14 studies identified, only two were focused in the global south, and these were the only ones which considered equity-related issues as either a specific barrier or determinant of app usage. For example, Joshi et al., (2023) created an app called SenseMaker to capture gendered experiences of climate change in Bihar, India [93]. This study acknowledged existing differences in literacy levels, with the national literacy rate among women being 51.5% compared to 71.2% among males, which influenced digital literacy, numerous health indicators, and ability to participate in climate change-related research initiatives [92]. Thus, Joshi et al., (2023) focused on co-design of a research framework and aimed to capture intersectional inequalities related to climate change vulnerability – a critical aspect of creating equitable climate action [92]. Enenkel et al., (2015) conducted a study in the Central African

Republic which importantly recognized that, “While droughts and their precursors (e.g. ocean temperature anomalies) can be monitored by satellites, the resulting socio-economic impacts [...] that are related to people’s vulnerabilities/coping capacities remain mostly hidden to the eye of a satellite” [84]. The Central African Republic has relatively low access to smartphones [72], and though the authors did not discuss the global digital divide or specific issues of digital literacy, they noted that community health workers had to be trained prior to data collection given their limited experience in using smartphones [84]. Ultimately, low digital literacy created specific challenges that could have impacted the uptake and use of the digital app (i.e., entering data into the smartphone-based app, understanding how to navigate the app including swiping versus tapping to access specific app functions) [84].

The ‘digital divide,’ while a prominent issue in the global context, is also necessary to consider *within* countries, as certain population subgroups (i.e., non-native language speakers, older adults) interact with and use technology in different ways, which could exacerbate disadvantages – particularly when essential health services or resources are being shared via digital means. Issues of digital literacy and internet access are important for digital apps to capture, not only as potentially confounding factors (i.e., which could affect app uptake and use), but also to improve reach to populations in an equitable manner.

The need for digital tools to monitor, mitigate, and manage climate change impacts

The digital apps uncovered in this scoping review importantly demonstrated a range of approaches to participant involvement in either app development or deployment, including contributory, collaborative, and co-creation. Participant or user involvement was essential to not only ensuring relevance of the digital apps for users’ needs, but also ultimately to the uptake and use.

The use of mobile digital technology has the potential to enable continuous citizen involvement and equitable reach to geographical rural and remote communities, including vulnerable populations who may not have easy physical access to information or resources to manage adverse climate change impacts [126]. Citizen science has a history of engaging people to capture environmental data [54–59]. Thus, using digital citizen science (i.e., citizen participation in studies/projects via digital means), there is potential to generate enormous amounts of big data from citizen-owned devices (i.e., smartphones) which can transform how climate change events are not only surveilled, but also the prediction and prevention of community health impacts related to food security and mental health [34,54–59,127]. Three studies identified in this scoping review employed citizen science approaches. Calvet-Mir et al. (2018) applied a collaborative citizen science method, enabling user input to promote collaborative documentation and sharing of traditional ecological knowledge and practices [83]. Enenkel et al. (2015) trained community health workers familiar with the basics of food security assessments to conduct data collection within the community, showcasing a contributory citizen science approach that has the potential to significantly enhance the efficiency of food security assessments [84]. Joshi et al. (2023) utilized a co-creative approach, allowing citizen scientists to lead the analysis of their own data, while researchers adopted a facilitative role, mitigating subjective biases [92]. Despite the advantages of citizen science approaches, the majority of the studies reviewed did not use them.

In addition, the inherent complexity and interdisciplinarity of climate change impacts requires the use of big data and a systems thinking lens that works across sectors (i.e., food, health, environment, justice) to address risks and opportunities [50,128,129]. Digital apps have the ability to reach a larger and more geographically diverse user base [130], as mentioned in the study by Calvet-Mir et al., (2018) where their user engagement included 150,000 app visits across 467 users one year after its launch [83]. In this digital age, the use of innovative approaches such as ecological momentary

assessments (EMAs) can play an important role as they allow researchers to potentially capture the mental health status of populations with reduced recall biases compared to traditional retrospective surveys [131,132]. One study collected data from users to examine associations between climate change predictors and mental health outcomes [91] and utilized EMAs to allow users to self-report their mental health. Advanced processing techniques such as remote sensing can also be utilized to make predictions and identify trends in real-time [133].

Overall, the digital apps identified in this scoping review were designed to provide citizens with a service, whether it was for use during or immediately following a climate change-related natural disaster, or preventive management of ongoing risks. Thus, there is immense potential for the use of digital technologies to mitigate, manage, and potentially prevent food insecurity and mental distress, particularly if these issues are addressed concurrently and holistically given their interconnection.

Limitations

This scoping review presents a comprehensive search of both peer-reviewed and grey literature, and the use of multiple databases enabled the capture of a range of literature across disciplines. The majority of apps identified were published between 2015 and 2023, with 5 out of 8 apps uncovered from peer-reviewed literature published before 2019. The concentration of apps prior to 2019 may reflect the redirected focus of digital health research to the COVID-19 pandemic, thereby limiting work on climate change impacts on health [134–137]. This study excluded non-English language literature may have missed digital apps published in other languages. Moreover, this scoping review explored three distinct but interrelated research questions in an effort to identify digital apps for climate change impacts on both food security and mental health; however, we were unable to assess the quality of the shortlisted digital apps given the recency of most apps and lack of publicly reported evaluation activities. Given the recency of most shortlisted apps, there was no evidence of evaluations being conducted which limits our ability to understand the potential impact these apps had on improving food security and mental health.

Conclusions

This scoping review aimed to understand how digital apps have been used to capture human experiences of climate change impacts on food security and mental health. While some digital apps focused on food security or mental health, there were no apps identified which took a holistic approach to concurrently assess food systems and mental health outcomes associated with experiences of climate change. Participatory approaches were used to engage and involve app users, and a variety of app features were used to collect data, enable user communication about climate change-related events, and manage the risk of food insecurity or mental distress.

Given the frequency of adverse climate change-related events globally, there is an urgent need for future studies to comprehensively capture and evaluate the interconnections between food security, mental health, and climate change while considering communities' local knowledge, concerns, and specific risk factors. By harnessing the power of digital apps, researchers and decision-makers can partner with communities to effectively respond to and navigate climate change impacts on both food security and mental health. In particular, digital apps which enable near real-time alerts, communication, and potential for intervention can ensure that solutions are tailored to communities' specific needs and challenges, while fostering a sense of empowerment and ownership among citizens.

Acknowledgements

The authors would like to acknowledge Western University librarian, Nina Nouwens, for her support

in developing the search strategy.

This study was conceptualized by JB. NE and JB led the development of tailored search strategies, and NE and JP conducted database and grey literature searches. NE and JP reviewed all articles, and all authors reached a consensus on the final article shortlist. NE and JP led data abstraction, with findings interpreted by JB, NE and JP. All authors contributed to drafting and reviewing the manuscript.

Funding for this project was provided by the Canadian Institutes of Health Research (JB).

Data Availability

All referenced digital apps and tools have been cited and summarized in the included data summary tables.

Conflicts of Interest

The authors have no conflicts of interest to declare.

Abbreviations

App: application
CC: climate change
EMA: ecological momentary assessment
FEEDS: Food Equity and Environmental Data Sovereignty
FS: food security
MH: mental health
SDG: Sustainable Development Goals
TAeK: traditional agroecological knowledge

References

1. Pörtner HO, Tignor ES, Poloczanka K, Roberts DC. AR6 Climate Change 2022: Impacts, Adaptation and Vulnerability — IPCC [Internet]. 2022 [cited 2022 Apr 25]. Available from: https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

2. World Health Organization. COP24 special report: health and climate change. 2018;

3. WHO. Climate change [Internet]. 2023 [cited 2023 Oct 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

4. Agreement P. Paris agreement. In HeinOnline; 2015. p. 2017.

5. Kovats S, Hales S, Campbell-Lendrum D, Rocklov J, Honda Y, Lloyd S. Global Risk Assessment Of The Effect Of Climate Change On Selected Causes Of Death In 2030s And 2050s. ISEE Conf Abstr [Internet]. 2015 Aug 20 [cited 2023 Oct 16]; Available from: https://ehp.niehs.nih.gov/doi/10.1289/isee.2015.2015-1204

6. Harper SL, Cunsolo A, Babujee A, Coggins S, De Jongh E, Rusnak T, Wright CJ, Domínguez Aguilar M. Trends and gaps in climate change and health research in North America. Environ Res. 2021 Aug 1;199:111205.

7. Vermeulen S, Campbell BM, Ingram J. Climate Change and Food Systems. Annu Rev Environ Resour. 2012 Oct 17;37:195–222.

8. Watts N, Adger WN, Ayeb-Karlsson S, Bai Y, Byass P, Campbell-Lendrum D, Colbourn T, Cox P, Davies M, Depledge M, Depoux A, Dominguez-Salas P, Drummond P, Ekins P, Flahault A, Grace D, Graham H, Haines A, Hamilton I, Johnson A, Kelman I, Kovats S, Liang L, Lott M, Lowe R, Luo Y, Mace G, Maslin M, Morrissey K, Murray K, Neville T, Nilsson M, Oreszczyn T, Parthemore C, Pencheon D, Robinson E, Schütte S, Shumake-Guillemot J, Vineis P, Wilkinson P, Wheeler N, Xu B, Yang J, Yin Y, Yu C, Gong P, Montgomery H, Costello A. The Lancet Countdown: tracking progress on health and climate change. Lancet Lond Engl. 2017 Mar 18;389(10074):1151–64.

9. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, Dangour AD, Huybers P. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. Annu Rev Public Health. 2017 Mar 20;38:259–77.

10. McMichael AJ, World Health Organization, editors. Climate change and human health: risks and responses. Geneva: World Health Organization; 2003. 322 p.

11. Climate Effects on Health | CDC [Internet]. 2022 [cited 2023 Oct 16]. Available from: https://www.cdc.gov/climateandhealth/effects/default.htm

12. IPCC SP, Skea J, Buendia E, Masson-Delmotte V, Pörtner H, Roberts D, Zhai P, Slade R, Connors S, Diemen R. Summary for policymakers. Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Forthcoming. 2019;

13. Walsh M, Backlund P, Buja L, DeGaetano A, Melnick R, Prokopy L, Takle E, Todey D, Ziska L. Climate Indicators for Agriculture [Internet]. United States. Department of Agriculture. Climate Change Program Office; 2020 Jul [cited 2024 Feb 22]. Available from: https://handle.nal.usda.gov/10113/7201760

14. Owino V, Kumwenda C, Ekesa B, Parker ME, Ewoldt L, Roos N, Lee WT, Tome D. The impact of climate change on food systems, diet quality, nutrition, and health outcomes: A narrative review. Front Clim [Internet]. 2022 [cited 2024 Feb 22];4. Available from: https://www.frontiersin.org/articles/10.3389/fclim.2022.941842

15. Gowda PH, Steiner J, Olson C, Boggess M, Farrigan T, Grusak MA. Chapter 10 : Agriculture and Rural Communities. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II [Internet]. U.S. Global Change Research Program; 2018 [cited 2024 Feb 22]. Available from: https://nca2018.globalchange.gov/chapter/10/

16. Pourmotabbed A, Moradi S, Babaei A, Ghavami A, Mohammadi H, Jalili C, Symonds ME, Miraghajani M. Food insecurity and mental health: a systematic review and meta-analysis. Public Health Nutr. 2020 Jul;23(10):1778–90.

17. Jones AD. Food Insecurity and Mental Health Status: A Global Analysis of 149 Countries. Am J Prev Med. 2017 Aug;53(2):264–73.

18. Raj S, Roodbar S, Brinkley C, Wolfe DW. Food Security and Climate Change: Differences in Impacts and Adaptation Strategies for Rural Communities in the Global South and North. Front Sustain Food Syst [Internet]. 2022 [cited 2023 Oct 26];5. Available from: https://www.frontiersin.org/articles/10.3389/fsufs.2021.691191

19. Fanzo J, Davis C, McLaren R, Choufani J. The effect of climate change across food systems: Implications for nutrition outcomes. Glob Food Secur. 2018 Sep 1;18:12–9.

20. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. [Internet]. Rome: FAO; 2017 [cited 2024 Feb 22]. Available from: https://venezuelanalysis.com/wp-content/uploads/2018/11/a-I7695e.pdf

21. Kumareswaran K, Jayasinghe GY. Systematic review on ensuring the global food security and covid-19 pandemic resilient food systems: towards accomplishing sustainable development goals targets. Discov Sustain. 2022 Aug 31;3(1):29.

22. Aday S, Aday MS. Impact of COVID-19 on the food supply chain. Food Qual Saf. 2020 Dec 1;4(4):167–80.

23. Peterson HH, DiGiacomo G, Court CD, Miller M, Oliveira G, Stevens AW, Zhang L, Baker LM, Nowak J, Orlando E, Saha BB. Impacts of COVID-19 on US agri-food supply chain businesses: Regional survey results. PLOS ONE. 2023 Feb 22;18(2):e0281930.

24. Lieber M, Chin-Hong P, Kelly K, Dandu M, Weiser SD. A Systematic Review and Meta-Analysis Assessing the Impact of Droughts, Flooding, and Climate Variability on Malnutrition. Glob Public Health. 2022 Jan;17(1):68–82.

25. Sharpe I, Davison CM. Climate change, climate-related disasters and mental disorder in low- and middle-income countries: a scoping review. BMJ Open. 2021 Oct 1;11(10):e051908.

26. Bakre S, Shea B, Ortega K, Scharen J, Langheier J, Hu E. Changes in Food Insecurity Among Individuals Using a Telehealth and Nutrition Platform: Longitudinal Study. JMIR Form Res. 2022 Oct 25;6(10):e41418.

27. Charlson F, Ali S, Benmarhnia T, Pearl M, Massazza A, Augustinavicius J, Scott JG. Climate Change and Mental Health: A Scoping Review. Int J Environ Res Public Health. 2021 Apr 23;18(9):4486.

28. Santiago PN, McLay RN, Hammer PS. Meteorologic Factors in Emergency Evaluation, Admission, and Discharge. Psychiatr Serv. 2005 Dec;56(12):1625–1625.

29. Palinkas LA, Wong M. Global climate change and mental health. Curr Opin Psychol. 2020 Apr 1;32:12–6.

30. Galea S, Brewin CR, Gruber M, Jones RT, King DW, King LA, McNally RJ, Ursano RJ, Petukhova M, Kessler RC. Exposure to Hurricane-Related Stressors and Mental Illness After Hurricane Katrina. Arch Gen Psychiatry. 2007 Dec 1;64(12):1427–34.

31. Nahar N, Blomstedt Y, Wu B, Kandarina I, Trisnantoro L, Kinsman J. Increasing the provision of mental health care for vulnerable, disaster-affected people in Bangladesh. BMC Public Health. 2014 Dec;14(1):708.

32. Fernandez A, Black J, Jones M, Wilson L, Salvador-Carulla L, Astell-Burt T, Black D. Flooding and Mental Health: A Systematic Mapping Review. PLOS ONE. 2015 Apr 10;10(4):e0119929.

33. Schmeltz MT, Gamble JL. Risk characterization of hospitalizations for mental illness and/or

behavioral disorders with concurrent heat-related illness. PLOS ONE. 2017 Oct 16;12(10):e0186509.

34. Schnitter R, Berry P. The Climate Change, Food Security and Human Health Nexus in Canada: A Framework to Protect Population Health. Int J Environ Res Public Health. 2019 Jul;16(14):2531.

35. Balogun A, Marks D, Sharma R, Shekhar H, Balmes C, Maheng D, Arshad A, Salehi P. Assessing the Potentials of Digitalization as a Tool for Climate Change Adaptation and Sustainable Development in Urban Centres. Sustain CITIES Soc. 2020 Feb;53.

36. Nakai H, Itatani T, Horiike R. Application Software That Can Prepare for Disasters Based on Patient-Participatory Evidence: K-DiPS: A Verification Report. Int J Environ Res Public Health. 2022 Aug 6;19(15):9694.

37. Susmini S, Feri J, Wijaya S, Wibowo WDA, Arifin H, Lee BO. The Effects of a Disaster Preparedness app on Community Knowledge and Intentional Behavior in Hurricane Risk Areas. Disaster Med Public Health Prep. 2022 Mar 25;17:e137.

38. Sari K, Komalasari R, Kanegae H. Disaster learning through a map-based mobile application: an evaluation of its readability and user satisfaction. In IOP Publishing; 2020. p. 012004.

39. Saritha G, Babu KM. AGRARIAN DISTRESS AND FARMERS SUICIDES IN ANDHRA PRADESH: A SOCIO-ECONOMIC ANALYSIS. Econ ANDHRA PRADESH. :90.

40. Agbehadji IE, Mabhaudhi T, Botai J, Masinde M. A Systematic Review of Existing Early Warning Systems' Challenges and Opportunities in Cloud Computing Early Warning Systems. Climate. 2023 Sep;11(9):188.

41. Hadley K, Wheat S, Rogers HH, Balakumar A, Gonzales-Pacheco D, Davis SS, Linstadt H, Cushing T, Ziska LH, Piper C, Sorensen C. Mechanisms underlying food insecurity in the aftermath of climate-related shocks: a systematic review. Lancet Planet Health. 2023 Mar 1;7(3):e242–50.

42. Danielson CK, Cohen JR, Adams ZW, Youngstrom EA, Soltis K, Amstadter AB, Ruggiero KJ. Clinical Decision-Making Following Disasters: Efficient Identification of PTSD Risk in Adolescents. J Abnorm Child Psychol. 2017 Jan;45(1):117–29.

43. Men F, Elgar FJ, Tarasuk V. Food insecurity is associated with mental health problems among Canadian youth. J Epidemiol Community Health. 2021 Aug 1;75(8):741–8.

44. Nagata JM, Palar K, Gooding HC, Garber AK, Whittle HJ, Bibbins-Domingo K, Weiser SD. Food Insecurity Is Associated With Poorer Mental Health and Sleep Outcomes in Young Adults. J Adolesc Health. 2019 Dec 1;65(6):805–11.

45. Pineau C, Williams PL, Brady J, Waddington M, Frank L. Exploring experiences of food insecurity, stigma, social exclusion, and shame among women in high-income countries: A narrative review. Can Food Stud Rev Can Études Sur Aliment [Internet]. 2021 Oct 30 [cited 2024 Feb 22];8(3). Available from: https://canadianfoodstudies.uwaterloo.ca/index.php/cfs/article/view/473

46. Arenas DJ, Thomas A, Wang J, DeLisser HM. A Systematic Review and Meta-analysis of Depression, Anxiety, and Sleep Disorders in US Adults with Food Insecurity. J Gen Intern Med. 2019 Dec 1;34(12):2874–82.

47. Leung CW, Laraia BA, Feiner C, Solis K, Stewart AL, Adler NE, Epel ES. The Psychological Distress of Food Insecurity: A Qualitative Study of the Emotional Experiences of Parents and Their Coping Strategies. J Acad Nutr Diet. 2022 Oct 1;122(10):1903-1910.e2.

48. Friel S, Berry H, Dinh H, O'Brien L, Walls HL. The impact of drought on the association between food security and mental health in a nationally representative Australian sample. BMC Public Health. 2014 Oct 24;14(1):1102.

49. Pasupuleti R, Orekanti ER. Resilience Nexus With Climate Change, Food Security, Mental Health, and Social Stability in a Changing World. In: Impact of Climate Change on Mental Health and Well-Being [Internet]. IGI Global; 2024 [cited 2024 Feb 22]. p. 67–81. Available from: https://www.igi-global.com/chapter/resilience-nexus-with-climate-change-food-security-mental-health-and-social-stability-in-a-changing-world/www.igi-global.com/chapter/resilience-nexus-with-climate-change-food-security-mental-health-and-social-stability-in-a-changing-world/338193

50. Katapally TR, Ibrahim ST. Digital Health Dashboards for Decision-Making to Enable Rapid Responses During Public Health Crises: Replicable and Scalable Methodology. JMIR Res Protoc. 2023 Jun 30;12(1):e46810.

51. Katapally TR. Smart Indigenous Youth: The Smart Platform Policy Solution for Systems Integration to Address Indigenous Youth Mental Health. JMIR Pediatr Parent. 2020 Sep 25;3(2):e21155.

52. Katapally TR. The SMART Framework: Integration of Citizen Science, Community-Based Participatory Research, and Systems Science for Population Health Science in the Digital Age. JMIR MHealth UHealth. 2019 Aug 30;7(8):e14056.

53. Khan SM, Shafi I, Butt WH, Diez I de la T, Flores MAL, Galán JC, Ashraf I. A Systematic Review of Disaster Management Systems: Approaches, Challenges, and Future Directions. Land. 2023 Aug;12(8):1514.

54. Soteropoulos DL, De Bellis CR, Witsell T. Citizen Science Contributions to Address Biodiversity Loss and Conservation Planning in a Rapidly Developing Region. Diversity. 2021 Jun;13(6):255.

55. McKinley DC, Miller-Rushing AJ, Ballard HL, Bonney R, Brown H, Cook-Patton SC, Evans DM, French RA, Parrish JK, Phillips TB, Ryan SF, Shanley LA, Shirk JL, Stepenuck KF, Weltzin JF, Wiggins A, Boyle OD, Briggs RD, Chapin SF, Hewitt DA, Preuss PW, Soukup MA. Citizen science can improve conservation science, natural resource management, and environmental protection. Biol Conserv. 2017 Apr 1;208:15–28.

56. Catarino AI, Mahu E, Severin MI, Akpetou LK, Annasawmy P, Asuquo FE, Beckman F, Benomar M, Jaya-Ram A, Malouli M, Mees J, Monteiro I, Ndwiga J, Neves Silva P, Nubi OA, Martin-Cabrera P, Sim YK, Sohou Z, Woo SP, Zizah S, Everaert G, Shau-Hwai AT, Krug LA, Seeyave S. Addressing data gaps in marine litter distribution: Citizen science observation of plastics in coastal ecosystems by high-school students. Front Mar Sci [Internet]. 2023 [cited

2024 Feb 22];10. Available from: https://www.frontiersin.org/articles/10.3389/fmars.2023.1126895

57. Zettler ER, Takada H, Monteleone B, Mallos N, Eriksen M, Amaral-Zettler LA. Incorporating citizen science to study plastics in the environment. Anal Methods. 2017 Mar 2;9(9):1392–403.

58. Mahajan S, Chung MK, Martinez J, Olaya Y, Helbing D, Chen LJ. Translating citizen-generated air quality data into evidence for shaping policy. Humanit Soc Sci Commun. 2022 Apr 7;9(1):1–18.

59. Volten H, Devilee J, Apituley A, Carton L, Grothe M, Keller C, Kresin F, Land-Zandstra A, Noordijk E, van Putten E, Rietjens J, Snik F, Tielemans E, Vonk J, Voogt M, Wesseling J. Enhancing national environmental monitoring through local citizen science. In: Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J, Bonn A, editors. Citizen Science [Internet]. UCL Press; 2018 [cited 2024 Feb 22]. p. 337–52. (Innovation in Open Science, Society and Policy). Available from: https://www.jstor.org/stable/j.ctv550cf2.30

60. Lecomte T, Potvin S, Corbière M, Guay S, Samson C, Cloutier B, Francoeur A, Pennou A, Khazaal Y. Mobile Apps for Mental Health Issues: Meta-Review of Meta-Analyses. JMIR MHealth UHealth. 2020 May 29;8(5):e17458.

61. Toh SHY, Tan JHY, Kosasih FR, Sündermann O. Efficacy of the Mental Health App Intellect to Reduce Stress: Randomized Controlled Trial With a 1-Month Follow-up. JMIR Form Res. 2022 Dec 14;6(12):e40723.

62. Lu SC, Xu M, Wang M, Hardi A, Cheng AL, Chang SH, Yen PY. Effectiveness and Minimum Effective Dose of App-Based Mobile Health Interventions for Anxiety and Depression Symptom Reduction: Systematic Review and Meta-Analysis. JMIR Ment Health. 2022 Sep 7;9(9):e39454.

63. Litvin S, Saunders R, Jefferies P, Seely H, Pössel P, Lüttke S. The Impact of a Gamified Mobile Mental Health App (eQuoo) on Resilience and Mental Health in a Student Population: Large-Scale Randomized Controlled Trial. JMIR Ment Health. 2023 Jul 21;10(1):e47285.

64. Guo Y, Li Y, Yu C, Xu H, Hong YA, Wang X, Zhang N, Zeng Y, Monroe-Wise A, Li L, Liu C, Cai W, Lin A. Long-term Effects of a Social Media-Based Intervention (Run4Love) on Depressive Symptoms of People Living With HIV: 3-Year Follow-up of a Randomized Controlled Trial. J Med Internet Res. 2022 Jun 28;24(6):e36809.

65. Martin NM, Barnett DJ, Poirier L, Sundermeir SM, Reznar MM, Gittelsohn J. Moving Food Assistance into the Digital Age: A Scoping Review. Int J Environ Res Public Health. 2022 Jan 25;19(3):1328.

66. Katapally TR, Bhawra J, Leatherdale ST, Ferguson L, Longo J, Rainham D, Larouche R, Osgood N. The SMART Study, a Mobile Health and Citizen Science Methodological Platform for Active Living Surveillance, Integrated Knowledge Translation, and Policy Interventions: Longitudinal Study. JMIR Public Health Surveill. 2018 Mar 27;4(1):e8953.

67. Robin T, Burnett K, Parker B, Skinner K. Safe Food, Dangerous Lands? Traditional Foods and Indigenous Peoples in Canada. Front Commun [Internet]. 2021 [cited 2023 Oct 17];6.

Available from: https://www.frontiersin.org/articles/10.3389/fcomm.2021.749944

68. Shukla S, Alfaro J, Cochrane C, Garson C, Mason G, Dyck J, Beaudin-Reimer B, Barkman J. Nimiciwinán, nipimátisiwinán - “our food is our way of life”: On-Reserve First Nation perspectives on community food security and sovereignty through oral history in Fisher River Cree Nation, Manitoba. 2019 May;6(2):73–100.

69. Brown W. The Digital Divide. 2020 Aug 28 [cited 2024 Feb 23]; Available from: https://open.library.okstate.edu/learninginthedigitalage/chapter/the-digital-divide/

70. Silver L, Johnson C. 1. Majorities in sub-Saharan Africa own mobile phones, but smartphone adoption is modest [Internet]. Pew Research Center’s Global Attitudes Project. 2018 [cited 2024 Feb 23]. Available from: https://www.pewresearch.org/global/2018/10/09/majorities-in-sub-saharan-africa-own-mobile-phones-but-smartphone-adoption-is-modest/

71. Lamtey G. Use of smart phones still low in Tanzania [Internet]. The Citizen. 2024 [cited 2024 Feb 23]. Available from: https://www.thecitizen.co.tz/tanzania/news/business/use-of-smart-phones-still-low-in-tanzania-4507492

72. Tortora B, Rheault M. Mobile Phone Access Varies Widely in Sub-Saharan Africa [Internet]. Gallup.com. 2011 [cited 2024 Feb 23]. Available from: https://news.gallup.com/poll/149519/Mobile-Phone-Access-Varies-Widely-Sub-Saharan-Africa.aspx

73. Vassilakopoulou P, Hustad E. Bridging Digital Divides: a Literature Review and Research Agenda for Information Systems Research. Inf Syst Front. 2023;25(3):955–69.

74. Imran A. Why addressing digital inequality should be a priority. Electron J Inf Syst Dev Ctries. 2023;89(3):e12255.

75. Mammen JT, Rugmini Devi M, Girish Kumar R. North–South digital divide: A comparative study of personal and positional inequalities in USA and India. Afr J Sci Technol Innov Dev. 2023 Jun 7;15(4):482–95.

76. Wilson J, Heinsch M, Betts D, Booth D, Kay-Lambkin F. Barriers and facilitators to the use of e-health by older adults: a scoping review. BMC Public Health. 2021 Aug 17;21(1):1556.

77. Khanlou N, Khan A, Vazquez LM, Zangeneh M. Digital Literacy, Access to Technology and Inclusion for Young Adults with Developmental Disabilities. J Dev Phys Disabil. 2021 Feb 1;33(1):1–25.

78. Buchan MC, Bhawra J, Katapally TR. Navigating the digital world: development of an evidence-based digital literacy program and assessment tool for youth. Smart Learn Environ. 2024 Feb 7;11(1):8.

79. Todowede O, Lewandowski F, Kotera Y, Ashmore A, Rennick-Egglestone S, Boyd D, Moran S, Ørjasæter KB, Repper J, Robotham D, Rowe M, Katsampa D, Slade M. Best practice guidelines for citizen science in mental health research: systematic review and evidence synthesis. Front Psychiatry. 2023 Sep 8;14:1175311.

80. Rubio-Iglesias JM, Edovald T, Grew R, Kark T, Kideys AE, Peltola T, Volten H. Citizen Science and Environmental Protection Agencies: Engaging Citizens to Address Key

Environmental Challenges. Front Clim [Internet]. 2020 [cited 2024 Feb 23];2. Available from: https://www.frontiersin.org/articles/10.3389/fclim.2020.600998

81. Ryan SF, Adamson NL, Aktipis A, Andersen LK, Austin R, Barnes L, Beasley MR, Bedell KD, Briggs S, Chapman B, Cooper CB, Corn JO, Creamer NG, Delborne JA, Domenico P, Driscoll E, Goodwin J, Hjarding A, Hulbert JM, Isard S, Just MG, Kar Gupta K, López-Uribe MM, O'Sullivan J, Landis EA, Madden AA, McKenney EA, Nichols LM, Reading BJ, Russell S, Sengupta N, Shapiro LR, Shell LK, Sheard JK, Shoemaker DD, Sorger DM, Starling C, Thakur S, Vatsavai RR, Weinstein M, Winfrey P, Dunn RR. The role of citizen science in addressing grand challenges in food and agriculture research. Proc R Soc B Biol Sci. 2018 Nov 21;285(1891):20181977.

82. The first touch-free thermometer that plugs directly into your smartphone - element14 Community [Internet]. 2015 [cited 2024 Feb 23]. Available from: https://community.element14.com/technologies/sensor-technology/b/blog/posts/the-first-touch-free-thermometer-that-plugs-directly-into-your-smartphone

83. Calvet-Mir L, Benyei P, Aceituno-Mata L, Pardo-de-Santayana M, Lopez-Garcia D, Carrascosa-Garcia M, Perdomo-Molina A, Reyes-Garcia V. The Contribution of Traditional Agroecological Knowledge as a Digital Commons to Agroecological Transitions: The Case of the CONECT-e Platform. SUSTAINABILITY. 2018 Sep;10(9).

84. Enenkel M, See L, Karner M, Álvarez M, Rogenhofer E, Baraldès-Vallverdú C, Lanusse C, Salse N. Food Security Monitoring via Mobile Data Collection and Remote Sensing: Results from the Central African Republic. PloS One. 2015;10(11):e0142030.

85. Ramos S, Larrinaga L, Albinarrate U, Jungbluth N, Ingolfsdottir G, Yngvadottir E, Landquist B, Woodhouse A, Olafsdottir G, Esturo A, Zufia J, Perez-Villareal B. SENSE tool: easy-to-use web-based tool to calculate food product environmental impact. Int J LIFE CYCLE Assess. 2016 May;21(5):710–21.

86. Your Virtual Cold Chain Assistant [Internet]. Your Virtual Cold Chain Assistant. [cited 2023 Oct 17]. Available from: https://yourvcca.org/

87. Good Empire [Internet]. [cited 2023 Oct 17]. Available from: https://www.goodempire.org/

88. Floop App | Food Carbon Footprint Calculator [Internet]. Floop App. [cited 2023 Oct 17]. Available from: https://www.thefloopapp.com/

89. Olio - Your Local Sharing App [Internet]. Olio | At Home. [cited 2023 Oct 17]. Available from: https://olioapp.com/en/

90. Tomczyk S, Rahn M, Markwart H, Schmidt S. A Walk in the Park? Examining the Impact of App-Based Weather Warnings on Affective Reactions and the Search for Information in a Virtual City. Int J Environ Res Public Health. 2021 Aug 6;18(16).

91. Bundo M, Preisig M, Merikangas K, Glaus J, Vaucher J, Waeber G, Marques-Vidal P, Strippoli MPF, Müller T, Franco O, Vicedo-Cabrera AM. How ambient temperature affects mood: an ecological momentary assessment study in Switzerland. Environ Health Glob Access Sci Source. 2023 Jul 11;22(1):52.

92. Joshi D, Panagiotou A, Bisht M, Udalagama U, Schindler A. Digital Ethnography? Our Experiences in the Use of SenseMaker for Understanding Gendered Climate Vulnerabilities amongst Marginalized Agrarian Communities. Vol. 15, SUSTAINABILITY. ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND: MDPI; 2023.

93. Price M, Yuen EK, Davidson TM, Hubel G, Ruggiero KJ. Access and completion of a Web-based treatment in a population-based sample of tornado-affected adolescents. Psychol Serv. 2015 Aug;12(3):283–90.

94. Seligman J, Felder SS, Robinson ME. Substance Abuse and Mental Health Services Administration (SAMHSA) Behavioral Health Disaster Response App. Disaster Med Public Health Prep. 2015 Oct;9(5):516–8.

95. Eco-Anxious Stories [Internet]. 2022 [cited 2023 Oct 17]. Available from: https://ecoanxious.ca/

96. Climate Awakening [Internet]. [cited 2023 Oct 17]. Available from: https://climateawakening.org/

97. Marks L, Laird Y, Trevena H, Smith BJ, Rowbotham S. A Scoping Review of Citizen Science Approaches in Chronic Disease Prevention. Front Public Health [Internet]. 2022 [cited 2024 Feb 23];10. Available from: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2022.743348

98. Gomez-Zavaglia A, Mejuto JC, Simal-Gandara J. Mitigation of emerging implications of climate change on food production systems. Food Res Int Ott Ont. 2020 Aug;134:109256.

99. Kumar L, Chhogyel N, Gopalakrishnan T, Hasan MK, Jayasinghe SL, Kariyawasam CS, Kogo BK, Ratnayake S. Chapter 4 - Climate change and future of agri-food production. In: Bhat R, editor. Future Foods [Internet]. Academic Press; 2022 [cited 2023 Oct 26]. p. 49–79. Available from: https://www.sciencedirect.com/science/article/pii/B9780323910019000098

100. Peltonen-Sainio P, Jauhiainen L. Large zonal and temporal shifts in crops and cultivars coincide with warmer growing seasons in Finland. Reg Environ Change. 2020 Jul 18;20(3):89.

101. Qian C, Murphy SI, Orsi RH, Wiedmann M. How Can AI Help Improve Food Safety? Annu Rev Food Sci Technol. 2023 Mar 27;14:517–38.

102. Wudil AH, Usman M, Rosak-Szyrocka J, Pilař L, Boye M. Reversing Years for Global Food Security: A Review of the Food Security Situation in Sub-Saharan Africa (SSA). Int J Environ Res Public Health. 2022 Nov 11;19(22):14836.

103. Wolfson JA, Garcia T, Leung CW. Food Insecurity Is Associated with Depression, Anxiety, and Stress: Evidence from the Early Days of the COVID-19 Pandemic in the United States. Health Equity. 2021 Feb 25;5(1):64–71.

104. Fang D, Thomsen MR, Nayga RM. The association between food insecurity and mental health during the COVID-19 pandemic. BMC Public Health. 2021 Mar 29;21(1):607.

105. Myers CA. Food Insecurity and Psychological Distress: A Review of the Recent Literature. Curr Nutr Rep. 2020 Jun;9(2):107–18.

106. Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. Int J Ment Health Syst. 2018 Jun 1;12(1):28.

107. Cianconi P, Betrò S, Janiri L. The Impact of Climate Change on Mental Health: A Systematic Descriptive Review. Front Psychiatry [Internet]. 2020 [cited 2023 Oct 26];11. Available from: https://www.frontiersin.org/articles/10.3389/fpsyt.2020.00074

108. Berry HL, Waite TD, Dear KBG, Capon AG, Murray V. The case for systems thinking about climate change and mental health. Nat Clim Change. 2018 Apr;8(4):282–90.

109. Berberian AG, Gonzalez DJX, Cushing LJ. Racial Disparities in Climate Change-Related Health Effects in the United States. Curr Environ Health Rep. 2022;9(3):451–64.

110. Ngcamu BS. Climate change effects on vulnerable populations in the Global South: a systematic review. Nat Hazards. 2023 Sep 1;118(2):977–91.

111. Domingo A, Charles KA, Jacobs M, Brooker D, Hanning RM. Indigenous Community Perspectives of Food Security, Sustainable Food Systems and Strategies to Enhance Access to Local and Traditional Healthy Food for Partnering Williams Treaties First Nations (Ontario, Canada). Int J Environ Res Public Health. 2021 Apr 21;18(9):4404.

112. Oliver B, Deawuo LA, Rao S. A Food Sovereignty Approach to Localization in International Solidarity. Societies. 2022 Oct;12(5):145.

113. Martin NM, Sundermeir SM, Barnett DJ, van Dongen EJI, Rosman L, Rosenblum AJ, Gittelsohn J. Digital Strategies to Improve Food Assistance in Disasters: A Scoping Review. Disaster Med Public Health Prep. 2021 Oct 11;1–10.

114. Galanakis CMM. The “Vertigo” of the Food Sector within the Triangle of Climate Change, the Post-Pandemic World, and the Russian-Ukrainian War. Vol. 12, FOODS. ST ALBAN-ANLAGE 66, CH-4052 BASEL, SWITZERLAND: MDPI; 2023.

115. Farooq M, Riaz S, Abu Helou M, Khan F, Abid A, Alvi A. Internet of Things in Greenhouse Agriculture: A Survey on Enabling Technologies, Applications, and Protocols. IEEE ACCESS. 2022;10:53374–97.

116. Jia H, Wang J, Cao C, Pan D, Shi P. Maize drought disaster risk assessment of China based on EPIC model. Int J Digit EARTH. 2012;5(6):488–515.

117. Han H, Ahn SW. Youth Mobilization to Stop Global Climate Change: Narratives and Impact. Sustainability. 2020 Jan;12(10):4127.

118. Gasparri G, Omrani OE, Hinton R, Imbago D, Lakhani H, Mohan A, Yeung W, Bustreo F. Children, Adolescents, and Youth Pioneering a Human Rights-Based Approach to Climate Change. Health Hum Rights. 2021 Dec;23(2):95–108.

119. Sanson A, Bellemo M. Children and youth in the climate crisis. BJPsych Bull. 45(4):205–9.

120. Sanson AV, Van Hoorn J, Burke SEL. Responding to the Impacts of the Climate Crisis on Children and Youth. Child Dev Perspect. 2019;13(4):201–7.

121. Hickman C, Marks E, Pihkala P, Clayton S, Lewandowski RE, Mayall EE, Wray B, Mellor C,

Susteren L van. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Lancet Planet Health. 2021 Dec 1;5(12):e863–73.

122. Aithal SS, Sachdeva I, Kurmi OP. Air quality and respiratory health in children. Breathe. 2023 Jun;19(2):230040.

123. Collier S. If climate change keeps you up at night, here's how to cope [Internet]. Harvard Health. 2022 [cited 2024 Feb 24]. Available from: https://www.health.harvard.edu/blog/is-climate-change-keeping-you-up-at-night-you-may-have-climate-anxiety-202206132761

124. THE 17 GOALS | Sustainable Development [Internet]. [cited 2023 Oct 26]. Available from: https://sdgs.un.org/goals

125. Bhawra J, Skinner K, Favel D, Green B, Coates K, Katapally TR. The Food Equity and Environmental Data Sovereignty (FEEDS) Project: Protocol for a Quasi-Experimental Study Evaluating a Digital Platform for Climate Change Preparedness. JMIR Res Protoc. 2021 Sep 15;10(9):e31389.

126. Canada's most vulnerable: Improving health care for First Nations, Inuit and Métis seniors [Internet]. RCPS - CHWN. [cited 2023 Oct 26]. Available from: https://www.hhr-rhs.ca/index.php?option=com_content&view=article&id=466%3Acanadas-most-vulnerable-improving-health-care-for-first-nations-inuit-and-metis-seniors&catid=150%3Afeatures-rural-remote-aboriginal&lang=en

127. Dwivedi YK, Hughes L, Kar AK, Baabdullah AM, Grover P, Abbas R, Andreini D, Abumoghli I, Barlette Y, Bunker D, Chandra Kruse L, Constantiou I, Davison RM, De' R, Dubey R, Fenby-Taylor H, Gupta B, He W, Kodama M, Mäntymäki M, Metri B, Michael K, Olaisen J, Panteli N, Pekkola S, Nishant R, Raman R, Rana NP, Rowe F, Sarker S, Scholtz B, Sein M, Shah JD, Teo TSH, Tiwari MK, Vendelø MT, Wade M. Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. Int J Inf Manag. 2022 Apr 1;63:102456.

128. Clark S, MacLachlan M, Marshall K, Morahan N, Carroll C, Hand K, Boyle N, O'Sullivan K. Including Digital Connection in the United Nations Sustainable Development Goals: A Systems Thinking Approach for Achieving the SDGs. Sustainability. 2022 Jan;14(3):1883.

129. Pocock NS, Chan Z, Loganathan T, Suphanchaimat R, Kosiyaporn H, Allotey P, Chan WK, Tan D. Moving towards culturally competent health systems for migrants? Applying systems thinking in a qualitative study in Malaysia and Thailand. PLOS ONE. 2020 Apr 6;15(4):e0231154.

130. Ospina AV, Heeks R. ICT-Enabled Responses to Climate Change in Rural Agricultural Communities.

131. Ibrahim ST, Hammami N, Katapally TR. Traditional surveys versus ecological momentary assessments: Digital citizen science approaches to improve ethical physical activity surveillance among youth. PLOS Digit Health. 2023 Sep;2(9):e0000294.

132. Katapally TR, Chu LM. Digital epidemiological and citizen science methodology to capture

prospective physical activity in free-living conditions: a SMART Platform study. BMJ Open. 2020 Jun 28;10(6):e036787.

133. Kazemi Garajeh M, Salmani B, Zare Naghadehi S, Valipoori Goodarzi H, Khasraei A. An integrated approach of remote sensing and geospatial analysis for modeling and predicting the impacts of climate change on food security. Sci Rep. 2023 Jan 19;13(1):1057.

134. Heo S, Chan AY, Diaz Peralta P, Jin L, Pereira Nunes CR, Bell ML. Impacts of the COVID-19 pandemic on scientists' productivity in science, technology, engineering, mathematics (STEM), and medicine fields. Humanit Soc Sci Commun. 2022;9(1):434.

135. Raynaud M, Goutaudier V, Louis K, Al-Awadhi S, Dubourg Q, Truchot A, Brousse R, Saleh N, Giarraputo A, Debiais C, Demir Z, Certain A, Tacafred F, Cortes-Garcia E, Yanes S, Dagobert J, Naser S, Robin B, Bailly É, Jouven X, Reese PP, Loupy A. Impact of the COVID-19 pandemic on publication dynamics and non-COVID-19 research production. BMC Med Res Methodol. 2021 Nov 22;21(1):255.

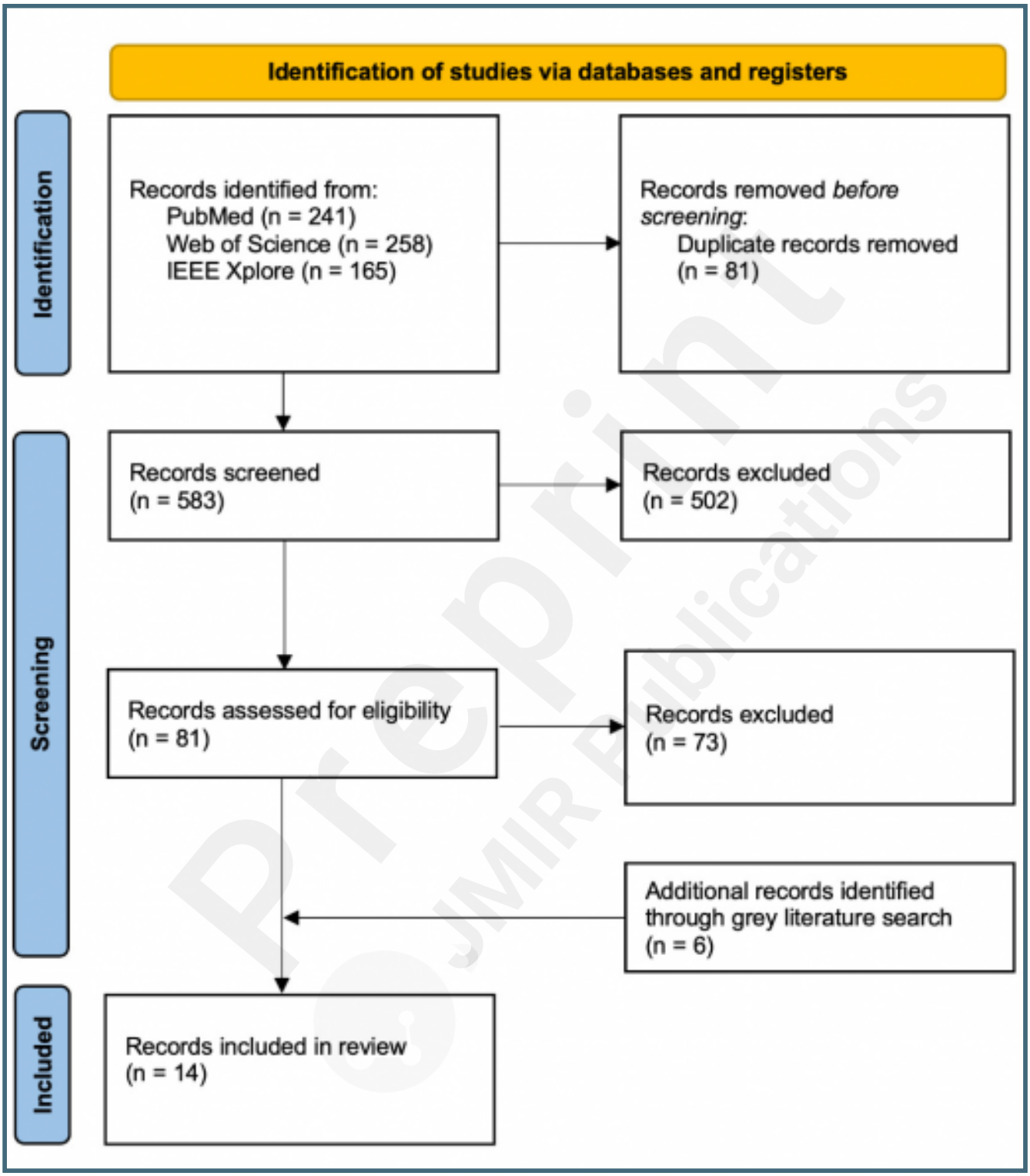
136. Riccaboni M, Verginer L. The impact of the COVID-19 pandemic on scientific research in the life sciences. PLOS ONE. 2022 Feb 9;17(2):e0263001.

137. Wang Q, Huang R. The impact of COVID-19 pandemic on sustainable development goals – A survey. Environ Res. 2021 Nov 1;202:111637.

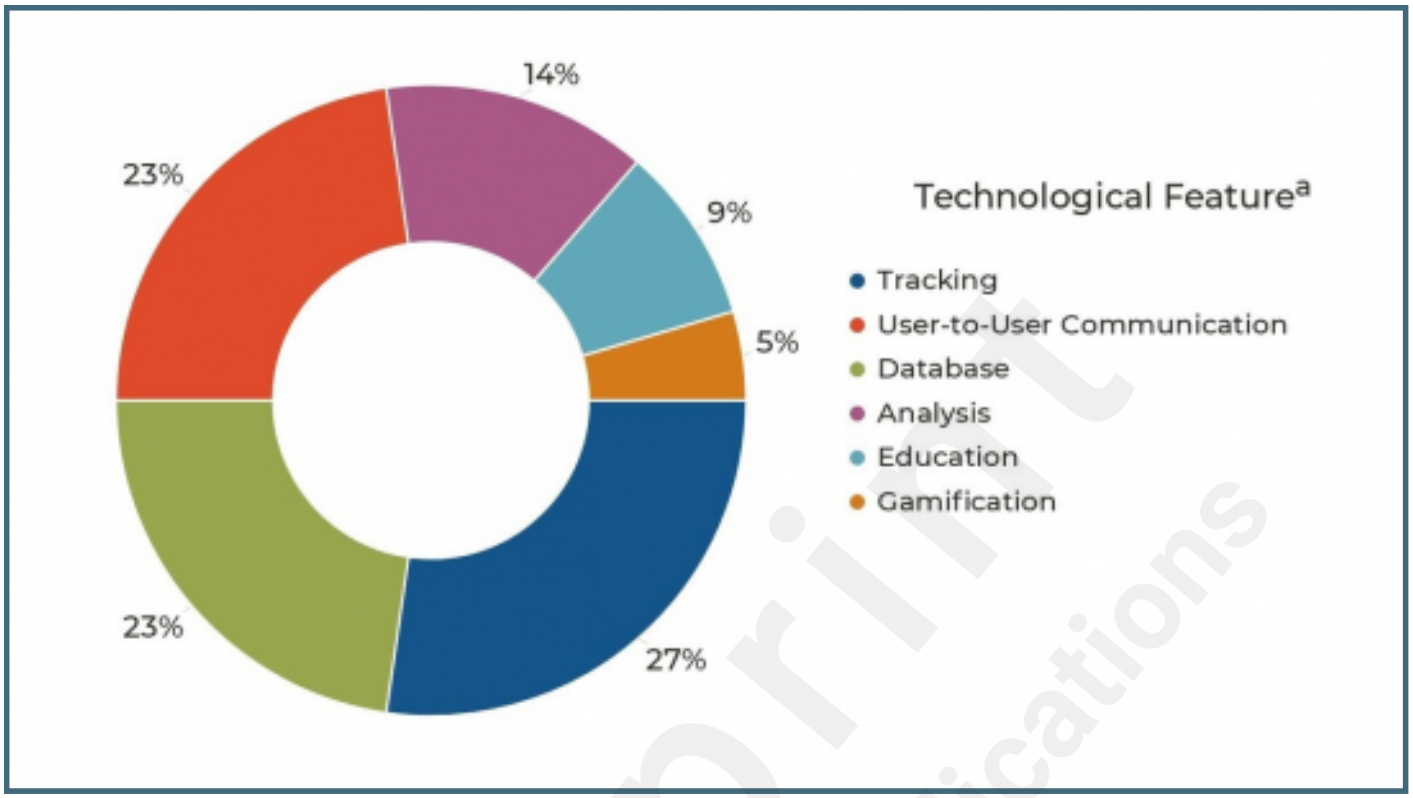
Supplementary Files

Figures

Flow diagram of the scoping review literature search process.



Distribution of feature frequencies across climate change digital apps.



Multimedia Appendixes

Scoping review data extraction table.
URL: http://asset.jmir.pub/assets/8b3890bb781e1eb6e8ce5d8a12a85b42.docx

CONSORT (or other) checklists

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.
URL: http://asset.jmir.pub/assets/d0c8b84d9dd83d842ec33e371cf200f2.pdf