Title:

Co-designing a Platform for Documenting African Indigenous Knowledge: Participatory Citizen Science and Data Science Approaches

Authors

Steven Sam
Department of Computer Science
College of Engineering, Design and Physical Science
Brunel University London, UK

Ximena Schmidt
Department of Chemical Engineering,
College of Engineering, Design and Physical Science,
Brunel University London, London, UK

Hugh Dickinson
School of Physical Sciences,
Faculty of Science, Technology, Engineering & Mathematics,
The Open University, UK

Jens Jensen
Scientific Computing Department
Sciences and Technology Facilities Council (STFC), UK

IAMCR Section
Participatory Communication Research Section (PCR

ExOrdo submission ID #2598

Co-designing a Platform for Documenting African Indigenous Knowledge: Participatory Citizen Science and Data Science Approaches

Steven Sam[1], Ximena Schmidt[2], Hugh Dickinson[3], Jens Jensen[4]

[1]Computer Science for Social Good Research Group, Department of Computer Science, College of Engineering, Design and Physical Science, Brunel University London, UK
[2]Equitable Development and Resilience Research Group, Department of Chemical Engineering, College of Engineering, Design and Physical Science, Brunel University London, London, UK
[3]School of Physical Sciences, Faculty of Science, Technology, Engineering & Mathematics, Open University, UK
[4]Sciences and Technology Facilities Council (STFC), Scientific Computing Department, Didcot OX11 0QX, UK

Abstract

Africa indigenous knowledge (AIK) is innovative and unique among local and subsistent smallholder farmers. AIK drives food production, preservation and consumption for more than 80% of citizens in Africa. However, AIK face risk of extinction due to increased rural-urban migration, land grabbing, penetration of multinational companies and the emergence of relatively small-scale indigenous commercial farming businesses. While this necessitates the documentation and strengthening the link between AIK and modern food production efforts in Africa, librarians and other information professionals in Africa are confronted with the challenges to capture and document this implicit knowledge. Our study combines data science and citizen science approaches through active community and smallholder farmers' participation and data-driven analytics to define a curated digital platform for capturing, documenting and sharing African indigenous knowledge of agriculture and food systems. The goal is to provide insights, facilitate learning and promote knowledge that is relevant for policy intervention and sustainable food production based on ethical and FAIR principles. The research results show the importance of stakeholders, in particular farmers, as active agents for co-designing the AIK management platform and bridging the gap between indigenous and scientific knowledge for promoting resilient food system. We conclude by arguing that learning from AIK by investigating what local communities know and have, can improve understanding of food production and consumption, particularly in times of stress or shocks affecting the food systems and communities.

1. INTRODUCTION

Africa indigenous knowledge (AIK) is innovative and unique among local and subsistent smallholder farmers, especially women and elders. AIK is generally recognised as an important tacit knowledge that drives food production, preservation and consumption for more than 80% of citizens in Africa. However, AIK faces the risk of extinction due to increased rural-urban migration, land grabbing, penetration of multinational companies and the emergence of relatively small-scale indigenous commercial farming businesses. While this necessitates documentation and strengthening of the link between AIK and modern food production efforts in Africa, librarians and other information professionals are confronted with the challenge of capturing and documenting this implicit knowledge. This paper reports a study that combines data science and citizen science approaches through active community and smallholder farmers' participation and data-driven analytics to define a curated digital platform for capturing, documenting and sharing African indigenous knowledge of agriculture and food systems. The goal is to provide insights, facilitate learning and promote knowledge that is relevant for policy intervention and sustainable food production based on ethical and FAIR (Findable, Accessible, Interoperable and Reusable) principles.

There is no one definition of what Indigenous knowledge (IK) is (NAFA, 2006); however, some of the key characteristics are that IK is held by members of communities, based on observations of nature, their interaction with it and their decision making, passed on by generations. IK is then intergenerational, being part of the collective memory of members of the community. It is also adaptive, cumulative and dynamic. IK is holistic in nature, connecting all aspects of life with the environment. IK is usually transmitted orally, through stories, songs, language, etc. (ICT Inc., 2018). Therefore, any attempt to connect with IK in the context of agriculture and food systems requires an active participation of those who have, have received, teach and use the knowledge, who are community members, especially women and elders. In doing so, it is important to use methods that enable working together in a way that is beneficial for both citizens and researchers, with methods that enable meaningful scientific interactions for all actors and providing insightful analytics for policy decision making and strengthening agriculture and food systems.

Citizen science is one of several such methods. It is a participatory method that invites citizens to be active collaborators and scientists in the creation of new knowledge or understanding of existing knowledge. The connections between citizen science and IK is taking a larger presence in the literature, with recent studies looking at how citizen science has been used with IK in different fields. For example, Tengö et al. (2021) analysed different projects related to stewardship and conservation, critically assessing the methodologies, the project aspirations and risks; the authors highlighted the potential of these approaches in relation to "mobilising vast knowledge in use" for policies, decision making and management. Danielsen et al. (2018), who also highlighted the challenges of using and validating information coming from "different knowledge systems", delivered similar conclusions. UNESCO has also been promoting the integration of IK and citizen science at different levels; projects like Sandwatch looking to build resilience to climate change and preserve beach environments, is one of the examples (UNESCO 2022).

Similarly, the application of citizen science in sustainable food systems is also gaining more popularity since 2019, as shown in the review done by Oakden et al. (2021). Even the UK Food Standard Agency (FSA) (2021) released a special review on food and citizen science, concluding the use of this approach provides not only benefits for research and research community, but also to the wider society. The authors highlighted that citizen science promotes ownership of policies in addition to public awareness, and that the use of this method could be beneficial to "infom and target policies", among others.

So far, there is limited information about projects using citizen science approaches to learn about AIK and food systems, that not only focus on a specific aspect but that tackles the issues of information sharing, capturing and documenting. Hence, this project aims to combine data science and citizen science approaches, with a focus on integrating stakeholders, particularly smallholder farmers, as active agents for generating and analysing IK of agric-food systems data and defining a curated AIK platform to document AIK and provide insightful analytics for policy decisions and learning. Detailed description of how these two approaches are integrated to document and share insights of AIK of agriculture and food systems in Sierra Leone (a case study) are presented in the rest of the sections of this paper.

2. BACKGROUND CONTEXT

Sierra Leone is among the world's poorest countries, ranking 181st out of 189 countries in the UN Human Development Index. It has a population of about 7.7 million, with 58% living in the rural areas (HDI, 2019). Sierra Leone, like many sub-Saharan African countries, is at the crossroads of small-scale commercial agricultural transformation, with rapidly emerging local SMEs and a sizable penetration of multinational agricultural companies disrupting rural livelihoods, traditional farming and food

production systems. These disruptions have had detrimental effects on agricultural and food production in Sierra Leone, which in the rural areas include loss of land and livelihoods, loss of valuable nutritious food sources for the rural populations, increase in urban migration, and lack of documentation and integration of AIK into modern food production efforts.

Importantly, the emerging modernisation of the agricultural sector seeks to undermine sustainable and inclusive agricultural development through displacing women from their traditional productive functions, and diminishing incomes, power and community status. According to the FAO (2018), women represent 70% of the agricultural labour force of Sierra Leone and play an important role in indigenous agricultural and food production. In other words, women are rich sources for integrating AIK of agriculture, natural resource management and food production into modern agricultural policies and practices in an ethical and fair manner. Thus, to leverage digital technology for AIK management, we focus on gender equality and inclusive agricultural development by acknowledging and amplifying women's roles in the changing agricultural landscape and food production in Sierra Leone.

3. DEFINING AIK PLATFORM DESIGN: A FOCUS ON METHODOLOGY

This section explains the methodology developed and applied in this project, starting with the citizen science approaches used for collecting and analysing data followed by the data science approaches for defining the AIK platform and processing and calibrating a variety of AIK data types.

3.1 Citizen science approach

The application of Citizen science focuses on three perspectives in this study: farmers' participation for data generation, citizen-centred data interpretation using Zooniverse and citizen-led technology development. The following section describes these approaches, detailing the technologies used and how the work was carried out.

3.1.1 Farmers generated data

The first attempt to apply citizen science in this study involves leveraging the active participation of farmers to produce and make sense of data that reflect their everyday experiences of indigenous food systems. The farmers' generated data is distinct from 'big data' or 'social media data', which is indirectly created by citizens through interaction with digital technology such as mobile phones or social media platforms (Andrade et al., 2021). Rather than collecting data about them, we engaged farmers directly as equal research partners, by allowing them to generate and interpret data suited and relevant to their contexts. The approach characterises a fundamental Citizen Science framework, which reinforces active citizens' engagement and contributions to scientific research activities either with their intellectual effort or surrounding knowledge or with their tools and resources (ECSA, 2020).

In the first instance, our aim was to understand existing and emerging practices embodied in AIK agriculture and farming practices, and then use the knowledge to provide guidelines and requirements for developing the AIK platform and back-end data sources for enhancing learning. To achieve this, we adopted participatory photo and video elicitation approaches to have farmers self-report their everyday experiences of indigenous food systems. The approach involves the process of using videos and photos generated by research participants to facilitate discussions regarding a specific topic (Vieira et al., 2014). We recruited and trained 20 farmers and had them make photo and video diaries of their everyday farming and food systems activities. Farmers were given the freedom to capture what is meaningful to them based on different themes generated by them. The photo and video elicitation of participants followed a strict ethical consideration, ensuring that no participant is

subjected to any form of risk. The generated data shows that farmers' electronic self-recording of everyday traditional practices and active participation in data interpretation can contribute to new discoveries and develop technologies and applications likely to enhance inclusive agriculture and improve sustainable, healthy and nutritious food security. Farmers collected videos and photos to document all aspects of agriculture and food system practices -such as cultivation, harvesting, processing, preparation, consumption and preservation.

3.1.2 Citizen-centred data interpretation

Citizen science is also integrated in the interpretation of data through two routes - by farmers' interpretation of the data and the Zooniverse platform.

Interpretation by farmers: As part of the participatory photo elicitation process, the farmers interpreted and reflected on the videos and photos produced by them through interviews and group discussions. The analysis provides a critical pedagogical site for eliciting in-depth accounts of their experiences, facilitating farmers-to-farmers learning, and generating valuable resources for further citizen-centred analysis on Zooniverse and knowledge sharing on the proposed AIK platform. This citizen science approach offers legitimacy to agricultural research and a 'double win' of supporting effective scientific knowledge generation and interactive learning for and from farmers (Van De Gevel et al., 2020).

Interpretation by Zooniverse: Data collected are also analysed using the UK Science and Technology Facilities Council's proven citizen science Zooniverse platform, one of the largest global digital platforms that enables citizen science research (Zooniverse, 2022). Zooniverse exploits the human capacity for recognising patterns by enabling citizens (volunteers) to join scientists in their research, helping with large-scale data analysis that would otherwise be an impossible task to achieve in a short period. Zooniverse has been widely used in the field of physics and astronomy, nature and recently in climate, medicine, language and humanities (Zooniverse 2022). In the field of food systems, this approach is in its infancy, with only few studies found (Armstrong et al. 2021, Bridge et al. 2021, Armstrong et al. 2020).

In our study, Zooniverse enables the annotation and classification of the data in the AIK platform through a series of activities involving a pilot Zooniverse project: "African Indigenous Knowledge (AIK-M)". Citizen scientists (including farmers) analyse a series of pictures, tagging and identifying the foods and tools present in the pictures. They do this through tasks that involve drawing a rectangle where "foods" or "tools" are seen in the pictures, and also performing tasks that ask to identify (and select) specific foods or tools found in the pictures. The goal is to test the platform for citizen-centric data interpretation through a curated citizen science platform and to identify potential barriers for users in Africa. Preliminary analysis shows that the involvement of these volunteers relies on access to digital devices and the internet. These requirements present potential barriers to entry that are important to consider when understanding the usefulness of Zooniverse for worldwide projects and the potential "biases" of the citizen scientists that will be able to contribute. A full Zooniverse project will be carried out following the pilot project. We aim to store the full data and tags generated in the AIK database and make it accessible via the front-end of the AIK platform.

3.1.3 Citizen-led technology development

The characteristics of most citizen science projects typically involve the use of digital technology to enable participation, data collection, communication and collaborations among scientists and non-scientists in research. However, in this project, we also show that citizen science efforts can involve different roles such as allowing active farmers' participation in defining digital technology solutions

for knowledge sharing and learning (Van De Gevel, 2020). The goal is to cater for multiple points of entry of citizen science by including farmers and other relevant stakeholders in the co-designing and testing of the AIK platform. The final activity of the project integrates this perspective of citizen science through participatory stakeholder workshop. Twenty participants including farmers and policy stakeholders are targeted to discuss outcomes of the famers' activities, co-design and validate AIK conceptual design prototypes and formulate the AIK knowledge sharing standard framework and copyright agreement. The outcomes of the participatory workshop offer insights into how novice scientists (e.g. farmer researchers) can contribute to reimagining participatory citizen-centric technology design in agriculture.

In contrast to the traditional form of participatory process that originated largely in public participation/deliberative democracy with well-defined questions that need to be answered (Van De Gevel, 2020), our approach sits at the intersection between participatory approach and design thinking framework (Katoppo & Sudradjat, 2015; Behrendorff et al., 2011). It involves an interactive sharing between farmers, policy stakeholders and researchers to define technology solutions based on their experiences, needs and contexts. The study contributes to the understanding of integrating participatory approaches and citizen science in technology design processes, with a focus on ethically including citizens in co-designing a digital platform for promoting innovation in African agriculture and food systems.

3.2 Data science approach

The data science approach to the project focuses on the computational processing, calibration and annotation of a variety of AIK data types from multiple sources (videos, texts and images), making it accessible and reusable for policy, research and practice and enabling connectivity with national and international archives. Our approach is driven by the need to minimise technical (or technological) obstacles that impede access to open data, which has been recognised for strengthening agriculture and food systems (Protopop & Shanoyan, 2016).

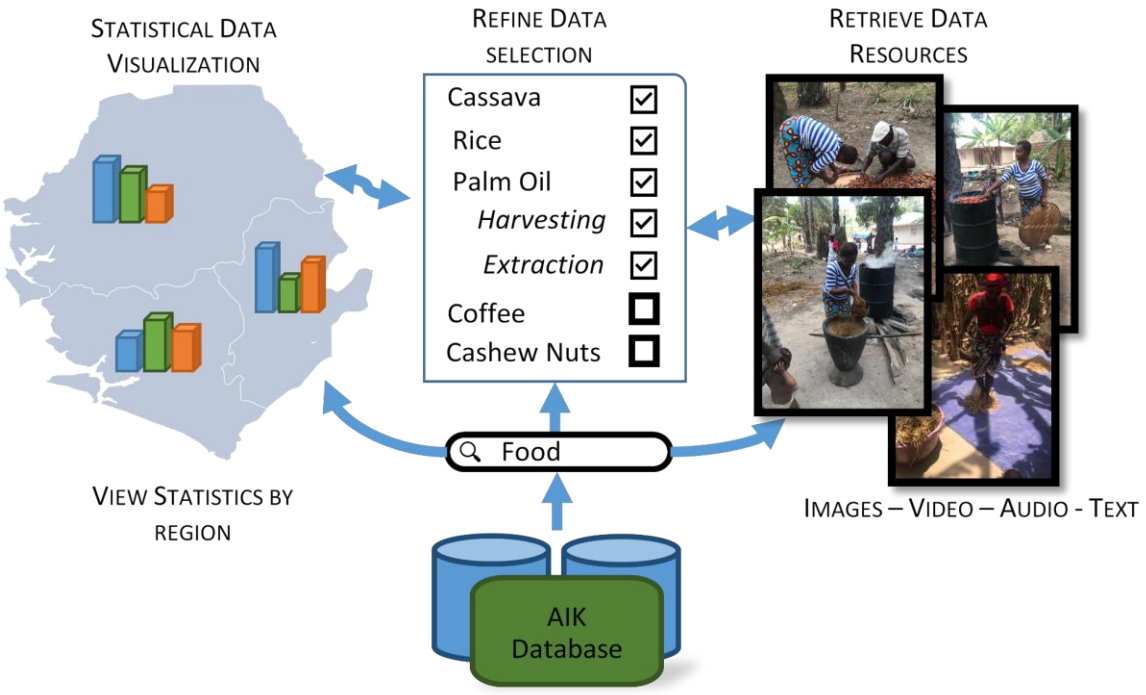

Figure 1: A snapshot of AIK platform architecture

Widespread access to open data can encourage collaborations between institutions, improve agricultural management decision-making processes and promote gender equality and inclusive agricultural development (Andrade et al., 2021). Our main activities include the development of an open-access AIK platform with a multimedia database designed to store, sort, manage and share AIK. Figure 1 provides a snapshot of the preliminary architecture of the AIK platform prototype with backbone capabilities such as classifying data (e.g. images and videos), visualisation and discovery and retrieval of diverse data types.

Specifically, the data science approach to the study focuses on three overlapping principles: computational, API access and FAIR metadata. The principles are drawn on to ensure an effective implementation, best practices and ethical standards for collecting and sharing open AIK of agriculture and food systems data. The computational principle characterises the systems for managing and analysing data to extract predictive patterns, which can guide farmers, scientists, or policy makers to take better decisions that lead to transformative actions for agriculture and food systems. The initial AIK architecture uses the Open Source *Django* Python framework to implement a database-driven web platform with front-end features including search functions, menus and map-based visualisation features, all linked to a server-side backend (Figure 1). The database uses an Open Source MySQL relational database model to manage data using tables with a custom schema that we have designed to support the goals of our project. When complete, the AIK open source platform will also be accessible via mobile, and support bring-your-own-cloud analytics to augment inbuilt advanced machine learning analytical capabilities for better predictability and computability.

AIK-APIs are developed and configured to handle and exchange AIK datasets across systems and applications on the platform. It addresses the problem of accessing, integrating and exchanging large, complex and FAIR agriculture and food systems data datasets (Devare et al., 2021). Thus, the FAIR principles are integrated to increase the access to AIK data on the platform by creating metadata, which allows the data to be searchable and accessible. With the help of the AIK-APIs, the FAIR principles are also maintained through enabling system interoperability and reusability of the data.

4. INTEGRATING CITIZEN SCIENCE AND DATA SCIENCE

Our study attempts to bring to light the importance of combining citizen science and data science to address the fundamental challenges underpinning agricultural innovation and big data applications in food systems productivity in the Global South. The research results show the importance of stakeholders, in particular farmers, as active agents for co-designing the AIK management platform and bridging the gap between indigenous and scientific knowledge for promoting a resilient food system.

Increasingly, there is high interest in adopting new technologies and exploring the potential for open data and smallholder farm-oriented big data-driven solutions to strengthen the agric-food systems. Research reports that big data offers a potent digital solution for harnessing the potential of open data in agriculture (Andrade et al., 2021). However, the benefit to indigenous smallholder farmers has come under serious scrutiny regarding the limitation of farmers' role and generating and analysing data that reflect their reality using technology (Protopop & Shanoyan, 2016; van Etten et al., 2017). The application of big data solutions relies on high volume and variety of quantifiable data generated through users' interaction with technologies (Protopop & Shanoyan, 2016). For smallholder farmers, weak digital infrastructure, affordability, and low levels of e-literacy, and digital skills limit their capacity to interact with digital technologies to generate the expected data and benefits the innovations can have on indigenous agric-food systems (Trendov et al., 2019).

The AIK project provides an alternative solution for embedding data-driven solutions into indigenous agricultural development to support learning and decision-making in technology and resource-poor environments. We focus on integrated open access data-driven solutions to: (i) unravel AIK of agric-food systems' potential to solve modern agricultural development problems and (ii) provide citizen and technology data-driven insights to scientists, policymakers, farmers and consumers. As depicted in figure 2, we achieved this through integrating citizen science and data science approaches.

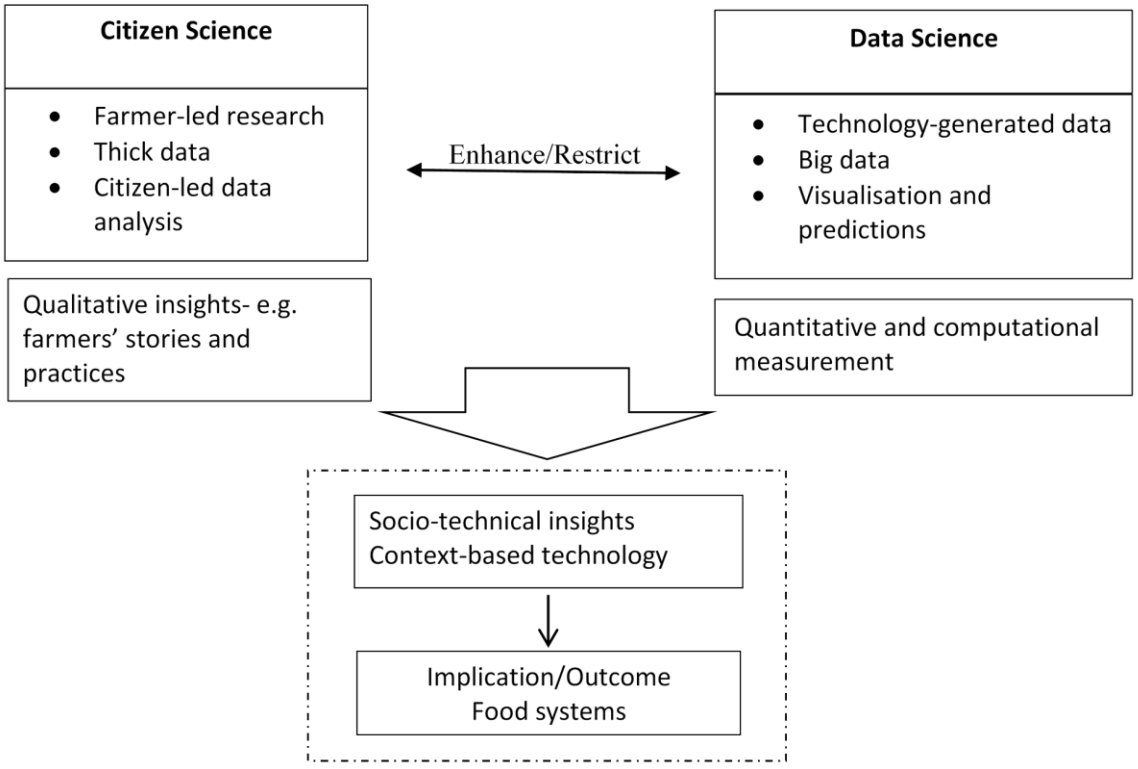

Figure 2: Integrating citizen science and data science

The citizen science approaches provide input for data science in various formats; from generating raw data in the form of pictures, videos, texts, and audios, to producing "pathways" to making databases accessible and analyseable in the front-end, and finally by producing a tailored platform. Data generated through farmers' direct engagement can be converted into useful analytical data-output for farmers oriented big data-driven solutions, addressing the problems of lack of farmers' role and technology limitations (Andrade et al., 2021). Additionally, the active involvement of farmers/citizens in data collection and interpretation reinforces the understanding of the users' needs and the incredible depth of meanings and stories from farmers in data-driven agric-food solutions. The farmers' involvement produces iterative feedback loops that inform new citizen science activities in "the data interpretation" steps, as they could be tailored to aspects of specific users (e.g., food supply chain, gender aspects, nutrition, etc.). Collectively, our work collaborates with a handful of initiatives (e.g., Observatories, WaPOR and FAOSTAT) developed in the agriculture sector to capture and harmonise data from various open access sources to build relevant indicators for decision-making (Andrade et al., 2021). We show that the combination of citizen science and data science can result in a complementary gathering and interpretation of data, and generate relationships of trust between farmers, researchers and big data solutions in technology and resource poor contexts.

5. CONCLUSION

This paper has demonstrated how citizen science and data science approaches can be integrated to bridge the gap between indigenous and scientific knowledge of agricultural and food systems practices and experiences of smallholder farmers. It seeks to address the limitations embodied in agricultural innovation and farmers' oriented data-driven solutions in the Global South through active farmers' involvement to generate qualitative data suited to their needs and contexts and define the AIK platform for IK data storage and analytics. Traditional big data approach to solve agricultural problems has seen the limited role of indigenous farmers' involvement and benefits due to the digital divide (Trendov et al., 2019). This limitation accentuates the problem of data availability, representativeness and quality (Andrade et al., 2021). Our aim has been to suggest an alternative approach through active farmers' involvement in data collection, interpretation and defining an AIK data management platform for computational processing and enabling open access to AIK of agricultural and food systems. The argument is that learning from AIK, by investigating what local communities know and have, can improve understanding of food production and consumption, particularly in times of stress or shocks affecting the food systems and communities. We have shown that this approach can contribute to addressing the barriers of availability and accessibility of farmer-generated data, standardisation and interoperability of data analytics, data privacy and ownership concerns. Future studies will examine the effectiveness of the AIK platform in detail in bridging the gap between citizen science and data science approaches for strengthening agricultural productivity and food systems.

Acknowledgement

STFC Food System Network + 2.0 - scoping projects grant who funded this project.

Zooniverse.org platform is funded by generous support, including a Global Impact Award from Google, and by a grant from the Alfred P. Sloan Foundation.

References:

Armstrong, B., Reynolds, C., Bridge, G., Oakden, L., Wang, C., Panzone, L., ... & Serjeant, S. (2021). How does Citizen Science compare to online survey panels? A comparison of food knowledge and perceptions between the Zooniverse, Prolific and Qualtrics UK Panels. *Frontiers in Sustainable Food Systems*, 306.

Armstrong, B., Bridge, G., Oakden, L., Reynolds, C., Wang, C., Panzone, L. A., ... & Serjeant, S. (2020). Piloting citizen science methods to measure perceptions of carbon footprint and energy content of food. *Frontiers in Sustainable Food Systems*, 120.

Behrendorff, C., Bucolo, S., & Miller, E. (2011, June). Designing disruption: linking participatory design and design thinking in technology orientated industries. In *Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces* (pp. 1-8).

Bridge, G., Armstrong, B., Reynolds, C., Wang, C., Schmidt, X., Kause, A., ... & Oakden, L. (2021). Engaging citizens in sustainability research: comparing survey recruitment and responses between Facebook, Twitter and qualtrics. *British Food Journal*.

Devare, M., Aubert, C., Benites Alfaro, O. E., Perez Masias, I. O., & Laporte, M. A. (2021). AgroFIMS: A tool to enable digital collection of standards-compliant FAIR data. *Frontiers in Sustainable Food Systems*.

ECSA, 2020. The characteristics of citizen science. https://zenodo.org/record/3758668#.Ym_ho9PP1hE. Access date, 06/06/2022

Food Standard Agency (FSA) (2021). Citizen Science and Food: A Review . https://www.food.gov.uk/sites/default/files/media/document/citizen-science-and-food_a-review_26mar.pdf

Katoppo, M. L., & Sudradjat, I. (2015). Combining Participatory Action Research (PAR) and Design Thinking (DT) as an alternative research method in architecture. *Procedia-Social and Behavioral Sciences*, *184*, 118-125.
National Aboriginal Forestry Association (NAFA) (2006). Definitions of traditional knowledge. http://nafaforestry.org/forest_home/documents/TKdefs-FH-19dec06.pdf. Access date, 06/06/2022
ICT Inc (2018). What Does Indigenous Knowledge Mean? A Compilation of Attributes. https://www.ictinc.ca/blog/what-does-indigenous-knowledge-mean. Access date, 06/06/2022
Oakden, L., Bridge, G., Armstrong, B., Reynolds, C., Wang, C., Panzone, L., ... & Serjeant, S. (2021). The importance of citizen scientists in the move towards sustainable diets and a sustainable food system. *Frontiers in Sustainable Food Systems*, *5*.
Protopop, I., & Shanoyan, A. (2016). Big data and smallholder farmers: big data applications in the agri-food supply chain in developing countries. *International Food and Agribusiness Management Review*, *19*(1030-2016-83148), 173-190.
Tengö, M., Austin, B. J., Danielsen, F., & Fernández-Llamazares, Á. (2021). Creating synergies between citizen science and Indigenous and local knowledge. *BioScience*, *71*(5), 503-518.
Danielsen, F., Burgess, N. D., Coronado, I., Enghoff, M., Holt, S., Jensen, P. M., ... & Rueda, R. M. (2018). The value of Indigenous and local knowledge as citizen science. UCL Press.
UNESCO (2022a). Local, indigenous and scientific knowledge. https://en.unesco.org/themes/biodiversity/knowledge. Access date, 01/06/2022
Trendov, M., Varas, S., & Zeng, M. (2019). Digital technologies in agriculture and rural areas: status report. *Digital technologies in agriculture and rural areas: status report.*
Van De Gevel, J., van Etten, J., & Deterding, S. (2020). Citizen science breathes new life into participatory agricultural research. A review. *Agronomy for Sustainable Development*, *40*(5), 1-17
Van Etten, J., Steinke, J., and van Wijk, M. (2017). How can the Data Revolution contribute to climate action in smallholder agriculture? 30, 44–48. Available online at: https://hdl.handle.net/10568/81375
Vieira, E. R., O'Rourke, H. M., Marck, P. B., & Hunter, K. F. (2014). Using video-elicitation to assess risks and potential falls reduction strategies in long-term care. *Disability and rehabilitation*, *36*(10), 855-864
Zooniverse (2022). https://www.zooniverse.org/about