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RESEARCH AND EDUCATION HIGHLIGHTS

Changing gardeners' point of view on soils with a citizen science project in Southern-East France

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Abstract

Soil and the threats it faces nowadays are often underestimated by citizens. This is rather due to a lack of awareness than to a lack of interest. In France, the surface covered by private gardens is not negligible, as it represents 2% of the territory, which is four times larger than the area of natural reserves in the country. Therefore, ensuring the protection and preservation of healthy soils in these areas is of great importance. Citizen science is a good way to raise awareness about scientific issues. Using a scientific and educational approach, the citizen science project "La clé du sol," funded by the Fondation de France coordinated by the evertéa Foundation, aimed to raise home gardeners' awareness of soil complexity and how to maintain healthy soil, as well as help them realize the possible consequences of their practices. For 2 years, fourteen gardeners participated in the project which involved theoretical and practical workshops where cultivation practices were listed, garden soils were sampled, and their physico-chemical and biological parameters as well as contaminants were analyzed. The strength of this project was the close interaction between the gardeners, a local citizen association, agronomy students, and researchers to decipher and interpret the results and learn how to translate them into practical advice. The progress of the project is presented in this article. Moreover, the scientific, social, and educational contributions of "La clé du sol" as well as the challenges inherent in citizen science projects involving long-term citizen engagement will be discussed.

Keywords Participatory science · Vegetable gardens · Soil health · Indicators · Contaminants

Introduction

Soil health has been defined by the Intergovernmental Technical Panel on Soils (ITPS) as "the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems" (FAO 2020). Preserving soils is essential as they are the basis for numerous ecosystem services and functions such as the production of food, fiber, construction materials or fuel, but also carbon sequestration, water purification and climate regulation. In fact, 95% of our food comes directly or indirectly from soils (FAO 2015a), so maintaining soil functions is crucial for producing high-quality, healthy and nutritious food (Montanarella and Panagos 2021). In recent years, the importance of the role of soils

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in the fight against climate change and its consequences has also been highlighted. Sustainable soil management (SSM) can improve water storage and infiltration while reducing the water runoff and evaporation, thereby mitigating the effects of extreme events such as floods and droughts (Saco et al. 2021). Carbon sequestration by soils could also play a role in mitigating climate change (Don et al. 2024; Lal 2004), while increasing soil fertility which is partly determined by the soil organic carbon (SOC) content and composition (Trivedi et al. 2018). This idea of using soil to sequester excess carbon emitted by human activities was brought to light with the "4 per 1000" initiative, which was presented by researchers at COP21 in 2015 (Soussana et al. 2019). With adapted practices, agricultural and forest soils could become carbon sinks, maintaining food security while combating climate change. However, in 2015 about 33% of the world soils were moderately to highly degraded—biologically, chemically and/or physically, meaning a loss of soil fertility, biodiversity or an increase in soil contamination (FAO 2015a). Every year, 12 million hectares of agricultural soils are lost globally through soil degradation (Plant Production and Protection Division 2015) caused by urban expansion, overgrazing or unsustainable agricultural practices (Maximillian et al. 2019). By 2050, up to 90% of the planet's land surface could be degraded, posing major risks for biodiversity and human life (European Commission: Joint Research Centre et al. 2018). This trend continues despite growing awareness of the importance of maintaining healthy soils.

In Western culture, soil is still often seen as something dirty and inert (Fournil et al. 2018; Latawiec et al. 2022). Even direct users, such as home gardeners, often underestimate soil functions, its complex composition (physical, chemical and biological) and its processes. Raising citizens' awareness of soils—what they are, what they do and how to keep them healthy or restore them—would be a first step towards their protection (Brevik et al. 2022). Citizen science seems to be an efficient way to achieve this, as shown by the number and variety of citizen science projects that exist in Europe, listed by Mason et al. (2024). Citizen science is a collaborative research method that actively engages the public in scientific processes. It includes various methodologies and involves communities at different levels of participation. For instance, existing citizen science projects on soil range from fully co-constructed such as "BRIDGES" in Italy (www.progetto-bridges.it), a transdisciplinary project focusing on the co-construction of proposals on soil fertility involving citizens, farmers and researchers, to projects where citizens primarily serve as sample collectors such as "Vigilantes del Suelo" in Spain (https://vigilantesdelsuelo.es/) which focuses on the development of a soil health map using results from soil samples collected by citizens. Moreover, the EU Mission "A Soil Deal for Europe" strongly mobilizes citizen science with the establishment of many living labs. The project "La clé du sol" (the soil's key) targets soils in vegetable gardens. Globally, a diversity of citizen projects focusing on home gardens and gardeners exists, aiming, for instance, to understand pesticide and fertilizer use (the "In my backyard" project, in Portugal, Monteiro et al. 2020), test soil and crop quality ("VegeSafe", in Australia, Taylor et al. 2021; "City-Zen Boden" in Austria, Ziss et al. 2021) or collect biological data ("Earthworm Watch" in the United Kingdom, Burton et al. 2024; "Microbelix" in Germany, www.microbelix.de; "QUBS, "www.qubs.fr. and "Jardibiodiv, https://ephytia.inra.fr/fr/P/165/jardibiodiv, in France). Urban gardening is expanding worldwide, and its integration into educational and social programs has been shown to improve nutrition and food security (Eigenbrod and Gruda 2015). However, despite all these existing programs, home garden soils are still poorly studied and not well understood, mainly because they are located on private land and are therefore difficult for scientists to access. Yet, their surface area can be significant. In France for instance, they represent 2% of the national territory, which is four times larger than the area of natural reserves in the country (Riboulot-Chetrit 2015). As a result, home gardens could be considered an important area for biodiversity in urban environments. Moreover, home-grown vegetables can account for between 5 and 18% of all vegetables consumed, as shown in a study of three urban areas studied in the western France (Rennes, Caen and Alençon) (Marie 2019). It has also been demonstrated that vegetables grown in home gardens can contribute to climate change mitigation due to reduced transport needs and lower greenhouse gas emissions compared to purchased vegetables (Cleveland et al. 2017). However, soil contamination in urban and peri-urban agriculture remains an open issue, and home garden soils are not exempt, as land-use history and surrounding activities may lead to contaminant presence (Pelfrêne et al. 2020). Additionally, in France 10,000 tons of pesticides (representing 8% of national consumption) are used yearly in private gardens (Barrault 2009), meaning gardening practices could also impact the soil quality. Yet, data are lacking to link gardening practices to soil contamination in home gardens.

The citizen science project "La clé du sol" funded by the Fondation de France and coordinated by the evertéa Foundation, involved home gardeners and lead them in discovering their soil and considering how to adapt their practices to preserve its health. This article presents the project's objectives and progress as well as the scientific, social, and educational contributions. It does not focus on the scientific results of the project but rather on the social outcomes and lessons learned, aiming to provide the necessary keys for tackling the challenges inherent in this kind of project, which requires long term participants engagement rather than a one-time sample collection.

"La clé du sol": citizen-science project focused on soils and gardeners

Project objectives

The project "La clé du sol" was a citizen science initiative aimed at gardeners, with both scientific and educational dimensions, fostering soil awareness. By creating new connections between scientists, agronomy students and gardeners the project aimed to i) establish a link between cultivation practices and soil health in vegetable gardens, ii) encourage participants to reflect on the concept of healthy soil using their own gardens as case studies, and propose a set of practices to maintain or improving soil health, and iii) promote environmental stewardship through practice engagement.

The objectives were achieved by conducting out an inventory of non-professional cultivation practices and soil quality analyses, allowing for a comparison of soil health based on three factors: location, composition, and practices. To help gardeners deepen their understanding of soil systems, participatory workshops were organized with all the project stakeholders to interpret the results and translate them into practical recommendations.

Project origin

Since its beginning, the evertéa foundation (formerly the Rovaltain foundation) has been involved in citizen science projects on soils, bringing together farmers, students and local institution from the Drôme territory. The Citizen's Association for Liaison and Study (ACLE) from Mours-Saint-Eusèbe learned about those projects and contacted evertéa foundation to help them implement a similar initiative for local gardeners.

Project stakeholders

The stakeholders involved in the project and their connections are illustrated in Fig. 1.

The project was initiated, managed and coordinated by the evertéa Foundation which assembled a Scientific Committee of academic experts specializing in various fields of soil science including biogeochemistry, microbial ecology, ecotoxicology, biochemistry, agronomy, etc. The six researchers from the Scientific Committee trained gardeners in sampling techniques and assisted in interpreting the results. The local association ACLE (Citizen's Association for Liaison and Study) from Mours-Saint-Eusèbe (France), played a key role in communicating with participants, primarily through direct meetings and local newspapers.

Later, agronomy students from a local agricultural high school (Terre d'horizon in Romans-sur-Isère, France; https://terre-horizon.fr/) were also involved in the project. Their participation was part of their training as they acted as consultants, providing advice on how to interpret standard agronomical data and select appropriate practices.

Finally, home gardeners, residents of Mours-Saint-Eusèbe with a private vegetable garden and experience of gardening, were recruited on a voluntary basis. Seventeen gardeners, most of them newly retired men, initially expressed interest, but three withdrew due to the time and commitment required by the project. Ultimately, 14 gardeners participated. They were involved in soil sampling from their vegetable garden,

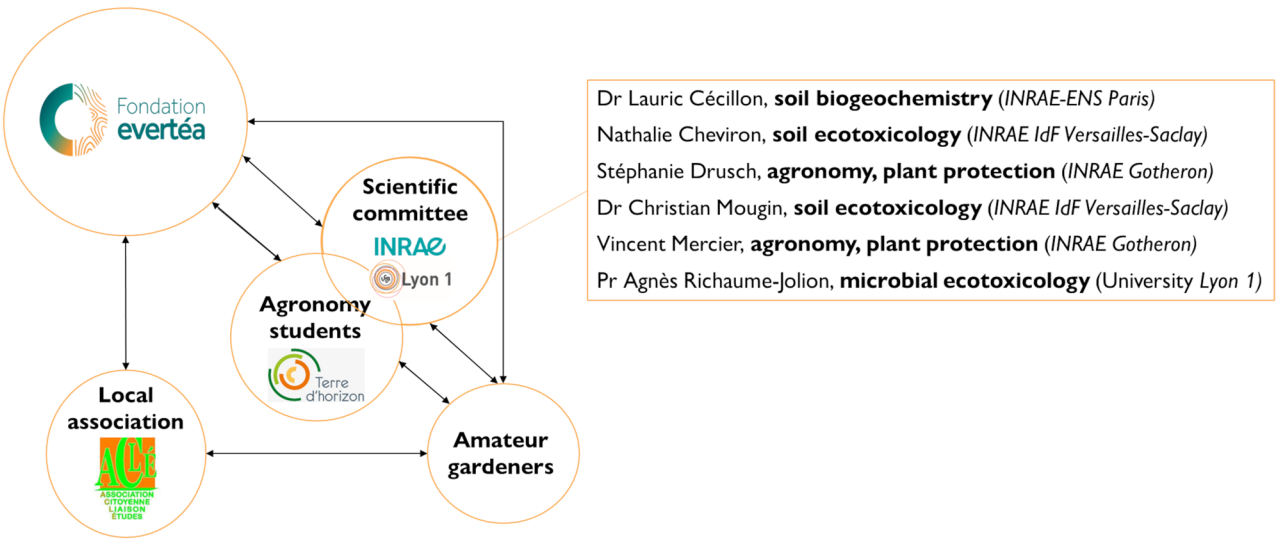


Fig. 1 Stakeholders involved in the project "La clé du sol," and their connections

comparing analysis results, exchanging information about their practices, and researching the local history of the soils.

Project implementation

Before launching the project, a communication campaign was carried out in Mours-Saint-Eusèbe to identify interested and motivated gardeners. The project was officially presented on March 2020 and the final results were shared on June 2022 (Fig. 2).

The project launch coincided with the first lockdown due to the COVID- 19 health crisis in France, so participation initially began remotely. Participants completed a survey about their gardens including details on location, surroundings, and cultivation practices. They then received several documents introducing soil diversity, the complexity of assessing soil health and description of the soil health indicators included in the proposed analyses (1 to 2 pages per indicator) (Fig. 2). The indicators were selected by the scientific committee based on their expertise, ensuring a comprehensive assessment of soil health from biological and physico-chemical perspectives. These indicators provided insights into soil fertility, contamination levels, and overall health. At the end of this phase, the gardeners approved the analysis of all the proposed indicators, including pollutant analysis.

Soil sampling took place at the end of August 2020. During practical training sessions, researchers from the Scientific Committee introduced the sampling equipment (auger, sieve), demonstrated its proper use and cleaning procedures, and trained gardeners in soil sampling protocols. These protocols included mixing samples to obtain a representative composite sample as well as proper sample storage and labeling. Participants were then able to meet in small groups of two or three to independently collect soil samples from their vegetable garden.

The samples were sent to several laboratories for the analysis of most of selected indicators (Fig. 3): physico-chemical parameters, soil organic carbon, microbial biomass, enzymatic activities and pollutants (Cu, Zn, and 234 pesticides).

While waiting for the results of the soil analyses, practical workshops on soil biodiversity were organized where participants performed simple experiments such as the Berlese funnel experiment to extract and observe soil mesofauna (González et al. 2021), pitfall traps to sample surface-active invertebrates (Woodcock 2005) and earthworm extraction using the mustard method following the OPVT protocol (Guernion et al. 2016; Starking and Roloff 2019).

In June 2021, six meetings were organized to interpret and discuss the results obtained from the different analyses. The transversal participation working group model was implemented, following the EPSEAL project (Lees et al. 2022). During this phase, some participants expressed difficulty in understanding the results, finding them too theoretical, as they had expected more practical advice on how to improve their soil.

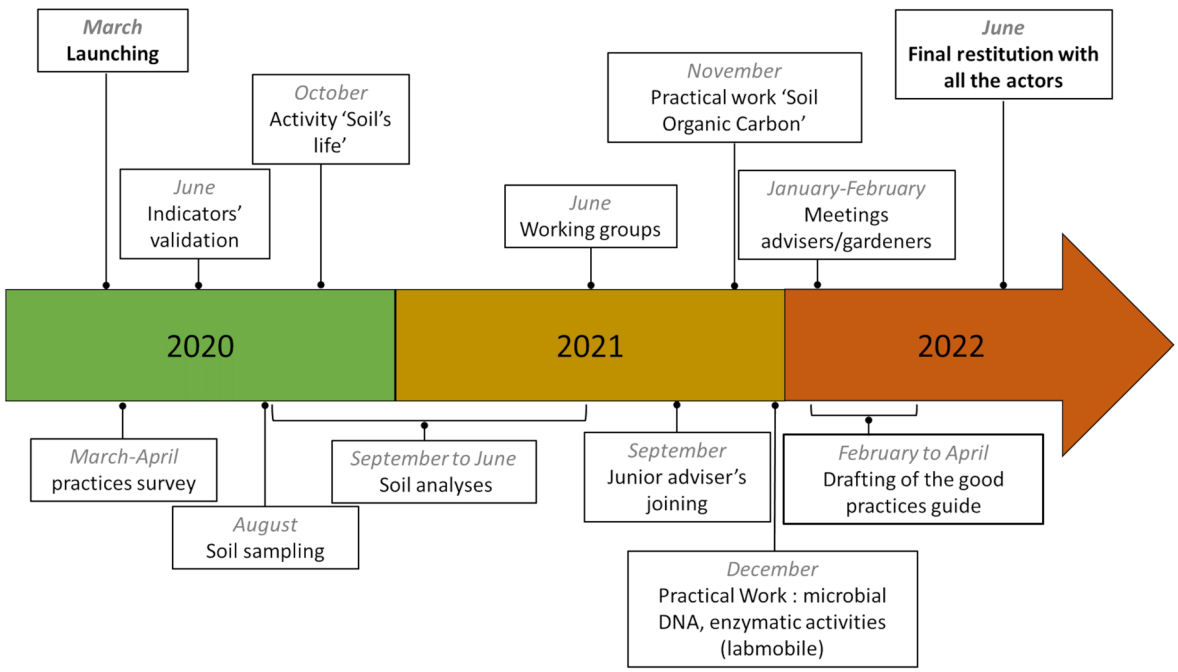


Fig. 2 Course of the project between March 2020 and June 2022

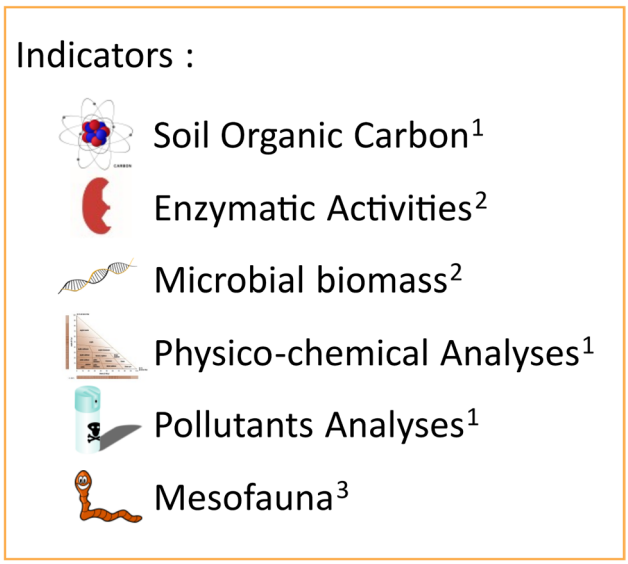


Fig. 3 Soil analyses proposed and validated for the project. The numbers correspond to the analyses performers: 1. analysis laboratory, 2. Agronomy students under the supervision of researchers, 3. Gardeners after presentation of the protocols

In response to the gardeners' questions and requests for practical recommendations, agronomy students joined as junior advisers from September 2021, after being trained by members of the Scientific Committee. This experience allowed them to develop new skills and provide tailored advice based on the results of the soil health indicators. The students worked in pairs, with each group responsible for advising two to three gardeners. At the end of the project, they sent a questionnaire to the researchers and gardeners to assess the project's impact and their personal takeaways from participating in "La clé du sol." For instance, in a questionnaire gardeners were asked to auto assess their soil knowledge before and after the project, and whether what they learned would influence their future practices. However, given the small sample size (14 gardeners and 6 researchers), only general trends could be identified.

Between February and April 2022, the gardeners met for a workshop dedicated to drafting a guide to good practices for the Mours-Saint-Eusèbe's gardeners. Articles for the guide (available online: https://fondationevertea.org/wp-content/uploads/2024/10/Guide-Pratique-Cle-du-Sol.pdf) were written during these workshops. They were later compiled and formatted by the coordinators. The guide was divided into two parts: one describing the town's soils through their geography (geology, relief, climate) and history using old maps, aerial photographs, and personal archives (pictures, memories) of local residents; and a second part presenting advice and practices based on the gardeners' experiences and what they learned during the project.

To conclude, a final (meeting was organized in June 2022. The first part was reserved for the participants (gardeners, scientists, students, coordinators, ACLE members), while the second part was open to the public and local press (around 50 people in total). All participants were able to freely share their feedback, impressions and conclusions about the project.

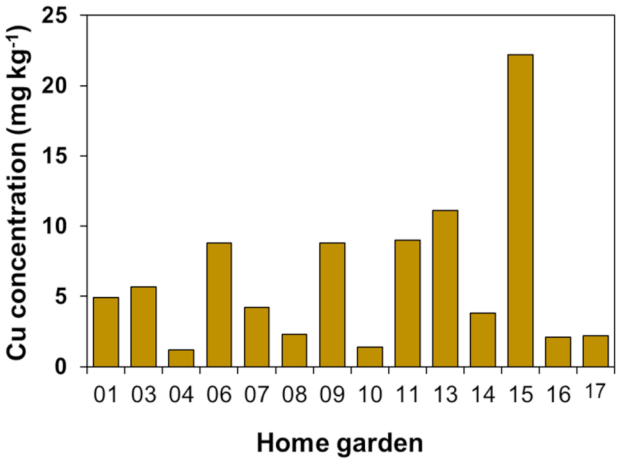
Scientific and social contributions of the project

Scientific contribution of the project

From the beginning, the project was designed to integrate innovative and complementary soil health indicators. The Scientific Committee strongly emphasized the importance of promoting the biological dimension of soils. It was agreed to study soil life using microbial DNA extracted from the soil (i.e. molecular microbial biomass) (Horrigue et al. 2016) and to determine enzymatic activities using the ISO 20130:2018 protocol (Cheviron et al. 2022). Unfortunately, the microbial DNA results were not usable due to problems with the DNA extraction process (defective DNA extraction kits), so these results could not be included in the results discussed with the gardeners.

Despite the geographical proximity, the results highlighted important physico-chemical and biological differences between the gardens. These could be explained by the geological diversity of Mours-Saint-Eusèbe, but also by differences in the practices used by the gardeners and history of each plot. It raised gardeners' awareness of the possible long-term effects of their practices, or past land use on soil health and quality, for instance through the persistence of pesticides, including those approved for organic farming. Indeed, the results highlighted high mobile Cu concentrations (extracted using diethylenetriaminepentaacetic acid (DTPA), AFNOR NF X31 - 121 1993) in the gardens where Bordeaux mixture was regularly applied (Fig. 4a). This is consistent with the Joimel et al. (2021) showing that gardens where Bordeaux Mixture was used had higher Cu concentrations (extracted with $CaCl_2$). However, as the extraction methods differ, it is not possible to compare the concentrations. To the author's knowledge no data on DTPA-Cu on French vegetable gardens are available, but they fall within the lower range of data obtained in vineyard soils treated with Bordeaux mixture in South of France (between 2.7 and 82.1 $mgkg^{-1}$) (Brun et al. 1998). Some pesticides that were already banned in France at the time of the sampling such as DDT (banned in the 1970s) were detected in a few gardens, as analyzed by "la Drôme Laboratoire" (https://www.

a)



b)

Home garden	Concentration in µg kg^{-1} DW			
	Propiconazole	Anthraquinone	4'4'DDE	DDT 44'
01	82			
03				
04				
06			24	
07				
08				
09		25		22
10		38	21	46
11		39	13	21
13				
14				
15				
16				
17				

Fig. 4 Pollutants detected in the studied home gardens: **a**) Copper (DTPA extraction) in mg kg^{-1} dry weight (DW) and **b**) pesticides in µg kg^{-1} DW. For pesticides only the results with concentration over the limit of quantification (QOL) are shown

ladromelaboratoire.fr/) according to an internal method (CMO_MT06; Fig. 4b), highlighting that some pesticides can remain intact in the environment for extended periods. Unfortunately, it was not possible to compare the contaminant concentration with soil maximum limits as these limits are not available for DTPA-Cu and pesticides. This made it difficult to assess the potential risk of cultivating vegetable in soils where contaminants were detected.

Overall, the data collected provided a good overview of the soil health status. However, they also highlighted the difficulty to addressing the project's scientific objective which was to link gardening practices with soil health. The limitation was partly due to the limited number of samples and gardens studied as well as the difficulty in assessing gardening practices as each gardener operates differently and may have changed practices multiple times over time.

Social and educational contribution of the project

The social and educational contributions were assessed by gathering feedback from all participants, i) through discussions during the final restitution, ii) via questionnaires which were designed by the students for the gardeners and researchers and designed by the teachers for the students.

All participants expressed their satisfaction with the exchanges that took place during the working groups, garden meetings and practical workshops. Moreover, the intergenerational dimension of the project, with an average age of over 65 years among the gardeners, proved to be beneficial for the project's development and enrichment. The interaction and social cohesion among the actors in the project were the driving forces behind "La clé du sol." The triangle of scientific experts, advisory experts, local experts, linked together by the coordinators and their representatives, appeared to be central to facilitating the exchange of knowledge.

It came out that students and gardeners appreciated to have access to cutting-edge research knowledge and methods directly from researchers. For their part, the researchers found the experience rewarding and appreciated the opportunity to transfer their knowledge to a non-academic audience.

Overall, from an educational and social point of view the project was a success with gardeners feeling that they had improved their knowledge about soils, biodiversity and practices (results from their self-assessment in the questionnaire). Most of them admitted that the project had changed their view of the soil. They realized that it is a living and more complex system than they initially thought and they learned to "respect" the soil, understanding how easily it can be degraded. As a result, most of them pledged to apply the students' advice in the next season to protect their soils and crops. It seems that the main message retained by the gardeners was the importance of keeping the soil covered, with mulch or green manure, to improve soil health and biodiversity. In their answers, most of them expressed their intention to try applying them in the future. Moreover, research into the history of the gardens for the drafting of the guide added an additional dimension to the project. The gardeners showed great enthusiasm for this historical research, highlighting the particular emotional connection that rural communities can have with local lands and soils. Indeed, this connection is often linked to a family history, echoing the cultural heritage function of the soil as defined by the FAO (FAO 2015b).

The students found it rewarding to use their theoretical knowledge to provide practical solutions for the gardeners. However, they expressed some frustration at not being able

to follow the long-term development of the recommendation they made to the gardeners.

Finally, the final restitution meeting gathered more than just the project participants, highlighting that through communication (local newspaper articles) and word-of-mouth, this kind of project can have a broader reach than just the participants. This demonstrates that there is a strong public interest in such activities and information. It also confirmed that changing the public's perception of soil, which is often viewed merely as a growing medium or even as dirt, depending on one's the relationship with it, is the first step in raising awareness of soil health issues and the importance of preserving it for our future. But the project also raised the importance of giving tools to help adapt the practices.

Challenges and solutions

The project "La clé du sol" was originally planned to last six months but ended up lasting two years. The project faced several challenges that ultimately led to positive developments and enriched the experience.

The main challenge was beyond the project's control, as it was caused by the COVID-19 pandemic. Several lockdowns occurred during the first year, with the first one taking place immediately after the project began. This made coordination difficult, as in-person meetings were prohibited. It was decided not to switch entirely to an online format, as not all the participants had the necessary equipment, and because the meetings were intended not only to be informative but also to foster social interaction. During this period, gardeners were instead asked to complete a detailed questionnaire about their practices and the history of their gardens. At the project's midpoint, during group meetings, some gardeners expressed frustration over the lack of practical, personalized, hand-on advice. To allow participants to voice their needs and expectations for the remainder of the project, one-on-one meetings were organized between the coordinator from the evertéa Foundation and the gardeners. These discussions revealed that most gardeners shared this feeling. As a result, in response to their request, junior advisers were brought into the project. The main lesson learned was that even when a project is co-constructed, it can evolve, and it is essential to listen to the requests of the different actors. The ability to adapt the project therefore seems to be fundamental to the success of citizen science especially when involving long term engagement.

From an organizational perspective, coordinating a project with frequent workshops and regular meetings was challenging, as everyone's schedules had to be taken into account. Some meetings and workshops were therefore held twice to allow the majority of participants to attend.

Another difficulty concerned the scientific results and their practical application for soil improvement. Although the data provided a good overview of the global state of soil health, students found it difficult to use the results directly to formulate specific management strategies for the gardeners. This suggests that action research should be encouraged to better connect data on soil health with sustainable soil management practices at restoring or maintaining soil quality.

Assessment of "La clé du sol" in the citizen science frame

Although citizen science projects increased over the past two decades (Ilhami et al. 2024), there is still no official definition of its methodologies. A classification based on the level of participation was developed (Haklay 2018) and a best practice guidelines were summarized in the10 principles of citizen science published (ECSA—European Citizen Science Association) 2015). Here, the aim is to examine how "La clé du sol" aligns with the classification and the seprinciples.

With the participation of the gardeners and students in data collection and analysis, and to some extent in problem definition, "La clé du sol" lies between levels 3 and 4 for the participation in citizen science, meaning between "participatory science" and "extreme citizen science". In addition, due to the long-term commitment of participants (2 years) and the project's educational goal of raising awareness while requiring support and facilitation, "La clé du sol" can be categorized in terms of engagement and skills as a high-engagement, low-knowledge citizen project.

Finally, the project meets most of the 10 principles of citizen science. By actively involving citizens in multiple stages of scientific endeavor and generating new knowledge and understanding that benefits both citizens and researchers, "La clé du sol" aligns with the first, third and fourth principles. With the publication of the "practical guide for Mours' gardeners," written by the gardeners themselves as well as various workshops to debrief the analyzis results and the final restitution, the fifth and eight principles were met as the gardeners got received feedback from the project and were acknowledged. Due to the sensitivity of the data (private garden location and contaminants), the project coordinators decided not to make it publicly available, thus respecting both the seventh and tenth principles. Finally, with this article, the project is evaluated for its scientific and social impact, aligning with the ninth principle.

Conclusions and perspectives

The main conclusion from the project 'La clé du sol' was that diversity, stakeholders commitment and adaptability are the key for successfully coordinating such a project: diversity of soil health indicators to provide a comprehensive overview of the soil conditions, but also diversity among the stakeholders involved (including social backgrounds, skills, ages, genders) and adaptability to their needs and expectations as well as to unforeseen challenges.

The project highlighted that it is essential to combine theoretical and practical approaches to effectively shift gardeners' perceptions of soil and enhance their understanding of its complexity, while ensuring participants remain engaged and committed through the entire project. It has also demonstrated a strong interest in this topic among the gardening community and showed that even complex scientific concepts can be effectively conveyed. The potential impact of this type of audience on maintaining healthy soils should not be underestimated. Indeed, by targeting home gardeners, it is possible to reach people who are not professional soil users and therefore do not typically have access to traditional soil science or agricultural projects. Although it is gradually changing with the development of citizen science projects worldwide (Pino et al. 2022), initiatives where citizens, particularly gardeners, are in direct contact with researchers, carry out their own experiments, and/or discuss their own results, as "La clé du sol" remain relatively rare. This was possible only because "La clé du sol" was a small-scale pilot project, involving a limited number of gardeners from a specific area. in contrast, other citizen science projects involving gardeners have focused on national territories and have consequently been conducted primarily online via surveys, such as the Portuguese project "In my backyard," or have required citizens only to collect and send samples such as the projects "Microbelix" in Germany (www.microbelix.de), "Vegesafe" in Australia (Taylor et al. 2021) and "Earthworm watch" in the UK (Burton et al. 2024). While all these projects aimed to gather data from private areas that are usually inaccessible, the main goal of "La clé du sol" was to bring soil knowledge directly into home gardens. In this context, the project illustrates that measuring soil health alone is not enough to foster awareness and stewardship, a key factor is the facilitation and coordination provided by the project team. Expanding the project while maintaining the same framework could allow for the collection of additional data on soil health and the impact of gardening practices in these understudied areas. A next step could involve implementing the project in a larger city, potentially engaging a broader and more diverse population of gardeners, compared to the current project where participants were mostly men over the age of 60.

Achieving nationwide data collection could also be considered in order to completement existing databases on soil contaminations in agricultural, forested or protected areas, such as the French soil database "Gissol" which compiles information on French soils. However, this would likely result in the loss of the direct dialogue between researchers and gardeners, which was one of the project main strength. Nonetheless, involving a new generation of soil advisors, as promoted by the EU Mission 'A Soil Deal for Europe' and initiatives linked to it such as Benchmark (https://soilhealthbenchmarks.eu/), PrepSoil (https://prepsoil.eu/) or ECHO (https://echosoil.eu/), could help enhance soil awareness and stewardship among citizens. To achieve this, in addition to regular training sessions organized locally across the country, developing a standardized soil health kit, with easy-to-use protocols and build on commercially available soil analysis kits could be a way to collect data nationally while promoting soil health to more gardeners and potentially all citizens. The kit could include protocols, based on commercially available soil analysis kits, could be an effective way to collect data on a national scale while promoting soil health to a wider audience, including gardeners and potentially the general public. The kit could include detailed protocols, basic chemicals and guidelines for interpretating results related to key soil health parameters, such as soil aggregate stability, pH, organic matter content, major nutrients content, invertebrate biodiversity.

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Author contribution Conceptualization: WS, EE, DD and MB; Data curation: MB, DD, LC, CM, SD, NC, VM; Funding acquisition: DD, WS, EE; Supervision: DD, MB; Inverstigation: MB, LC, NC, SD, CM, VM, AR; Visualization: MCA, MB; *Methodology: MB, NC, SD, CM, VM, AR; Writing – original draft: MB,* MCA; *Project administration: MB, DD; Writing – review and editing: LC, NC, SD, CM, VM, AR, DD, MCA, WS, EE.*

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Declarations

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Consent to participate Not applicable.

Consent to publish Not applicable.

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