Agroecology TPP

One Million Voices Global Review

A review and analysis of existing citizen science initiatives and projects supporting agroecology and agroecological transitions

Lily Cannell van Dien
Lisa Elena Fuchs

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The Transformative Partnership Platform on Agroecology (Agroecology TPP)

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The Transformative Partnership Platform on Agroecology

CIFOR Headquarters
Jalan CIFOR
Situ Gede, Sindang Barang
Bogor Barat 16115
Indonesia

ICRAF Headquarters
C/O World Agroforestry Centre
United Nations Avenue, Gigiri
Mailing address: P.O. Box 30677 – 00100, Nairobi,
Kenya

T +62-251-8622-622
E agroecology-tpp@cifor-icraf.org

bit.ly/AgEc_TPP

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Executive summary

Purpose of the report

This report presents the results of a worldwide review and analysis of existing projects and initiatives for citizen science that support agroecology and agroecological transitions. The aim of this review is to inform on existing citizen science projects that support agroecology and to inspire and underpin the overall goal of developing a tool, or a series of tools, that enable farmers, producers' organizations, consumers or other potential end users to inclusively participate in agroecology movements. The tool's objective will be to promote sustainable adoption of agroecology, while also contributing information to fill key knowledge gaps on the performance of agroecology, while adding value and avoiding duplication. In addition the report also underpins and informs parallel regional dialogues — through which diversified visions for how citizen science can be put to use for agroecology will emerge.

Methods used

This review combines four different data streams to search and identify citizen science projects and initiatives. These data streams include a systematic review of three citizen science platforms (EU-citizen.science, Zooniverse and SciStarter), a systematic literature review in Web of Science, projects and initiatives proposed during earlier engagement of the One Million Voices citizen science initiative, and finally a Google search. Projects are included when they are citizen science, relate to food systems and address one or more of the principles of agroecology.

Findings and conclusions

This report includes 57 projects that support agroecology and agroecological transitions. The report is accompanied by a database that contains more detailed information about the individual projects. The topics of the projects included in the review are subdivided into three categories: agricultural production, agroecosystems, and markets, consumption and diets. The majority of projects have a strong focus on the natural farming aspect of agroecology. In addition, there were also projects that focused more clearly on the social justice aspect, and even fewer had a circular economy focus. There were several projects that addressed more than one aspect. However, none of the projects included covered all three aspects holistically. Furthermore, there is a lack of published or easily accessible citizen science projects related to food systems and agroecology in the Global South as well as a gap in projects that focus on other elements besides on-farm agroecological practices.

Recommendations for the One Million Voices citizen science initiative

- **Understand the motivation for participation.** Citizen science builds on the voluntary time, efforts and skills of participants. The reasons for participation are different for various stakeholders and can range from participating for fun to expecting something in return.

- **Give back to participants.** What do participants get out of participating in the project? Look at both the long-term benefits (research outcomes) and short-term benefits such as advice, data visualizations, access to educational materials and information.

- **Make it accessible for diverse groups of participants.** In order for people to participate in a citizen science project, the project has to be accessible. Think about preferred communication channels and making the tool available in different languages. Keep statements, instructions, and questions short and concise and use illustrations or pictures.

- **Keep it simple.** Complicated participation tasks will discourage people from participating in the project. Start with a simple concept and a clear question and expectation.

- **Build on existing networks.** Engaging and involving people takes time and requires relationship building. By utilizing existing networks and partners to reach participants and scale, you will save time and increase your chances of success.

1 Introduction

The One Million Voices citizen science initiative is a project of the Transformative Partnership Platform on Agroecology (the "Agroecology TPP"). This initiative was launched by the TPP at an the United Nations Food Systems Summit (UNFSS) side event in September 2021. The Agroecology TPP, supported by the Swiss Agency for Development and Cooperation (SDC), wished to launch a bold citizen science campaign to involve smallholder farmers, farm workers, and food consumers in generating knowledge to accelerate and document agroecological transitions. This initiative aims to give a voice to all small-scale farmers who practise agroecology in their own way and to encourage consumers who are committed to sustainable and equitable systems to participate in defining national food system transition pathways.

The overall goal of the project is to develop a single or a series of contextually relevant approaches and tools that enable farmers, producer organizations, consumers, or other potential end users to inclusively participate in agroecology movements. Smallholders occupy various positions in value chains, including producers, transporters, transformers, distributors, and sellers, and are in a unique position to elicit and contribute information to fill key knowledge gaps on the performance of agroecology. The objective of the initiative is to bring them together and have them lead the way to identify and develop solutions to support agroecological transitions, generate knowledge and data on agroecology, and follow the principles of participation, inclusion, and overall social equity in its approach.

Central to the project are a series of regional dialogues that covered four *regions* that are partly geographically defined and partly informed by specific agroecological dynamics. The regions include:

- West Africa (Burkina Faso, Mali, Ghana)
- Latin America (Bolivia, Colombia, Ecuador, Peru)
- 13 countries in South, South-East, and Central Asia (Cambodia, Indonesia, Laos, Philippines, Thailand, Timor Leste, Viet Nam, Bhutan, Bangladesh, India, Nepal, Sri Lanka, Mongolia)
- South Asia (India)

The regional dialogues were fundamental to designing the outlines of the overall initiative. The dialogue structure was collaboratively designed with regional leaders and ICRAF engagement scientists and followed a user-centred design approach to discuss with the target end users what their interests are and how we could address them while also aligning with the project goals. The regional dialogues identified a series of potential solutions to perceived barriers to participation in agroecology, the deepening of agroecological integration, and support for agroecological transitions in the region. Additionally, the dialogues led to the formulation of action plans for developing and/or testing identified solutions with end users that can be implemented subsequently.

The One Million Voices initiative facilitated an inclusive engagement process with key user groups, whose voices we hope to emphasize. The engagement process was designed and implemented in a unified way across the four regions while providing space for each region to follow its own ideas and interests for citizen science. Since the objective of the initiative is to develop tools, platforms, or other digital solutions, the engagement process also followed the nine Principles for Digital Development. These principles guide a user-centred design approach to identify and develop tools that fit user needs, are scalable and sustainable, and capitalize on the existing data ecosystem and tools in use.

In addition to the four regional dialogues, a global review was conducted to identify existing citizen science projects and initiatives that support agroecology and agroecological transitions. The review was to serve as a background resource that informs and inspires the development of the initiative as well as underpin the regional dialogues through which diverse but aligned visions for how citizen science can be put to use for agroecology emerged. The review also directly contributed to the overall goal of developing a tool, or a series of tools, that enable farmers, producers' organizations, consumers, or other potential end users to participate in agroecology movements, support sustainable agroecology adoption, and contribute information to fill key knowledge gaps on agroecology performance. Finally, the review is in line with one of the core principles of the TPP, which is to always add value and not duplicate.

This report contains the results of the global review and analysis of citizen science projects and initiatives that support agroecology and agroecological transitions. It includes an overview of the selected initiatives and an analysis of their relation to agroecology and agroecological transitions. The report is accompanied by a database that contains an overview and detailed information on all the included projects.

The structure of the project is as follows: The second chapter of this report provides information on the three concepts that are the principle focus of this review: 1) citizen science; 2) agroecology; and 3) the Principles for Digital Development. Chapter 3 outlines the methodology used for identifying and selecting the initiatives from which the results will be presented in more detail in Chapter 4. The results are followed by a discussion and conclusions in Chapters 5 and 6.

2 Background

2.1 Citizen science

There are a multitude of definitions used to describe citizen science as a practice, but at its core citizen science can be characterized as a practice that involves citizens or non-professionals/non-experts, that are involved in the production of new scientific knowledge, that overall aim to “make the world a better place” (Strasser and Haklay 2018). Another fundamental characteristic of citizen science is voluntary contribution: money is rarely – if ever at all – the fulcrum of these collective projects and initiatives – at its core it is participatory action for scientific advancement (Mondardini 2022).

The lack of precise definitions presents some difficulties in clearly understanding what citizen science entails. A study by Haklay et al. (2021) looked at the different understandings of citizen science through the use of short vignettes. Participants were asked to rate 50 short examples on whether the example presented a citizen science case or not. The results highlight the co-existence of a multitude of different opinions and understandings of citizen science.

The European Citizen Science Association developed a comprehensive set of 10 principles of citizen science (ECSA, 2015). These principles (see Box 1) can help guide our understanding of what a good citizen science project is. The first principle reads “citizen science projects actively involve citizens in scientific endeavors that generate new knowledge or understanding” (ECSA 2015). However, the level to which citizens are involved in the project can differ considerably. First of all, a project can be contributory, where scientists design the project and citizens mainly contribute data to it. This dynamic forms the vast majority of projects, which essentially implies a rather top-down approach. The second level of engagement is collaborative. The projects are designed by scientists but citizens help with different aspects of the research. Examples are project design, data analysis and dissemination of findings. The final level of engagement is co-creation. These projects are designed by scientists and citizens together and citizens are included in most, if not all, aspects of the research process. The most desirable approach to citizen science is co-creation in which scientists and citizens create questions and projects together.

Another relevant differentiation that can be made is the type of actual contribution that citizens can make. Overall, the contribution of citizens can be classified into two categories. First of all there are projects in which citizens are involved in the collection of primary or secondary data, such as images, answers, samples, descriptions, etc. The second category is data analysis, which often involves web-based tasks that are unsuitable or difficult to perform by computers, such as image analysis, pattern recognition, text transcription, and mapping.

Another key aspect of citizen science is that both scientists and citizen scientists benefit from their participation in the project. These benefits are different for researchers and citizens. Scientists can benefit from the spatial and temporal resolution that data collected by large groups of people can provide. Additionally, interacting with citizens can provide a very new perspective and conversations can bring a lot of richness to research. The benefits for citizens include the personal satisfaction of being able to contribute to something bigger, personal development and the opportunity to gain experience, knowledge and skills, the social dimension of being able to connect with like-minded people and finally for fun.

Box 1. ECSA Ten Principles of Citizen Science

1. Citizen science projects actively involve citizens in scientific endeavours that generate new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.
2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratization of science.
7. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.
8. Citizen scientists are acknowledged in project results and publications.
9. Citizen science programs are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

Source: European Citizen Science Association (2015)

Maria (Rosy) Mondardini, Managing Director of the Citizen Science Center Zurich, and one of the project's core knowledge partners gave a presentation introducing citizen science and the possible contributions to agroecology. Citizen Science Center Zurich can assist with methodology, tools, community, and networks. When citizen science has a strong methodology, the quality of data equals that of a professional scientist.

In addition, they also have two open access tools for developing a citizen science project:

1. CS project builder: digital data — on this platform one can create a platform to involve the crowd
2. CS Logger: web/mobile-based tool (survey, collecting images, etc.)

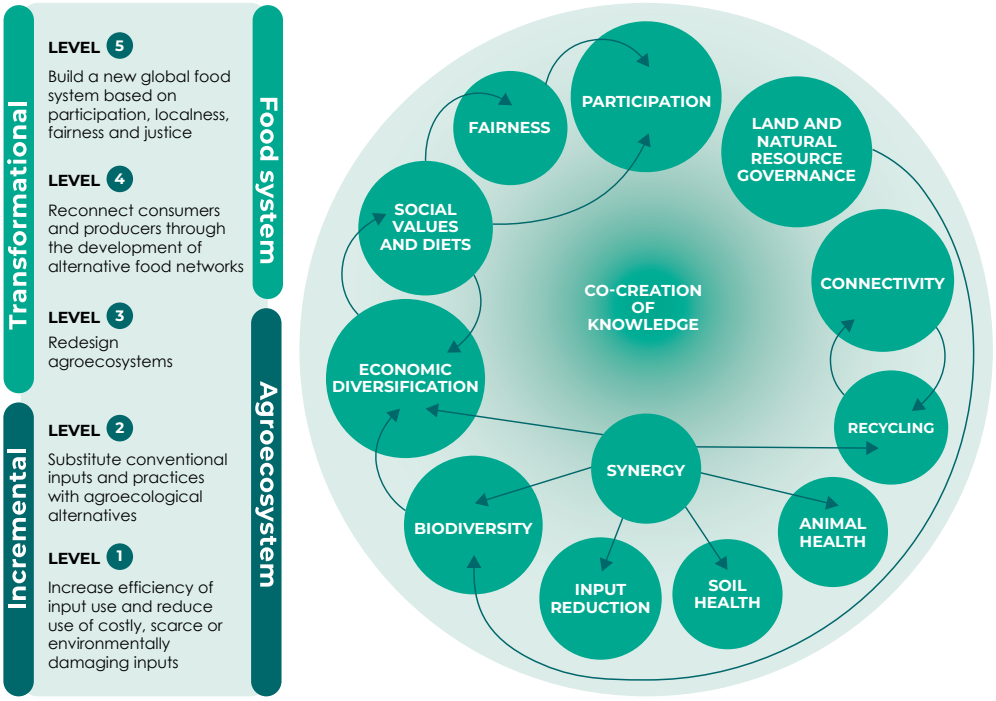
2.2 Agroecology

Agroecology is a polysemic concept with over 30 definitions adopted by different actors that includes ecological and social considerations, pursues better interactions between plants, animals, humans and the environment, and focuses on a sustainable and fair food system. Fundamentally, agroecology is human-centred and focuses on contextualized solutions. The bottom line is, agroecology focuses on how to live well, both individually and as a community, how to eat well, how to work in a dignifying way while taking inspiration and respecting traditions and culture and while respecting and harnessing nature. Agroecology does not just refer to a set of practices that aim to improve agroecosystems, but also to the science and to a social movement to address current challenges related to food systems (HLPE 2019).

There are several conceptual frameworks but the two most used are the FAO 10 elements and the HLPE 13 principles. The One Million Voices initiative is based on and guided by the 13 CFS HLPE Agroecological Principles, a set of 13 explicit, normative and causative statements that guide decisions and action. These principles include focus both on transforming the agroecosystem as well as food system level. The 13 principles of agroecology are Recycling , Input Reduction, Soil Health, Animal Health, Biodiversity, Synergy, Economic Diversification, Co-creation of Knowledge, Social Values and Diets, Fairness, Connectivity, Land and Natural Resource Governance, and Participation (see Figure 1 for a more detailed explanation of the 13 principles). The 13 individual principles are nested under three so-called organizing principles: Resource Efficiency (principles 1 and 2), Strengthening Resilience (principles 3 to 7), and Securing Social Justice (principles 8 to 13).

Source: Sinclair et al. (2019)

Figure 1. The 13 HLPE Principles of Agroecology



Source: Adapted from Wezel et al. (2020)

Figure 2. The 13 HLPE Principles of Agroecology and Gliessman's Transition Levels

Agroecology encompasses both the agroecosystems as well as the broader food system as illustrated in Figure 2. It also shows the different levels of transformation towards agroecological food systems. The core principle of co-creation of knowledge (placed at the centre of Figure 2) requires a very different approach to research in which farmers and stakeholders are at the centre of defining the research agenda, as well as developing solutions together with scientists (HLPE 2019). Citizen science provides the perfect format for co-creation, one of the core principles of agroecology. Developing a citizen science project that is designed by citizens and scientists, and in which citizens are actively involved in most, if not all aspects of the research process, can support the democratization of science. It provides a way to capture and build on the diversity of knowledge across different actor categories. This will ensure that the citizens that are participating in the project benefit from the data generated for and by them.

2.3 Principles for digital development

The principles for digital development are a set of nine principles (see Box 2) that help guide best practices of technology-enabled programs. The principles were developed through a collaboration between International donor and multilateral organizations (digitalprinciples.org/about/). Since citizen science often makes use of digital tools for data collection or analysis at a large scale, it is important that these projects adhere to the Principles for Digital Development.

Box 2. The Principles for Digital Development

1. Design with the User
2. Understand the existing ecosystem
3. Design for scale
4. Build for sustainability
5. Be data driven
6. Use open standards, open data, open source, and open innovation
7. Reuse and improve
8. Address privacy and security
9. Be collaborative

Source: Principles — Principles for Digital Development (n.d.)

The principles of digital development clearly align with the principles of agroecology and citizen science and therefore provide relevant guidelines when developing digital tools. The principles “design with the user” and “be collaborative” are closely related to the principle of co-creation of knowledge and the participation of citizens in multiple research components. Additionally, the principles of digital development emphasize the importance of using open standards, open data, open source, and open innovation. This is a crucial aspect of making a citizen science project accessible. Conducting this review strongly builds on the principles of “understanding the existing ecosystem” and “reuse and improve”.

3 Methods

A systematic review of existing citizen science initiatives was conducted in order to answer the main question "What are existing citizen science approaches, initiatives and projects currently supporting agroecology and agroecological transitions worldwide in line with the Principles for Digital Development?"

Citizen science is an approach that focuses on public participation and voluntary contributions to science-based knowledge production. Citizen science brings together the public and scientific spheres, and therefore this review focuses both on scientific literature, as well as grey literature found on citizen science platforms and through a web-based search. The selection of projects and initiatives was based on them fulfilling three criteria. In addition, several ground-proofing interviews were conducted to gain more insights into the development of a citizen science project, the use of digital tools, the role of co-creation and the challenges and opportunities that come with conducting a citizen science project. The projects selected in this review are also included in an easily accessible database here: https://bit.ly/OMV-DB-Global_Review.

There are certain limitations to the research underpinning this review. A systematic review is often limited to scientific publications in peer-reviewed articles that can be searched in databases such as Web of Science and JSTOR through the use of replicable search terms. Not all citizen science projects, however, are published in peer-reviewed journals, and many can be found on search engines and large platforms that showcase citizen science projects. Even though these citizen science platforms provide a great gateway for searching and identifying initiatives, the limiting factor of these platforms is that they mainly exist for projects in Europe and the United States. Citizen science projects in Africa, Asia and Latin America are not always well documented or reported on in a manner that allows for identification through a structured review. The methodology used tries to overcome these limitations but at the same time acknowledges that the data collected in this review are biased towards projects conducted in the Global North.

3.1 Approach to searching and identifying existing projects and initiatives

To address some of the limitations indicated above, four different data streams were included in the search for existing projects and initiatives. The presentation of each data stream includes a brief description of the respective data source, the analysis methods used, and a statement on relevant considerations.

Data stream 1. Large-scale citizen science platforms
Data source:

- eu-citizen.science is an online platform for sharing knowledge, tools, training and resources for citizen science – by the community, for the community.
- The Zooniverse is the world's largest and most popular platform for people-powered research.
- SciStarter is a globally acclaimed, online citizen science hub where more than 3,000 projects, searchable by location, topic, age level, etc., have been registered by individual project leaders or imported through partnerships with federal governments, NGOs, and universities.

Methods:

- Each of the platforms has a search option and projects are classified into different categories which allows one to search in a systematic way
  a. The categories reviewed on eu-citizen.science: agriculture and veterinary services, ecology and environment, biodiversity, food science, natural resource management
  b. The categories reviewed on The Zooniverse: agriculture, food, ecology and environment, social science
  c. The categories reviewed on SciStarter: climate, nature
- The projects in these categories were reviewed based on the assessment criteria proposed in Section 3.2 of this report.

Considerations:
Especially in Europe and the United States, there are a growing number of citizen science platforms. In Europe, many countries have developed their own citizen science portal (Liu, et al. 2021). Most of these platforms contain country-specific projects in a range of languages. After consulting with Rosy Mondardini, the Managing Director of Citizen Science Center Zurich, the cited citizen science platforms were considered for the review. These are the three most-used and well-known platforms. eu-citizen.science contains projects from all over Europe, whereas The Zooniverse and SciStarter have a focus on projects in the United States.

Data stream 2. Structured literature review of scientific publications of citizen science projects
Data source:

- A structured review was conducted on Web of Science.

Methods:

- An initial search syntax was created to systematically search databases with publications following an iterative process. The search syntax consists of three components:
  a. Search terms relating to citizen science:
  "Citizen science" OR "community science" OR "crowd science" OR "crowd-sourced science" OR "civic science" OR "volunteer monitoring" OR "participatory science" OR "community action science"
  b. Search terms relating to agroecology and food systems:
  "Agro-ecosystem*" OR "Agricultur*" OR "farm*" OR "food system*" OR "food" OR "Agroecolog*" OR "value chain" OR "consumption" OR "market" OR "Circular" OR "Social justice" OR "food sovereignty" OR "Holistic" OR "Socio-ecological" OR "Social-ecological" OR "Sustainab*" OR "Organic" OR "indigenous knowledge" OR "local knowledge" OR "farmer knowledge"
  c. A third criterion was added to filter out the more theoretical discussions on the potential and role of citizen science in relation to food systems and agroecology:
  "Example" OR "case-study" OR "case study" Or "project" OR "initiative"
- The list with results yielded in the search was transferred into MS Excel to remove duplicates
- The 'clean' list was imported into a systematic review software (rayyan.ai). Articles were included or excluded, after reading the abstract. Articles were excluded according to the following conditions:
  a. Article has no abstract
  b. Article has no clear case study/initiative/project
  c. Project or initiative is not related to food systems and/or agroecology
  d. Article does not describe a citizen science approach (are citizens voluntarily involved in the generation of new scientific data for the sake of "making the world a better place"?)

Considerations:
Searching was done based on the abstract rather than the title of the article since the abstract contains more detailed information about the article.

Data stream 3. Suggestions from previous engagements of the OMV project
Data source:

- Preliminary results from the regional dialogues in South-East Asia and West-Africa
- Projects presented during the project launch of the One Million Voices initiative in 2021
- Suggestions made by Rosy Mondardini, the Managing Director of Citizen Science Center Zurich
- Materials prepared prior to and during the project (proposal, notes from meetings, email exchanges)

Methods:

- All the materials created during the development and initial stages of the project were read. This includes the recording of the OMV launch, preliminary results of the regional dialogues, presentation by Rosy Mondardini, and other additional materials.
- A list was compiled that contained all the citizen science initiatives mentioned. These were reviewed based on the proposed assessment criteria presented in Section 3.2 of this report.

Considerations:
Due to delays in partnership agreements being finalized, the regional dialogues had not been concluded by the time this review was conducted. Only preliminary results from South-East Asia and West Africa were included.

Data Stream 4. Google search
Data source:

- Google online search

Method:

i. A broad search using the terms "citizen science projects agroecology", "citizen science projects agriculture", and "citizen science projects food".

Considerations:
There is a significant likelihood that a large part of citizen science initiatives and projects, especially in Africa, Asia and Latin America is not represented in one of the databases or in scientific publications. Therefore, we opted to include a final data stream resulting from a Google search. This step is not replicable since the Google algorithm does not necessarily produce the same results twice. However, this helped identify otherwise overlooked projects and initiatives that are especially relevant in the context of the One Million Voices Initiative.

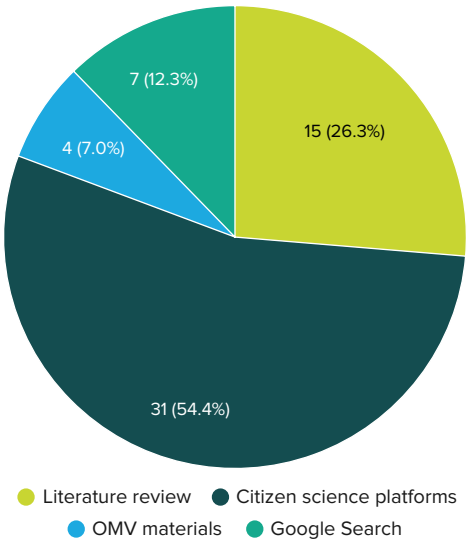


Figure 3. Number of results from the four data streams

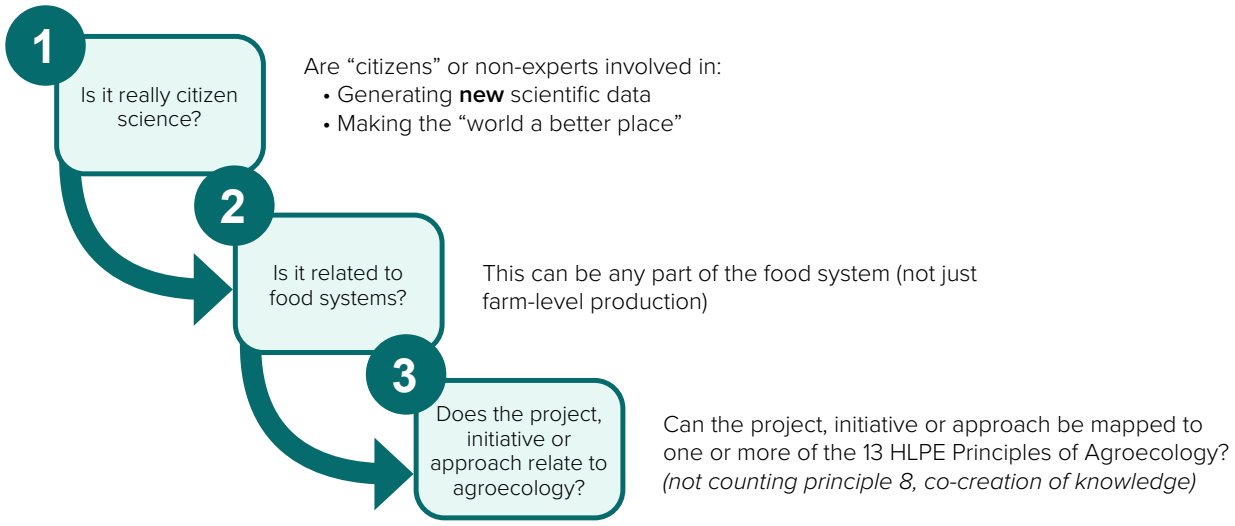


Figure 4. Steps for assessing relevant projects and initiatives

Most of the projects that were included in the analysis were identified through the structured literature review (data stream 2): a total of 31 projects and initiatives. The citizen science platforms (data stream 1) yielded 15 results and the OMV materials (data stream 3) and Google search (data stream 4) produced an additional four and seven initiatives respectively (see Figure 3).

3.2 Criteria to map and assess existing citizen science projects and initiatives

The criteria used to map and assess existing citizen science projects and initiatives are fairly general for various reasons. First of all, an initial exploratory search of large citizen science platforms and scientific publications showed that citizen science in the *food space* has yet to reach its full potential and the number of citizen science initiatives that specifically mention agroecology is close to none. Another reason for keeping the criteria broad is that agroecology does not focus on agroecosystems alone, but rather on the entire food system. Keeping the criteria for inclusion broad allowed for a wider variety of citizen science projects that relate to different elements of the food system. Finally, the aim of this review is to both inform and inspire. Including more projects, initiatives and different approaches offered a wider variety to choose from and provided more comprehensive background for informing the development of the One Million Voices tool. Figure 4 illustrates the three steps taken or "questions asked" for including relevant initiatives, approaches and projects. A project was included when firstly it is citizen science, secondly, it is about some aspect of the food system and finally it can be mapped to at least one principle of agroecology aside from principle eight, co-creation of knowledge, since using a citizen science approach implies this already.

Projects that met all three criteria were included in the review. These projects are presented in the results chapter, and they are also included in a database that contains additional information about the project. This database provides an overview of basic characteristics and links to webpages and publications. The outline of the database and corresponding details can be found in Appendix 1.

4 Results

4.1 General characteristics of citizen science projects included in the review

The global review of citizen science projects and initiatives that support agroecology and agroecological transitions yielded 57 results. These core topics were divided into three main categories: 1. Production; 2. Agroecosystems; and 3. Markets and consumption. A range of sub-topics were defined for each of the main topics. This subdivision is presented in Table 1. The results are subdivided and presented in line with these main topics.

Table 1. Topics included in the global review

Production	Agroecosystems	Markets and consumption
Agricultural inputs • Measuring inputs in urban agriculture • Pesticide use • Fertilizer	Soil • Soil health • Soil pollution • Decomposition rates	Diets
Agricultural pests and pathogens	Climate change	Food waste
Rainwater harvesting	Earth systems	Food prices
Renewable energy for agriculture	Land acquisition	Food environments
Seeds and crops • Crop adaptation • Trait selection • Preserving agrobiodiversity • Indigenous practices	Land potential	
	Pollination	

Another way of grouping the results would have been to differentiate them according to the type of citizen participation or involvement. Overall, citizen involvement can be categorized into two groups. The first is data collection. This involves the collection of primary or secondary information. The second category is data analysis, which often entails web-based tasks that are unsuitable or difficult to perform by computers. The majority of projects included in this review can be classified as data collection projects. Only two projects involve citizens only in data analysis tasks and five projects include citizens in both (see Figure 6). Most of the projects that involve citizens in both data collection and analysis are co-created, as citizens are involved in almost all aspects of the project. Other modes of engagement are contributory projects that are designed by scientists for which citizens primarily contribute data and collaborative projects designed by scientists for which citizens help with project design, data analysis and/or dissemination of findings (see Figure 5).

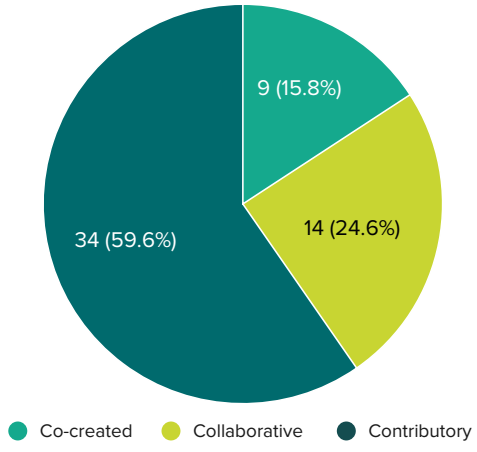


Figure 5. Projects by type of citizen engagement

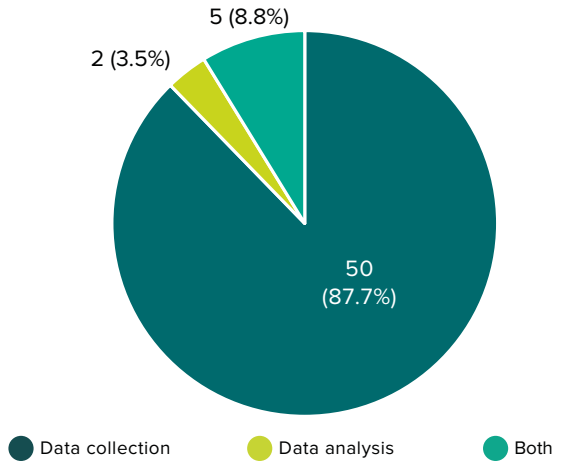


Figure 6. Projects by type of citizen contribution

When zooming in on the data collection projects, there is also a subdivision there. First, there are projects for citizens to make observations and take measurements. These projects are non-intrusive and often easy and accessible since participants only have to record observations and measure what is already out there. Examples include taking pictures of pests, recording the number of crops you grow in your garden, documenting fertilizer use or providing information on food options in specific places such as schools. Another method of gathering information is collecting data through experimentation. Citizens are asked to conduct experiments and through this answer a set of questions. Many of these experiments are some form of participatory breeding, where citizens receive a variety of seeds, grow the crops and report on various characteristics. Thirdly, there are also projects that ask participants to collect physical samples. These can be soil samples, air quality samples, water samples or samples of pests. Finally, there are also projects that use a gamification approach, and engage participants in a game while simultaneously gathering data.

When looking at the location of the included projects, it becomes clear that the distribution is strongly skewed towards the Global North: 73% of the projects included in this review are located in North America, Europe and Australia. Twenty-one percent of the projects and initiatives are in Africa, Latin America and Asia, while 7% are global. Figure 7 shows in more detail the different countries in which the projects are taking place.

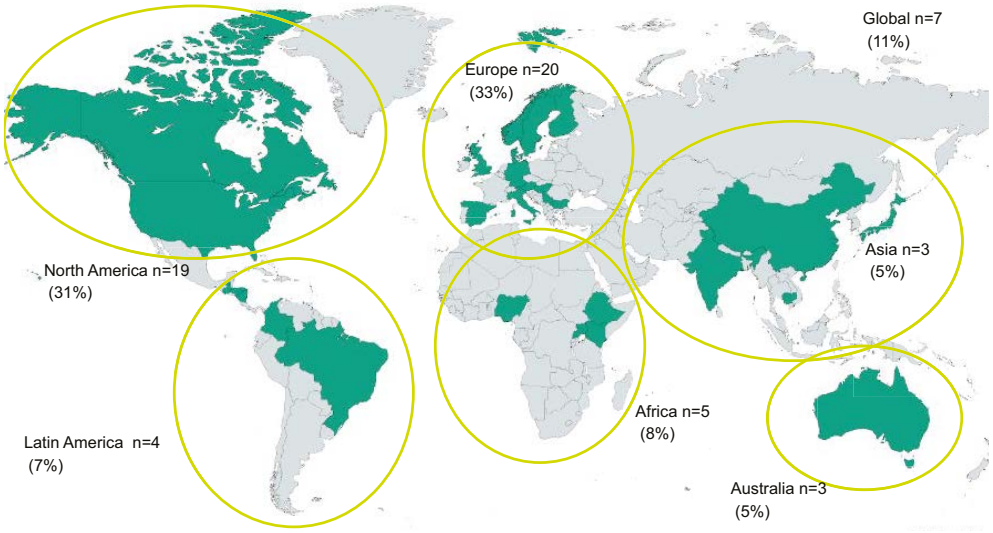
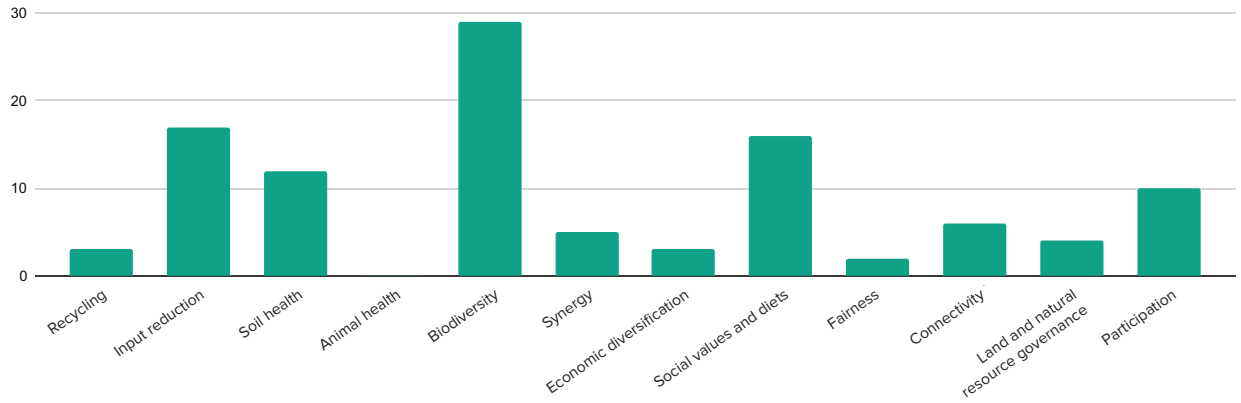


Figure 7. Map showing the spatial distribution of included citizen science projects



Note: Principle 8 on co-creation is not included here since citizen science, by definition, involves co-creation and all 57 projects address the co-creation principle. Mentions are cumulative, in case a project addresses several principles.

Figure 8. Relationship between reviewed citizen science projects and the 13 HLPE Principles of Agroecology

Part of the approach to identify relevant initiatives and projects was to map them to the 13 HLPE agroecological principles (see Figure 8). The strength of the connection between the projects and the principles varies. Some projects are related to one principle, while others could be mapped to two or more. The results of this mapping are presented in Figure 8. Principle 8, co-creation of knowledge is not included in this mapping, since it is an inherent part of citizen science methodology, and all projects involve this method. Biodiversity (principle 5) is most commonly addressed by the projects in this review, followed by Input reduction (principle 2), Soil health (principle 3), and Social values and diets (principle 8).

Another way of representing the relationship between the reviewed citizen science projects and agroecology is by grouping them under three identified agroecological aspects: 1. Natural farming; 2. Social Justice; and 3. Circular economy (see Figures 9 and 10).[1]

Figure 9. Relationship between reviewed projects and the three core aspects of agroecology

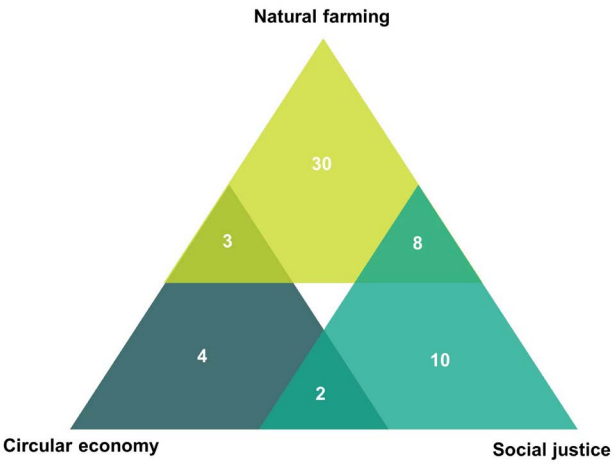


Figure 10. Number of reviewed projects addressing one or several of the three core aspects of agroecology

1 Attempting to identify the core aspects that represent the essence of agroecology in a holistic manner, an alternative way of nesting the 13 HLPE Principles of Agroecology was used here. Here, agroecological principles 1 to 5 are nested under the aspect Integrated natural farming, principles 6, 7, 10 and 11 under the aspect Circular economy, and principles 8, 9, 12 and 13 under the aspect Social justice. Building on these three main aspects, we propose that it is possible to confer a holistic agroecological essence if at least one of the principles falling under each aspect is addressed or engaged by a project or initiative.

The majority of projects have a focus on natural farming. This is not strange since this review also includes some results of other reviews focused on citizen science for sustainable agriculture (Mourad 2020; Ebitu et al. 2021), citizen science projects for food waste (Pateman 2020), and citizen science for sustainable diets and food systems (Oakden et al. 2021). However, agroecology encompasses more than sustainable on-farm practices, and this review also includes a large variety of food system components. Projects addressing these broader agroecological questions are likely to be mapped to the aspects Social justice and the Circular economy.

4.2 Production

4.2.1 Pests and pathogens

There are various citizen science projects that focus on the spread of pests, diseases and invasive species. The initiatives included in this report focus on pests that impact agricultural crops. Generally, these projects fall into two categories. The first category contains projects that involve citizens collecting samples for DNA analysis. Examples are Obtectus Finders, a project that focuses on the collection of seed beetles or *Acanthoscelides obtectus* to understand their genetic variability and to develop new methods for biocontrol, the Pieris Project in which citizens can participate by collecting white cabbage butterflies which are analysed to gain a better understanding of the history and spread of the pest, and Mildew Mania an educational project carried out in Australian schools. In this project children grow different types of wheat and barley and monitor them for signs of powdery mildew disease. When the disease is present samples are sent off to researchers to map the different strains of the disease.

The second category consists of projects that ask participants to record sightings of the pest and send them to the researchers or upload observations to a digital portal. This includes projects such as IPM Popillia, that allows citizens to upload sightings of the Japanese beetle (*Popillia japonica*) or damaged crops to a database. Similarly, BugMap is a mobile application on which sightings of two invasive insect pests, the tiger mosquito (*Aedes albopictus* Skuse) and the brown marmorated stink bug (*Halyomorpha halys* Stål) can be reported (Malek et al., 2019). Another example is Blight Tracker App, on which late blight attacks can be registered.

Not all pest monitoring uses digital tools. In a smaller study conducted in Japan, participants submitted pictures and geolocations of *Limax maximus* (great grey slug or leopard slug) pests via mail (Morii et al. 2018). A case study in the Jiangxi Province of China looked at the benefits of volunteered geographic information (VGI) for integrated pest management (IPM). Farmers were asked to report pest infestations via SMS but also received personalized pest management information (Yan et al. 2017).

Pest-related projects are not necessarily agroecological in nature. The projects aim to contribute to a better understanding of pests and contribute to new pest management strategies, but the projects do not explicitly mention all-natural pest-management strategies. However, since most of these projects focus on understanding and mapping the spread of pests, this information can also provide insight to pest management strategies that can be considered agroecological.

4.2.2 Agricultural inputs

Pesticide use

Besides citizen science projects that look at the spread of agricultural pests and how to prevent them, there are also projects that look at the effects and dangers of heavy pesticide use on the environment and on human health. The Pesticide Action Network (PAN) has several initiatives in which they create awareness of the presence of pesticides through public participation. The

Pesticide-CheckUp initiative checked 300 people across Europe who sent in samples of their hair for analysis of the presence of pesticide residues (PAN-Europe 2022). In another initiative PAN is training citizens to use an air monitoring device, also known as the Drift Catcher, to measure the extent to which pesticides drift when they are being sprayed on nearby farms (Rotenberk 2013). While the other projects have a strong focus on mapping and understanding the spread of pests and diseases, these two initiatives are trying to change the way pesticides are currently being used and the dangers they can pose to the health of humans and the environment.

Fertilizer

Besides the use of pesticides, there are also projects that look at fertilizer use. One example is the Urine My Garden project by the Rich Earth Institute. Participants are provided with a step-by-step guide on how to collect, store and fertilize crops with urine. Participants or practitioners are asked to fill out a survey to "better understand how urine fertilization works for different plants, with different people, and in different places."

Inputs in urban agriculture

With the pressures of feeding a growing population, the role of urban agriculture in feeding large populations has become a popular topic (Csortan et al. 2020; Dobson et al. 2021). There are several citizen science initiatives that engage urban growers to better understand the role they play in local and global food production. MYHarvest (Measure Your Harvest) is a citizen science initiative that aims to determine how much own-grown food people in the UK are producing and whether this can contribute to food security and the possibility of biofuels. Participating is simple. After harvesting citizens weigh their crops and submit these data together with the size of the area on which these crops are grown. In a project that aims to better understand the resource requirements of urban horticulture, Dobson et al. (2021) recruited a number of allotment farmers via the MYHarvest portal to engage in another citizen science research. The participants were asked to keep an "allotment diary", a standard page with basic information about the conditions and inputs in their plot (see Dobson et al. 2021). The participants were asked to fill out these pages on each visit to their garden over the course of a year providing the researchers with extensive temporal data. In a similar vein, the Edible Gardens project on urban agriculture in Australia looked at the inputs and outputs of home gardeners. The participants were sent a data collection toolkit with instructions, data recording sheets and additional tools including water meters where necessary. Participants entered their data in the online Edible Garden portal and automatically received interactive graphs of the input and yield results for each garden (Csortan et al. 2020). A somewhat similar project in California employed a citizen science method to gain insights into water usage in urban gardens (Egerer et al. 2018). The Farming Concrete project takes a different approach and focuses on co-creatively developing a data collection toolkit to better understand the various aspects related to urban farming and measure how much food is grown in community gardens and in New York City. The metrics developed do not only look at the food production component but also include data about environmental, social, health and economic aspects of urban gardening. The metrics were tested and adjusted by urban growers during the growing season. These metrics are now available online and can be used by anyone worldwide.

4.2.3 Water harvesting and renewable energy

The use of renewable energy is imperative for realizing agroecological transitions. Biovision's F-ACT tool, developed to assess the level of agroecological integration on the farm has a separate category asking questions about the use of renewable energy. The Off-Grid Renewable Energy in Agriculture project by STEP CHANGE aims to co-create knowledge about the impact of renewable energy for agricultural use in rural Uganda via a citizen science approach. The project is expected to run until 2025 and involves agricultural cooperatives from three districts in Uganda. Even though this is a

crucial topic and not widely addressed through citizen science, no information is available about its methodology.

Similar data collection projects can be done for water quality. The Off the Roof project asked participants to collect water samples from rain barrels and send them to the water department of the United States Environmental Protection Agency (EPA) for analysis. The aim of the project is to better understand water quality from roof runoff and analyse the samples for potential pathogens. This is only one example of a range of citizen science projects that study the water quality of rivers, lakes and streams. For more information on the contribution of citizen science to water quality and additional resources see Capdevila et al. (2020).

4.2.4 Seeds and crops

Experiments for breeding better adapted crops

The Harnesstom project brings together consumers, chefs and farmers in a participatory breeding and citizen science project focused on the variety of tomato species. Participants interested in joining will receive five tomato varieties, grow the plants and score them on plant and fruit characteristics. This project is being conducted in three European countries with the aim of developing locally adapted varieties. The project also includes consumer-driven trait selection. The 1000 gardens project takes a similar approach but focuses on soybeans. Besides better understanding soybean adaptation to northern latitudes, the project also aimed to improve public perception of the soybean as both a crop for regional agriculture as well as its health effects. The project recruited 2492 volunteers in Germany to participate in the project. They were all sent instructions for the experiment and 12 bags of different seeds. The collected data were entered into an online database for analysis (Würschum et al. 2019).

Experiments for smallholder farmers in a development context

While both Harnesstom and 1000 gardens focus on a European context, the Seeds for Needs initiative by Bioversity International (now Alliance Bioversity & CIAT) involves over 20,000 smallholder farmers in 14 different countries. The project uses a tricot approach (triadic comparisons of technologies) in which farmers receive three randomly assigned varieties to compare to their own in on-farm trials. The farmers are also involved in evaluating and selecting varieties which gives the researchers information on preferred traits (Beza et al. 2017; Van Etten et al. 2019). The data are entered using ClimMob, an online software program that assists agricultural citizen science projects. Other work by Steinke and Van Etten (2017) that looks at participatory trait selection for smallholder farmers uses a gamification citizen science approach. AgroDuos is a game that resembles a combination of memory, Loteria and bingo and is played with farmers to select their preferred traits of a certain crop (Steinke and Van Etten 2017). Similar to Seeds for Needs, AgroDuos data are also entered into the ClimMob application.

Experiments for preserving agrobiodiversity

Other projects such as INCREASE (Intelligent Collections of Food Legumes Genetic Resources for European Agrofood Systems) aim at fostering agrobiodiversity across Europe. A total of five varieties of beans from all over Europe are available for participants to plant, grow, harvest, cook, taste, and share experiences. The project is not as much about perfecting bean varieties as it is about conserving agrobiodiversity. In order to keep the citizen science initiative going beyond INCREASE's five-year cycle, seeds are disbursed to citizens once. Citizens are encouraged to exchange the seeds with other citizens and besides recording the process and sharing tips and tricks in the INCREASE app, citizens can also share recipes which will be published in the *Thousands of traditional and innovative recipes to cook beans*. Another project that is focused on preserving

the diversity of food crops is ADAPT by the nonprofit Seed Savers Exchange in the United States. Gardeners and farmers test varieties from the Seed Savers Exchange collection and give information on their performance. Participants can select the crops they are interested in and submit information through an online platform called SeedLinked. This platform allows participants to not only submit data, but also get information about the varieties, view the results of the trial, interact with other participants and create a wish list of their favourite varieties. A third project that focuses on preserving agrobiodiversity and the promotion of traditional seeds is the Ambassadors of Biodiversity project. Local growers from Northern Spain volunteer to grow traditional seeds that are often not grown anymore. CITA research centre's seedbank has preserved these seeds for years. Besides involving local food growers to revive traditional food crops, the project also targets various schools in the region. Local students can grow crops and collect data and information according to their educational level to learn more about the importance of biodiversity conservation in the future.

Experiments with native growers and indigenous agricultural practices

The last two initiatives included in this section are the 3SI-Net project, a co-created project with native growers centred around the three sisters approach (native approach for intercropping maize, beans and squash). The experimental part of the project is a comparative trial between monocropping and using the three sisters approach. Besides the environmental component, the native growers highlighted the importance of using indigenous agricultural practices for food sovereignty, community well being, intergenerational knowledge sharing and seed rematriation (Kapayou et al., 2022), and the FEEDS (The Food Equity and Environmental Data Sovereignty) project that engages Indigenous communities in Canada and is currently developing a digital rapid response platform to promote food sovereignty, food security and detect impacts of climate change. The projects follows five phases, in all of which citizens are included. These phases are as follows: (1) participatory project planning, (2) digital platform customization, (3) community-led evaluation, (4) digital platform and project refinement, and (5) integrated knowledge translation (Bhawra et al. 2021). Eventually citizens will collect data in the FEEDS app on amongst other things environmental changes and hazards, food environments and well-being. These data will in turn help develop “culturally responsive interventions for climate change preparedness, food sovereignty, and solastalgia” (Bhawra et al. 2021, 7).

4.3 Agroecosystems

Soil health is another popular category when it comes to citizen science projects. One of the 13 principles of agroecology is dedicated to soil health (principle 3). There is a growing understanding of the urgency of maintaining and restoring healthy soils, which is reflected in the range of citizen science initiatives dedicated to this topic. There are several projects that engage citizens to contribute to data collection about various soil aspects by taking soil measurements, surveys and samples.

4.3.1 Soils

Soil health

GROW Observatory is a large-scale citizen science project conducted during 2016–2019. Citizen scientists across 13 European countries were engaged in a range of activities including taking soil moisture measurements to validate soil moisture information from satellite data. Besides soil data, citizens also collected data on edible plants, land management and polyculture experiments. The project also offered learning opportunities through Massive Open Online Courses (MOOCs) on citizen science and soil health (Ajates et al. 2020). The OPAL Soil and Earthworm Survey seeks to better understand the relationship between earthworms and soil organisms and the type of soil they live in. Citizens take soil samples, investigate soil properties, and record the organisms found in the

samples. OPAL Soil developed a simple booklet that explains the activities. Participants are asked to upload their findings to an online portal that gives information on soil quality and earthworm species across the UK. Another soil-related project in the UK is MySoil. This is a mobile platform that collects soil data on pH, texture, depth, organic matter and temperature that are combined into a detailed soil map. MO DIRT (Missourians Doing Impact Research Together) is a project that engages participants over a long period of time. Interested citizens are trained to conduct soil health surveys and monitor their chosen sites monthly for at least a year. They measure physical, chemical, and biological soil health indicators. The aim of the project is to better understand and be able to predict the impact of climate change on agricultural productivity. It also aims to understand how communities can respond to these challenges.

Decomposition rates

Other projects try to engage the public through fun and simple experiments that contribute to a better understanding of decomposition rates in soils. The Tea Bag Index asks citizens to bury two types of teabags in the soil and dig them up after three months. The project started in the UK and samples were sent back to the research team who analysed them for decomposition rates. However, now citizens from around the world can participate in the experiment and submit their data via a portal on the website. A similar experiment was also conducted with underwear. For the Soil Your Undies project participants buried a pair of white cotton underwear and dug them up after two months. The level of decomposition provides information about the health of your soil. The project was initiated by a range of organizations in different countries.

Soil pollution

Besides projects and initiatives that engage citizens in large-scale crowdsourcing of data and by conducting experiments, there are other projects that focus on soil pollution. Some of these projects have a strong social justice component since they address issues of inequality and health. Gardenroots is a project that engages citizens that live and grow foods adjacent to mining sites in Arizona. The project aims to determine the safety of foods grown by the community by measuring the uptake of arsenic in garden vegetables. The topic was a pressing issue and the community was involved in the complete research cycle from determining the research questions, collecting data, interpretation of data and dissemination of the results (Ramirez-Andreotta et al. 2015). The Gardenroots project is small scale but is an example of a truly co-creative citizen science project. Another small scale but co-created citizen science project with a strong social justice component looks at the contamination of wild berry patches. Fort McKay First Nation in Canada lies in the middle of oil sands development. Community members were concerned about contamination of traditionally significant blueberry and cranberry patches and in collaboration with a researcher developed a monitoring and sampling strategy. In this specific case, the community approached the researcher to assist them with research they wanted to conduct (Baker 2016). The Heavy Metal City-Zen project also examines how heavy metals are transferred into gardening crops through soil, but is not inspired by pressing societal concerns. Citizens across Vienna Austria were asked to bury pots in which they grew plants. After the growing cycle was completed the citizens collected soil and plant samples to send to the lab for a heavy metal analysis (Ziss et al. 2021).

4.3.2 Climate change

On Drought (Na suchu) is a citizen science project in the Czech Republic focused on monitoring the impacts of droughts on agriculture. Participants are invited to take photos of six different categories: solitary trees, crops occurring in the fields, biobelts and embankments, dirt roads, pools and areas for water retention and fruit trees for agroforestry. The project uses the iNaturalist app to collect observations and create a database showing the impact of drought on agriculture. iNaturalist is one of the largest platforms for crowdsourcing biodiversity data and hosts a variety of projects that allow citizens to contribute data to a specific project or to a large biodiversity database that contains

around 125,740,509 observations of 412,588 different species (www.inaturalist.org/observations, accessed on 28 January, 2023).

4.3.3 Earth systems

The Earth Challenge 2020 asks volunteers to classify pictures of six major crop types. Classifying large amounts of street-level photographs can help in developing and verifying large remotely sensed maps of crop areas and create a global database on the spatial distribution of staple crops. This is an example of how citizens are involved in simple data interpretation and analysis tasks. The project uses Picture Pile, an application that allows for rapid image classification. The Earth Challenge also has citizen science modules that look at plastic pollution, air quality and insect populations. Projects on drinking water and local impacts of climate change are currently being developed[2].

In the GLOBE Observer project, citizens participate through submitting observations of clouds, landcover, mosquitos and trees that complement observations made by NASA satillites. "GLOBE Observer is an international network of citizen scientists and scientists working together to learn more about our shared environment and changing climate". Submissions are classified and people can view all observations on an interactive map. The app is currently available in 12 languages.

4.3.4 Pollination

One topic that is popular among citizens and biodiversity observers is that of bees and pollination. The reason for this is that contributions are easy to make, and often only ask citizen scientists to submit their sightings of bees to an online portal. Bumblebee Watch is such a project that aims to track and conserve North American bumble bees. It asks citizens to take photos, classify the type of bees, geotag them and upload information into a database. It is similar to the Great Sunflower Project which requires citizens to record observations of pollinators in their yards, gardens and parks. However, the project also actively promotes pollinator health by providing information on how to improve pollinator habitat. Participants can also get more involved by planting a sunflower and observing the plant for any signs of pollinators.

Besides observing and counting the number of pollinators in a specific setting, other projects ask citizen scientists to conduct simple experiments in their gardens. In the Bees N' Beans project, participants conduct a simple experiment comparing broad beans in three different conditions: beans grown covered in a net, beans that are hand pollinated and beans that are left alone. Pollination Investigators takes a similar approach by only focusing on sweet peppers rather than beans. Both initiatives aim to better understand the pollination activities that bees are managing.

4.3.5 Land use

Both LandPKS and Land Matrix are initiatives that make use of crowdsourcing to acquire large sets of data. LandPKS (Land Potential Knowledge System) is an open-source application that can assist those interested in collecting, sharing and interpreting their own soil and vegetation cover data. Citizens can collect, share, and interpret their own soil, vegetation cover, and management data by submitting the data to an online portal. Individual users receive point-based estimates of land potential based on the integration of simple, geo tagged user inputs with cloud-based information and knowledge. Land Matrix is a public database that contains information about land acquisition data. It is a land monitoring initiative that looks at large-scale land acquisitions in low- and middle-income countries and is open to submissions from the public.

2 See for example: https://globalearthchallenge.earthday.org/pages/research-questions

4.4 Markets, diets and consumption

4.4.1 Diets

The following initiatives and projects are more directed towards consumption rather than the production side of food. A project focused on understanding diet quality in Rwanda used a questionnaire to crowdsource information on consumption of 26 different food groups. The questionnaire was distributed via text and contained 29 binary questions to which participants could only answer “yes” or “no”. The aim of the project is to develop a digital tool that can be applied in different contexts and can help in collecting large amounts of diet quality data (Manners et al. 2022).

Gamification can be a fun way for citizens to participate in science and data collection. In an article, Spitz et al. (2018), explain the development of a gamified citizen science tool that engages participants by having them play a game in which they have to report products that contain artificial additives. The DYET (Do You Eat This) app allows participants to “collect” products with harmful additives by scanning the barcode of the product. The idea is to make citizens more aware of food additives and the related risks and to influence consumers' food habits. By scanning a product the information is recorded in a database that contains information on harmful additives and products containing them. In 2018 the app was still in development (Spitz et al. 2018) and whether it was ever officially launched is unclear.

Citizen science projects related to nutrition are rare (Ryan et al., 2018). Different projects focus on nutrition and flavour such as a citizen science project looking at the quality and microbial substance of kombucha, or a project collecting data from bakers to better understand the microbes and the bread. Another project that combines research with education is Sourdough for Science or The Great Pumpkin Project in which students learn about the insects, microbes, beneficial bees, plant pollination and plant–insect–microbe interactions.

4.4.2 Food prices

Only one citizen science project in the review focused specifically on food prices and markets. The Food Price Crowdsourcing in Africa (FPCA) initiative by the European Commission's Joint Research Centre was implemented in two states in Northern Nigeria. Volunteers were asked to submit real time and georeferenced data of food prices at different stages of the value chain using an Open Data Kit (ODK) system which allows data to be stored in real time and sent when there is a connection (Solano-Hermosilla et al. 2020). To stimulate participation, the initiative also experimented with using monetary and social incentives for data submission (Solano-Hermosilla et al. 2022).

4.4.3 Food environments

Other projects do not focus as much on the quality of certain foods but rather on the complete food environment which includes food availability, food affordability, product properties, vendor properties and food messaging (The Food Systems Dashboard 2020). One example is the LEAF project (Local Environment Action on Food) in which citizens participated in an eight-step program that allowed them to prioritize the research area, collect data as well as creating recommendations for healthier food environments. The project used a web-based survey tool designed to collect data on the costs, availability and policies, programs, and resources related to healthy eating in school environments. The survey tool contained a set of questions and an option to upload pictures and documents (Aylward et al. 2022). The Food in This Place is another food environments initiative, specifically focused on retail food environments. During a workshop participants were trained in how to use an assessment tool that allowed them to observe and think about how “features of the retail food

environment, such as price, quality and merchandising, affect food purchasing and consumption" (Pomeroy et al. 2017, 637). The final example is a small-scale community science project involving youths from the Karuk Tribe in the United States as leaders to address tribal food security. Together with the researcher, the youth citizen scientists developed and conducted a survey to assess health and food security within their community. In this project, youth citizen scientists were involved in all aspects of the research. From definition and prioritization of research questions, data collection, analysis, application of findings to dissemination of knowledge (Kim et al., 2020).

A project focused on consumers' experiences is Food Glorious Food: Using Tweets to Understand our Food System. The aim of the project was to understand consumers experiences with food before and during covid to inform recommendations for changes. The researchers used Twitter to search for tweets related to food and participants were asked to contribute by validating the accuracy of the tweets and whether they are really concerned with the food system.

Finally, Járókelőkutató (or Passer-by Researcher) is an Hungarian digital citizen science tool that allows participants to record and share knowledge about urban alternative food production strategies. Due to COVID-19, the concept of food sovereignty strongly influenced the development of the tool. Citizens can share photos and videos of their methods and best practices, conduct farm trails, map water saving methods and contribute to a digital database of seed and crop variety across the country. The tool is currently only available in Hungarian.

4.4.4 Food waste

There is a whole range of citizen science projects that study both food waste and loss. A study by Pateman et al. (2020) looking at the role of citizen science in quantifying food loss and waste includes an extended review of citizen science for food loss and waste (Pateman et al., 2020). One example found on eu-citizen.science is Svinnkollen or The Food Waste Experiment. This Swedish citizen science project focuses on food waste in schools. The project uses artificial intelligence (AI) to calculate the amount of food waste in schools. By scanning their lunch plates before they eat, pupils and teachers train the AI to identify different kinds of food. After the AI is trained, participants scan their lunch plates before and after they eat, and the amount of food waste is automatically calculated. The project also includes a component on food preferences. The idea is that if consumers are more aware of the impacts of their food on the environment and if schools better understand the food preferences of students, the school kitchens can make better orders and reduce food waste all the way from the wholesale level.

A project that does not necessarily fit straightforward into a review of citizen science projects to support agroecology and agroecological transitions is a research into industrial hog industries. However, the research is included because it does address an important component of unsustainable food systems, namely industrial meat industries. In addition, there is a social justice component to the research, which was co-created with the community and a community-based organization. Research questions were developed based on existing questions and issues related to odor pollution and additional issues such as waste encountered by communities near the hog industry. Citizens living close to the industrial site were asked to step outside for 10 minutes a day at preset times to report on odor nuisance, and other experienced issues. In addition the researchers took air samples and conducted interviews (Wing et al., 2008).

4.5 The use of (digital) tools

4.5.1 The (digital) tools from the review

There is a whole range of tools that can be used for collecting data, analyzing data, visualizing data or connecting different participants. The majority of projects included in this review use some kind of digital tool as part of their research (see Figure 11).

Many projects make use of some form of digital survey to collect observed data, such as reporting data from experiments. There are various online tools that can be used for this purpose. Examples include Google Forms and Survey Monkey. These are accessible and free tools for anyone with access to a computer or smartphone.

It is also possible to use existing software that allows for structuring and building simple citizen science projects to collect data. For example, the CS Logger and CS Project Builder software developed by the Citizen Science Centre in Zurich. Another example is Spotteron, a paid and fully customizable software. It offers a range of features such as data quality and verification, motivations for participants, the ability to generate graphs and visualizations, interactive maps and much more. iNaturalist is a platform that is used for projects focused on observations of biodiversity. People can send in observations of virtually everything in the environment ranging from plants, insects, butterflies, animals, etc. The platform also allows for personalized projects for observations of specific species. The Global Amphibian BioBlitz (GAB) is an example of such a project dedicated to global observations of amphibians. A page is created that shows basic statistics, the number of observations and an interactive map with the location and pictures of the different observations (see Figure 12).

The final example is a citizen science software that is specifically tailored to agricultural citizen science projects. ClimMob is developed by the Alliance of Bioversity and CIAT and gives project developers the opportunity to develop large-scale experiments and test different technology options, such as crop varieties, food products, or agronomic practices. The software also helps to streamline the experimental cycle, and gives insights through automatically generated reports. The software also supports the Tricot approach (see Section 4.2.4 and Figure 13).

The ClimMob software makes use of ODK, which is an open-source mobile data collection platform that allows for data collection with limited internet connection. Users can fill out a form offline and these are forwarded to a server when there is an internet connection. Similar to ODK is Magpi, software that also works offline. Magpi supports different forms of data such as photos, GPS, multiple choice, Near-Field Communication technology (NFC), barcodes, numbers, subforms, signatures,

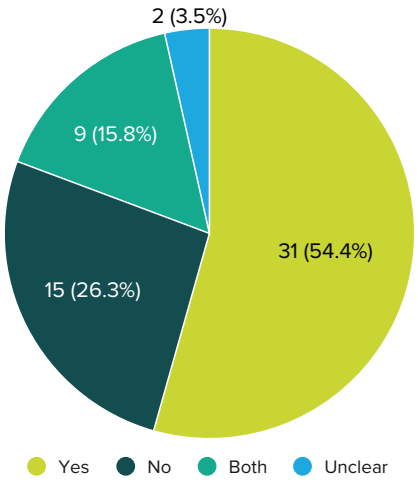


Figure 11. Number of reviewed projects using digital tools

Figure 12. Interactive map generated from the iNaturalist GAB project

Source: https://www.inaturalist.org/observations?project_id=13

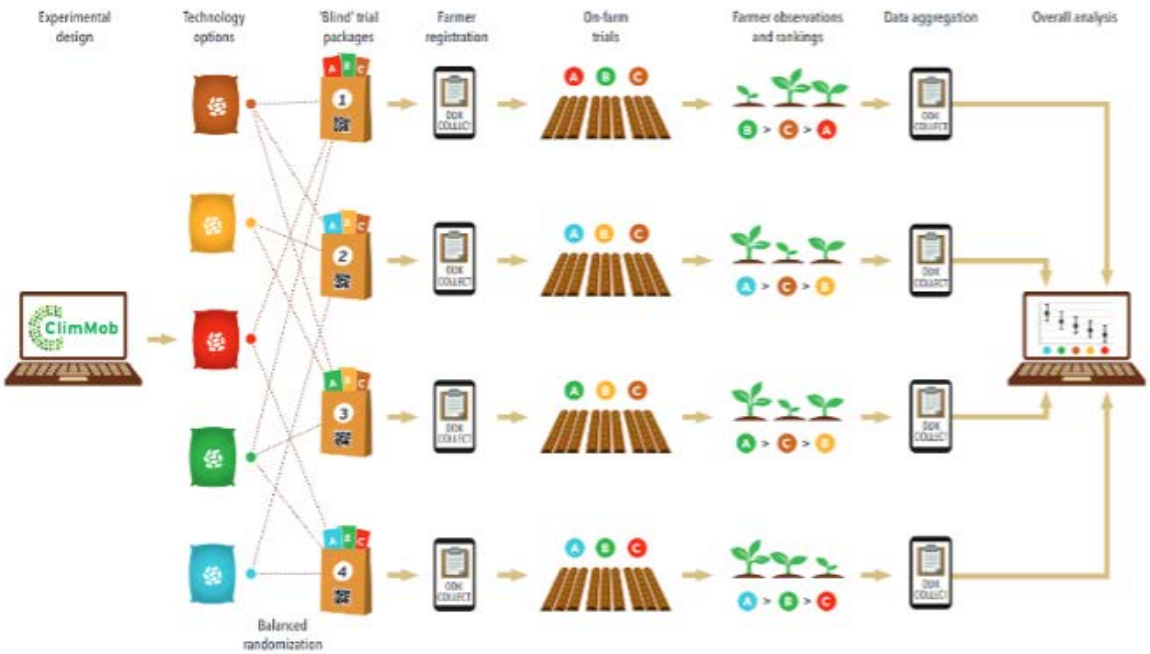


Figure 13. Illustration showing how to implement the Tricot approach using ClimMob software

Source: https://climmob.net/blog/

interactive voice messaging (IVM) and more. It also provides real-time dashboards and data visualizations as your data is collected.

In addition to these platforms that have an offline function for data collection, there are also methods available that do not need an internet connection at all. These methods can be used with the help of a simple phone. One example is using USSD (Unstructured Supplementary Service Data), similar to SMS, which allows for a two-way exchange of data. A similar system is that of IVM but rather than using written text, IVM utilizes voice, interacting with callers through a set menu.

Apart from tools for collecting data, there are also tools for analysing it. One example is Picture Pile, an online and mobile application for rapid image classification. This software is used in the Earth Challenge 2020 for verifying cropland images.

Besides maps that are automatically generated using citizen science software, a lot of projects also use Google Maps to create personalized maps with separate points for observations. Google Maps is free to use and also supports pictures and videos.

Finally, communication between participants can be an important element of citizen science campaigns. Connecting with like-minded people and being part of a larger community is often a major reason for citizens to participate. Some of the larger projects have communication capabilities integrated into their platform. Other projects make use of Facebook pages or WhatsApp groups. Participation is voluntary since not everyone has or wants access to these platforms.

4.5.2 Other digital tools for agriculture and farm management

Besides citizen science projects that are related to the food system or more specific agroecological practices and transitions, there are a range of existing farm management apps that can assist farmers with their work. In their article about the role of citizen science for sustainable agriculture, Mourad et al. (2022) provide a list of existing farm management apps. These apps range from apps that can help identify weeds and diseases such as the Bayer FieldMate. This app allows farmers to search for weeds, pests and disease in a large digital library. Another example is the BASF Cereal Disease ID app, that provides a similar function but is focused on diseases in cereal crops. Stockmove Express helps livestock farmers in Great Britain to manage their sheep and cattle register, whereas farmGRAZE helps farmers manage and maintain their pastures for livestock grazing. The platform Farmshine helps farmers connect to suppliers and service providers via a digital platform in order to minimize costs and maximize harvests. PlantVillage uses AI to help smallholder farmers identify crop diseases. In addition it is also developing the largest open-access crop health library.

These are only a few examples of the wealth of digital tools for agriculture that are currently being developed. The Digital Agri Hub is a platform that tracks the development of digital agriculture in low- and middle-income countries and contains numerous examples and tools for digital inclusion in agriculture The Agroecology TPP is also working on those domains with the TRANSITIONS project. In particular, the ATDT component focuses on the development of inclusive digital tools.

Besides farm management apps, there also exists a wide range of digital agricultural services, such as a web-based decision support system that supports Greek farmers in selecting alternative crops (Antonopoulou et al. 2010) or AgrIDS, an information dissemination system that can give farmers advice about what crops to cultivate based on the market's demand (Reddy and Ankaiah 2005).

5 Discussion

5.1 Agroecological-ness of citizen science

As listed by Ryan et al. (2018), the reasons for uniting citizen science and food systems are plenty and include the dwindling funding for agricultural extension, the increasingly global nature of the food system crisis and the way people are getting more and more disconnected from their food. Even though there are a variety of citizen science projects relating to different aspects of the food system, the topic of agriculture and food is relatively rare when looking at the broader citizen science spectrum. A search done by Ryan et al. (2018, 8) showed that "less than 1% of Scistarter's projects (as of 5 April 2018; scistarter.com) contain the tags 'agriculture,' 'food', or 'farm.'" When extending this search to the other two platforms included in this research, only 2.5% of projects listed on eu-citizen.science and less than 1% of projects listed on Zooniverse.org do.

Even though 57 projects are included in this review, none of them explicitly refers to or mentions agroecology in their project description. This is despite the fact that they do relate to some of the agroecological principles. Most projects included in this review focus on the on-farm elements of agroecology, such as pests, seed varieties, crops, and soils. Several projects mention preserving agrobiodiversity, local knowledge, indigenous crops, food sovereignty and seeds. There are a few citizen science projects that focus more on the consumer side and address the topic of healthy and culturally appropriate diets, nutrition, food prices, and food environments. However, these projects are usually limited and of a smaller scale.

Classifying these projects as being agroecological also relates to the broader question of when something is considered true agroecology. Should all the 13 HLPE principles be addressed, or is a single one sufficient, or should the project at least encompass the three aspects of natural farming, social justice and circular economy in some way or form? At the same time, not all questions can be answered using a citizen science approach. The use of citizen science can be beneficial in answering research questions that have a clear methodology and are easily addressed with simple methods, but integrating different agroecological elements into a project can complicate it. Defining a citizen science initiative that is both holistic and targeted enough to allow for citizen science methods to be applicable, requires careful planning and implementation.

5.2 Levels of citizen engagement

As shown in the results, the vast majority of citizen science projects are contributory. It is mostly these contributory projects that work at a large scale, involving citizens throughout countries, and sometimes even around the world. As expected, co-creation projects are more rare. The majority of co-created projects included in this review are small scale, or pilot projects. The projects have a more ambitious aim and target true participation of citizens in all aspects of the research. This requires planning, relationship building and effective communication between citizens and researchers. Most of these projects also address problems that directly affect the community they work with and therefore have a strong social justice component (Gardenroots, Industrial Hog Operations). Other projects revolve around Indigenous knowledge and work with local communities. These projects look for a more inclusive approach to data collection, knowledge sharing and participation (FEEDS,

3SI-Net project, Wild berry monitoring). Collaborative projects cover the middle ground. In most cases, they involve citizens in data collection as well as in data analysis, or in the development of research objectives (Food in This Place, MO Dirt, STEP CHANGE). Schools can use research as part of their curriculum in some projects (Ambassadors of Biodiversity, Mildew Mania). GROW Observatory also offers a MOOCs on the topic of soil and citizen science. The differences in scale between collaborative and co-created projects show the challenges of truly co-creative projects.

5.3 Citizen science in the Global North and South

The global distribution of citizen science projects is skewed towards the Global North. This is likely to be related to various reasons. First of all, citizen science in agriculture, agroecology and food systems often builds on the voluntary time, efforts and skills of farmers. Literature suggests that smallholder farmers often lack the ability to successfully participate in and benefit from systematic citizen science projects (Mourad 2020). Smallholder farmers are motivated to participate in citizen science projects when the project is directly relevant to their livelihoods. This is different compared with other contexts, where citizens often participate for personal recognition and pleasure (De Silva et al. 2013 in Ebitu et al. 2021). Another reason is the level to which citizen science projects are made available to the public. Not all projects are published in recognized peer-reviewed journals, or on publicly accessible websites or blogs. This review also collected data through a search of three major citizen science platforms. On those platforms, however, most of the projects were from Europe or North America. Citizen science platforms for other continents also exist but are not as well-known.

5.4 The use of digital tools

This difference between the Global North and South is also linked to the level to which participants have access to the digital tools that are often employed in citizen science. Over 50% of the projects in this review make use of digital tools in some form. These tools allow for a more efficient data collection process. Many of the tools have functions, such as geotagging photos, identifying species and visualizing data that save a lot of time and resources compared with analogue data collection tools. However, not everyone has access to digital tools, and especially the target audience of smallholder food system actors. However, around 25% of the projects included in this review do not use digital tools but these are often small scale and do not deal with thousands of submissions.

6 Conclusions

This report presents the results of a global review of citizen science projects that support agroecology and agroecological transitions. Following a rigorous selection process, a total of 57 projects and initiatives were included in the actual review. The level of 'agroecological-ness' depends on the project. The majority of projects (30 in total) have a strong focus on the natural farming aspect of agroecology. There were ten projects that focused on social justice matters and a total of four were mapped solely to the circular economy aspect. There were several projects that adhered to more than one aspect but none of the projects explicitly addressed all three aspects.

The topics of the projects discussed in the review were differentiated into three categories. First, projects that focused on agricultural production, such as the use of fertilizer and pesticides, inputs needed for urban agriculture, projects that focus on crop and seed varieties, monitoring agricultural pests and pathogens and finally projects focused on energy and water use for agriculture. The second category encompassed all projects that have a focus on agroecosystems. This included projects that look at pollination, different earth systems, climate change and land use. The final category of projects included in this review is that of markets, consumption and diets. This category features projects that focus more on the consumption side of the food system, looking at diet quality, food environments, food prices and food waste.

The review showed that there are many opportunities for citizen science and food systems, and the potential is not yet fully realized. The review also showed a lack of publicized or easily accessible citizen science projects related to food systems and agroecology in the Global South as well as a gap in projects that focus on other elements besides on-farm agroecological practices. The One Million Voices project presents a valuable opportunity to address the lack of agroecological citizen science projects.

6.1 Recommendations for the One Million Voices Initiative

Recommendation 1. Understand the motivation for participation

Citizen science builds on the voluntary time, efforts and skills of participants. As mentioned by Mourad (2020), literature suggests that smallholder farmers lack the capacity to engage in and benefit from systematic citizen science projects. Smallholder farmers are motivated to participate in citizen science projects when the project is directly relevant for their livelihoods. This is different compared with other contexts, where citizens often participate for personal recognition and pleasure (De Silva et al. 2013 in Ebitu et al. 2021). Research by Beza et al. (2017) looked at the variety of motivations people, and more specifically smallholder farmers, have to participate in citizen science.

Understanding the reasons why people might be motivated to participate in a citizen science project is important for finding engaged and committed participants. Some of the relevant motivations identified include contributing to scientific research, for fun (passing free time), interest in sharing information, expectation of something in return, interest in networking with experts, interest in

networking with other community members, a wish to help researchers, among many others. Being mindful of and eliciting conversations about users' motivation needs to be part of the co-creation process.

Recommendation 2. Give back to participants

Understanding the reasons and motivations for participation also links this idea of giving back. Participants might expect something in return, especially when they lack the time and capacity to contribute their time to the project. There might be long-term benefits connected to participating in a citizen science project, for example improved knowledge of the spread of agricultural pests can in the long run contribute to better measures that will eventually benefit those who have contributed to the project. However, there are also projects that provide more immediate benefits. Projects such as VGI for IPM and EuroBlight use the submitted observations about pests to report back about local outbreaks. GROW Observatory provides all participants with additional learning materials in the form of MOOCs. Other projects provide automatically generated visualizations and graphs based on the submitted data. This allows participants to analyse their data and compare it with others', such as is the case in the Edible Garden project. Another example is projects that provide a digital platform through which participants can communicate with each other. This fosters a sense of community and can be a place for sharing knowledge and experiences.

An important discussion in agroecology always links back to co-creation of knowledge and horizontal knowledge sharing. When thinking of an agroecological citizen science tool, we must ask whether it can be linked to a repository of agroecological practices, for example linking to the videos created by Access Agriculture both available on their website, and on EcoAgtube, a website dedicated to videos for agroecology and the environment or working together with organization and projects that have developed materials and guidelines such as the handbook on agroecological production by YALTA or the handbook on African Indigenous Leafy Vegetables developed by CSHEP in Kenya in collaboration with the Humboldt-Universität in Berlin (Henze et al. 2020).

Another thing to consider is whether there can be a way for participants to not only view other submissions but also communicate with each other, comment on practices, ask questions and exchange ideas. This is possible on iNaturalist, where people can give suggestions on the species of a referenced animal or comment on someone's observation. Other projects use online blogs or Facebook groups for discussion.

Recommendation 3. Make it accessible for diverse groups of participants

In order for people to participate in a citizen science project, the project has to be accessible. It is hence important to think about preferred communication channels and tools of target audiences. Additionally, one of the largest barriers to creating a citizen science project that is available in different locations around the world is that of language. As Roberto Papa from the INCREASE project pointed out "People can get easily frustrated and sometimes even angry when the project is not available in their language". There are tools available for overcoming these barriers. Many applications have a menu with different language settings, however these do not always translate perfectly and mostly feature only a limited range of languages. Other possibilities are using IVM (interactive voice messaging), clear illustrations and images and short and concise statements. One example would be the AgroDuos project which developed a game played with simple and clear illustrations that could be understood by farmers with different levels of literacy (see Figure 14).

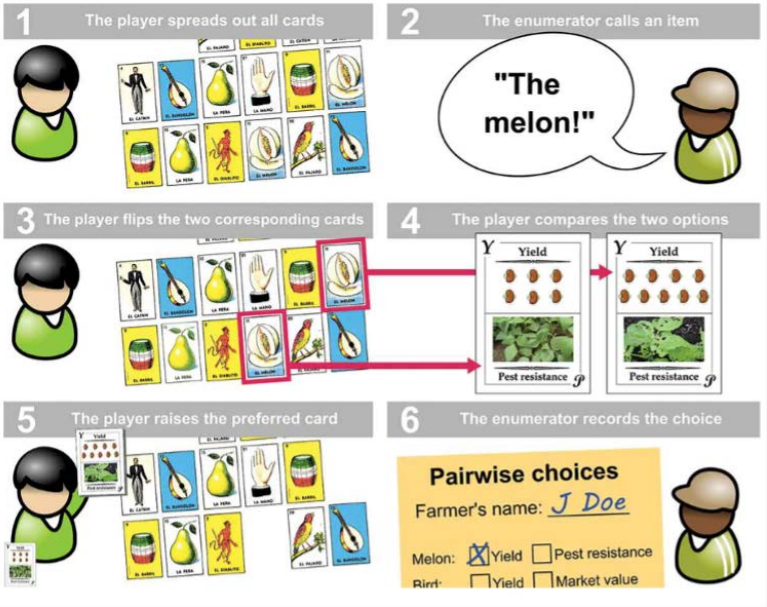


Figure 14. Visualization of AgroDuos gameplay

Source: Steinke and van Etten (2017)

Recommendation 4. Keep it simple

Especially when working with a variety of people from different places all over the world it is important to keep it simple. Clear communication is essential – avoid complicated language and focus on concepts that are easily understood by all. Start with a straightforward research question that can be answered by using simple and accessible tools and clear instructions. There is always an opportunity to expand the project, take on new questions and develop other modules.

Recommendation 5. Build on existing networks

The final recommendation is to build on existing networks. Reaching out to people and motivating people to participate takes time and involves relationship building. Rather than starting from scratch, it is important to use existing partners and their networks to design and popularize the initiative and scale. Another option is to find new partners whose activities and interests match with the ones of the One Million Voices initiative. An important entry point for building on existing high-quality and well-known work might be to seek collaboration with the team from Agroecology Map, an open platform maintained by a group of volunteers that allows exchanging agroecological experiences.

6.2 Building an inclusive citizen science platform to harness One Million Voices of Agroecology

The One Million Voices Initiative's goal has been to develop a tool, or a series of tools, that enable farmers, producer organizations, consumers and other potential end users around the world to:

- inclusively participate in agroecology movements,
- support sustainable adoption of agroecology,
- contribute to the collection, co-creation and sharing of information to fill key knowledge gaps on the performance of agroecology.

Inspired by agroecological, citizen science and digital development principles, and building on the insights of this global review, alongside the results of the dialogues held by four leading regional agroecology network representatives across the globe (which will be subject of a different publication), the One Million Voices team joined hands with the Agroecology Map team to develop the One Million Voices of Agroecology platform: https://onemillionvoices.agroecologymap.org/

The platform combines several main features:

- Users can map one or several locations where they practise agroecology – be it a farm, a community, a company, a landscape, or any other place of their choice. Beyond mapping, the platform allows registering characterizing details, asks about the users' dreams for the place, and provides a space to describe how agroecology is practised in a holistic way. Pictures can be uploaded.
- After mapping and describing a location, users can register one or several practices that they pursue in that location. This can encompass both on- and off-farm practices, for which users can upload pictures as well.
    - Users can then characterize their practice by indicating which of the 13 HLPE Principles of Agroecology they address, and which food system components they concern to emphasize how the respective practice relates to agroecology.
    - They can also evaluate the performance of your practice against different key interests and priorities. These include specific matters of interest that arose from the regional dialogues, as well as general questions about the performance of specific agroecological practices. Specific evaluation questions include general performance, unintended consequences, time and labour requirements, system integrity requirements and contributions, interactions with climate change vulnerability, etc. All evaluation questions combine fixed answer formats (drop-down menus) and open text fields, and any question can be skipped.
    - Users can also acknowledge and share their knowledge sources in writing, by linking online resources, and/or by uploading manuals and information material.

Users can connect with others by browsing the map, the locations, the practices, or by filtering their entries according to specific criteria. The platform allows for single and composite (combined criteria) searches. Users can also directly comment on others' practices, exchange with each other via the comment function, and ultimately mobilize and organize.

To ensure that the One Million Voices of Agroecology platform lives up to its promise, it:

1. Uses digital tools to allow global participation.
2. Supports the use of different languages. The platform starts with four languages (English, French, Spanish, Portuguese), but the language range can be expanded at users' request.
3. Works with local, regional, and global networks to support accessibility and fair participation for their constituencies by influencing the platform design and functioning, and to support them directly to use the platform.
4. Allows users to share as little or much as they desire (there are very few mandatory fields, and many optional questions).
5. Aims to foster co-learning and exchange while collecting and showcasing innovative ways of realizing agroecology in different contexts.
6. Hosts the data under a Creative Commons licence.

The platform's human-centred design aims to benefit diverse groups of users by fostering that they:

1. Share and show their experiences with other users.
2. Find others who do agroecology in their surroundings for exchange and collaboration.
3. See what others do around the world – in general, or by filtering the data in line with their specific interests (for example location, type of farming system, agroecological principles, system components, etc.).
4. Learn from others' experiences and their personal evaluation of the performance and contextual suitability of their practices.
5. Comment and ask other users questions about their locations and practices.
6. Access knowledge products such as manuals and guidance documents.
7. Learn more about agroecology and its different aspects and dimensions.
8. Are part of a growing community striving for positive change in food systems.
9. Get in touch with the Agroecology TPP and Agroecology Map researchers to share their experience and foster continuous improvement of the.

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Appendix 1. Interview guide ground proofing interviews

Name of the project:
Person interviewed
Date:

A. Project design and methodology:

1. Can you explain how the project evolved and why a citizen science approach was chosen?
2. Can you elaborate on the specific role of citizens in the project (what are their tasks, how do they contribute to the research, in which steps of the research are they involved)?
3. What strategy was used to engage citizens to participate in the project?
4. What were the reasons people participated in the project (what do they get out of it e.g. fun, relaxation, contributing to new knowledge, the knowledge generated is beneficial to them personally etc.)?

B. Data quality and accessibility:

5. What measures were taken to ensure data quality and consistency?
6. Are efforts made to make the data available and accessible to those who participated in the project?

C. Digital tools:

7. Did the project use any digital tools (for data collection, data storage etc.)?
8. If so, what type of tool and what are the different functionalities of the tool?
9. What is needed to use the tool and can it be used in different contexts (e.g. need for stable internet connection, is there an offline version, use of SMS, ODK, USSD?)
10. Are there any limitations to using the digital tools in your project?
11. Do you have any recommendations for the use of digital tools e.g. best practices, things to look out for?

D. Co-creation:

12. What were some of the mechanisms in place to ensure citizens were involved in different steps of the research?
13. What are some of the limitations (if any) of involving participants in all the steps of the project?
14. And what are some of the opportunities of involving participants in all the steps of the project?
15. Is there a possibility for participants to provide feedback, and how is this feedback incorporated?

E. Closing questions:

16. What are the main successes of the project/what is working well?
17. What are the main challenges encountered during the project?
18. Is there anything else you would like to share

Appendix 2. Layout of database

A database with all the selected projects is developed as part of this review. Here, more information about the specific projects can be found, as well as a link to the project page or the article. The database can be accessed here: https://bit.ly/OMV-DB-Global_Review

Column in the database	Explanation	Example
Title	Title of the project (if any)	Mildew Mania
Topic	Main topic (in a few words)	Pests and pathogens
Description	Short description of the project	Schools are provided with wheat and barley seeds to grow in their local area in order to 'catch' local strains of the powdery mildew disease. Schools are provided with 5 seed varieties – some of which are more susceptible to the disease than others. At the end of the growing season (June–Oct), if the powdery mildew disease is present, samples are then sent to Curtin University scientists.
Aim	The research aim(s) of the project	Protecting West Australia's barley and wheat crops from the damaging effect of powdery mildew diseases and mapping the various strains of the powdery mildew disease throughout Western Australia.
Location	Location(s) of the project	Western Australia
Link to page	Link to project page or scientific article that contains more information	https://scistarter.org/mildew-mania OR www.mildewmania.com.au
Status	Active, Finished, Unclear	Finished
Type of engagement	Contributory, Collaborative, Co-created	Contributory
Engagement explained	Explanation of why the project is classified as contributory, collaborative or co-created	Participants are not just involved in making observations and contributing data but there is also an educational element. Students are growing barley, observing for mildew and lessons build around the project.
Participation task	Few descriptive words of how citizens are participating	Growing barley, collecting samples, observation
Participation explained	Detailed explanation of citizen participation	Students in primary school and high school grow barley and observe the plant for signs of mildew. If these occur they take samples and send these to the researchers.
Funding	Funding of the project	Unknown
Type of participants	Who can participate	Students at schools

Column in the database	Explanation	Example
What is needed for participation	What is needed for participation (from digital devices to other materials)	Seeds are provided, place to grow barley at school
Use of digital tools	Yes, No, Both	No
Type of digital tool	Description of the type of digital tool	N/A
Connection to the HLPE 13 agroecological principles	To which of the 13 HLPE agroecological principles can the project be mapped (one or more)	input reduction, biodiversity
Data stream	Stream 1, 2, 3, 4	Stream 1
Citizen science platform	eu-citizen.science, Zooniverse, SciStarter	SciStarter
Link to agroecological aspects	Natural farming, social justice, circular economy	Natural farming

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This report summarizes the results of a global review and analysis of citizen science projects supporting agroecology and agroecological transitions. The purpose of the review is to provide information on existing projects and inspire the development of a citizen science tool that enables inclusive participation in agroecology movements. The report aims to promote sustainable adoption of agroecology, fill knowledge gaps, and avoid duplication. It also contributes to four regional dialogues that were held to support the development of the One Million Voices of Agroecology digital platform.

The review used four data streams, including three citizen science platforms, a literature review, projects proposed by the One Million Voices citizen science initiative, and a Google search. The report includes 57 projects categorized into agricultural production, agroecosystems, and markets, consumption, and diets. Most projects focus on natural farming, with some addressing social justice and circular economy aspects. However, none of the projects fully encompass all aspects of agroecology, and there is a lack of accessible projects in the Global South and those focusing on elements beyond on-farm practices.

The report provides recommendations for the One Million Voices citizen science initiative. These recommendations include understanding participants' motivations, providing benefits to participants, ensuring accessibility for diverse groups, keeping participation tasks simple, and leveraging existing networks and partnerships.

About the Agroecology TPP

The Agroecology TPP convenes a broad group of scientists, practitioners and policymakers working together to accelerate agroecological transitions. Since its official launch on 3 June 2021, the TPP has begun addressing knowledge gaps across eight domains that will support various institutions and advocacy groups in key decision-making processes. Its online 'Community of Practice' on GLFx is open to all, providing a space for members to share their insights, knowledge and experience.

This partnership was founded by CIRAD, The Alliance of Bioversity International and CIAT, BioVision, UNEP, FAO and CIFOR-ICRAF.