Engaging Communities with Farming through Data-Driven Soil Stories

Sebastian Prost
Department of Computer Science
City St George's, University of London
London, UK
sebastian.prost@citystgeorges.ac.uk

Nick Taylor
Open Lab
Newcastle University
Newcastle upon Tyne, UK
nick.taylor@newcastle.ac.uk

Jon Rogers
School of Design
Northumbria University
Newcastle upon Tyne, UK
jon.rogers@northumbria.ac.uk

Abstract*—Telling stories about eco-friendly farming can be an effective way of engaging non-farming audiences with farm life. However, most stories are anecdotal, while scientific data can be unengaging for laypeople. Farm Stories is a research-through-design project to create a decentralized mesh network of distributed sensors and an internet-connected processing and story-generating hub. Building on the pegBits platform, it enables farmers to deploy their own soil sensor devices across the farm, connect them to the hub, which uses generative AI to turn sensor data into stories, and share these stories about their soil with others. The research project aims to investigate possibilities and limitations for 1) farmers to engage in low-threshold physical prototyping using pegBits; 2) expanding the pegBits platform into outdoor environments; and 3) using soil data and generative AI for public engagement and advocacy.

I. INTRODUCTION

Digital agriculture involves a wide range of digital tools for farm management, planning, monitoring, decision-making, and automation. While these technologies promise to improve efficiency, productivity, and sustainability of farms, most such technologies are proprietary and costly, locking small-scale farmers into intellectual property right agreements, service contracts, and subscriptions [4]. Digitalisation in agriculture thus runs risk of further driving land and power concentration in an already very uneven industry.

Soil Stories is a research-through-design project building on prior fieldwork with agroecological farmers in Northern England [8]. Agroecology is a whole-system approach to farming that works with nature rather than against it. It includes approaches such organic, regenerative, or permaculture. This research provided key insights in relation to digital technology:

- Farmers value experiencing and working in nature. Digital tools should not diminish but enrich this experience. Appropriateness of any farm technology is a key consideration.
- Farmers value autonomy and strive to minimise external inputs and dependencies. This includes not only things like seeds and fertilisers, but also digital tools.
- Farmers face significant financial constraints, making it difficult to purchase modern digital technologies.
- Technological literacy is low, especially among older farmers (the average age of a UK farmer is 59).

Consequently, agroecological farmers make very selective use of digital technology.

Following the interviews, we developed these (and other) insights into speculative design probes. Probes exist in many forms but are generally a set of artefacts that invite participants to respond. They are a "playful, subjective and subversive approach to conducting user research" [2]. Our probes were sent to farmers in the form of hand-printed seed packets, each containing a description and illustration of a near-or-far-future technology and prompts to respond to in writing, drawing, by recording audio. The responses to these ideas were then discussed in two workshops in November 2024.

Fig. 1. The probe pack sent to farmers

One of the probes centred on data collection. While some farmers said they can sense more with their own eyes, ears, nose, and hands, they also acknowledged that data is important to provide evidence about the ecological benefits of their type of farming, to advocate for policy change, to strengthen funding applications, and to engage local and urban communities with the farm. This prompted us to envision a fantastical device – the *Soil Story Teller* (see Fig. 2). Its description read: "In the year 2051, the Soil Story Teller takes advanced soil measurements and turns them into stories about the soil as a living organism. Just stick it into the ground and it tells you a story about what's going on underground. Gather round and listen or share them to wider audiences." This paper outlines our plans to turn the design probe into a technology probe [5] – developing the paper probe into a working prototype of a device to facilitate critical reflection on the opportunities and threats of digital sensing, physical computing, and generative AI for technological sovereignty, community engagement, and advocacy of farms.


-- Soil Story Teller, 2051 --

Soil Story Teller

In the year 2051, the Soil Story Teller takes advanced soil measurements and turns them into stories about the soil as a living organism. Just stick it into the ground and it tells you a story about what's going on underground. Gather round and listen or share them to wider audiences.

Together with others on your farm, your task is to give the story teller prompts for 2 stories you want it to tell.

1. Peel back the protective layer from the double-sided tape. Use the sticky patch to take a sample of your soil.

2. Discuss the story prompts and fill in the blanks on each card (title, audience, mood, genre etc.).

3. Snap a quick photo of your completed story prompt and share it with Sebastian via WhatsApp or e-mail. Then put it back into the seed packet.

sebastian.prost@northumbria.ac.uk
07565 038782

Fig. 2. One of the design probes presents the Soil Story Teller design fiction through an illustration and text, and asking farmers to respond.

II. Related work

On-farm soil testing is a common activity to understand soil fertility, choose suitable crops, or improve soil quality. Accurate soil testing can be a complex and expensive endeavour, and methods vary hugely, from manual and visual methods (e.g. Soilmentor [11]) to lab analysis of core samples [7]. There are also various self-testing kits available, which allow simple tests on the farm.

Digital sensing is increasingly deployed and make data available to farmers via digital dashboards. However, such data is typically locked into proprietary platforms [10]. Traditionally, farmers have often built, maintained, and repaired their own tools. While proprietary systems, intellectual property rights, and authorised service contracts make this harder [4], alternative movements have sprung up that combine farmers' DIY ethos with principles of the maker, open-source, and open-hardware communities. Farm Hack is a grassroots open-source tool library for farmers to share and build their own tools, from simple hand tools to autonomous tractors [1]. Platforms like *Instructables* and *Thingiverse* also contain many farm-related design blueprints. Likewise, open farm data storage and planning tools, such as farmOS, exist as alternatives to commercial solutions [3]. However, these initiatives remain niches that are inaccessible for farmers without skills in programming and digital manufacturing [9].

The purpose of the Soil Stories project is to explore the middle ground between commercial off-the-shelf tools and coding and building one's own digital agricultural tools.

We intend to develop our prototype using pegBits [6], an emerging prototyping platform that presents such a middle ground. PegBits take the standard 0.1" spacing found on breadboards and extends it into 3D space. Inspired by block-based systems such as Lego or Meccano, it allows rapid prototyping of custom physical devices and enclosures (with deliberate constraints), avoiding novices needing to know CAD or 3D printing (see Fig. 3). However, pegBits are experimental and not tested with lay audiences. Furthermore, they have been designed for an indoor environment, requiring adaptations for the outdoors.

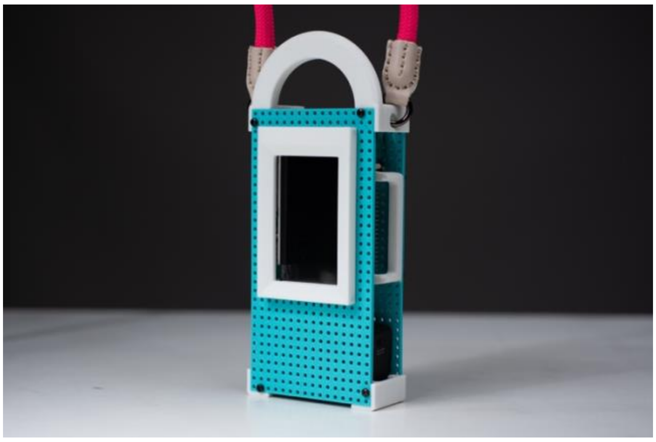

Fig. 3. Example of a pegBits device

Building on this existing work, the first aim of this project is to investigate how farmers could use pegBits to build their own soil sensor components. The second aim is to explore what adaptations pegBits needs to work in an outdoor environment (exposure to rain, heat, and humidity).

Beyond data collection, interpreting and responding to insights gained from sensor data remains a challenging task for farmers. For community-based farms, a particular challenge is to translate sensor data into engaging communication for lay audiences. While the focus of this paper and the goal for the summer school is on the collection and transmission of sensor data, the third aim of the Soil Stories project will be to explore the use of AI to turn sensor data into engaging stories for diverse audiences.

III. Imagined prototype

We imagine the Soil Stories system to consist of a variable set of distributed sensor devices and a Raspberry Pi-powered hub (see Fig. 4 for a schematic overview).

A. *Sensor Devices*

This will include both established and more experimental digital sensors to collect data of physical, chemical, and biological soil health indicators. Possible physical indicators include temperature, humidity, and density (using a penetrometer). Chemical indicators include pH, electrical conductivity, nutrient and carbon levels (using a near-infrared (NIR) spectrometer). Biological indicators include soil respiration (using a CO_2 sensor) and earthworm count (using a geophone). The selection of sensors will be up to the farmer and can be expanded as new sensors become available.

Sensors will be deployed throughout the farm as needed to give a comprehensive picture. As we cannot rely on power supply or batteries in remote locations, they would ideally be solar-powered. For similar reasons, we cannot expect a WiFi or mobile data connection to be available. Therefore, the sensor devices will send data to hub via the LoRa using (for example) the open-source Meshtastic community project [6].

B. *The Hub*

The hub will be based in an indoor environment, such as the farmhouse or a shed. While mains power and Wifi are possible, they are also not guaranteed, so solar power and a mobile data connection should be foreseen as options.

The hub houses a Raspberry Pi that connects to the Internet. It receives sensor data via the LoRa network. It also contains three simple physical dials that allow the user to set certain story parameters: 1) genre (e.g., comedy, drama, tragedy, horror, etc.) 2) audience (e.g., children, general public, farmers, politicians, planners, etc.) 3) the star of the story (e.g., earthworms, microbes, bugs, trees, fungi, humans, etc.).

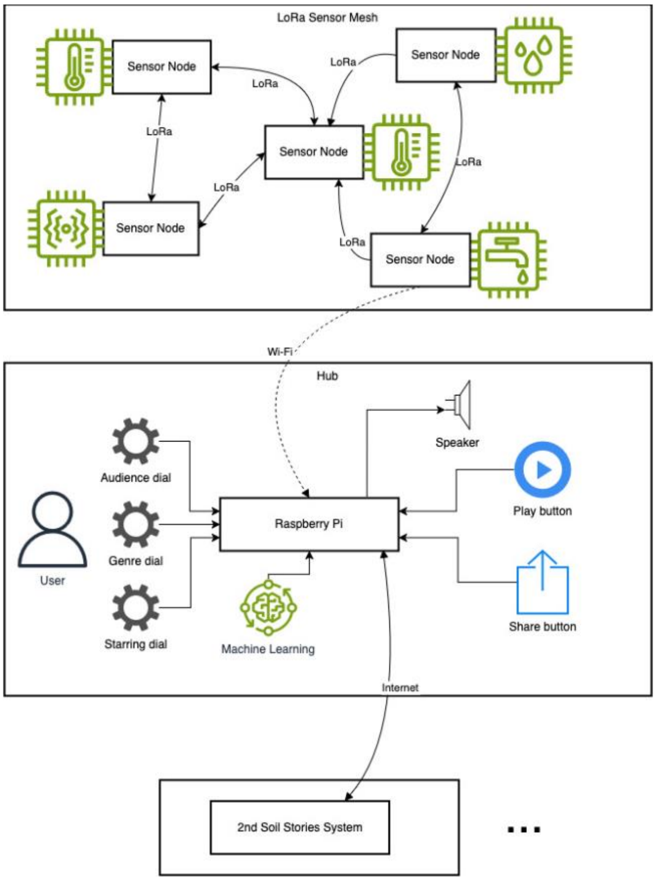

Fig. 4. A schematic overview of the Soil Stories system.

The story generation is yet to be defined in detail and not the focus of this paper, but for the sake of completeness briefly sketched out here. The Raspberry Pi will include an AI HAT+ and eventually run an on-device ML (such as tinyML) to classify sensor data. To generate stories, we will (for now) rely on off-device LLMs due to the limited computing capacity of a Raspberry Pi. The LLM generates data-driven stories about what goes on underground. Once a day, stories are read out through a built-in speaker. Stories can be re-played and shared on social media via dedicated buttons on the hub. If multiple hubs are deployed, stories from other hubs are also shared among the hubs. The hub then selects one of the available stories to playback, indicating where the story comes from.

C. *Enclosures*

We imagine sensor devices and hub to be kits-of-parts that can be assembled by farmers themselves using pegBits blocks. The pegBits system will allow them to use ready-made elements to build a custom-sized box to house the electronics components. For now, the outdoor sensor device will need to be placed in an additional water and dust-sealed project box, but we also want to explore sealed pegBits options.

IV. Responsible Innovation

This research project contributes to responsible innovation in two ways. First, as a prototyping project, it seeks to develop alternative approaches to the *un*responsible innovation seen in commercial agri-tech. We seek to empower agroecological farmers to gain technological sovereignty – their right to determine what technologies are considered appropriate in agriculture – analogue to how they fight for food sovereignty, their right to determine what and how food is grown appropriately. Or, in other words, we aim to give farmers the same level of gatekeeping of their data, as they already have over their livestock. It contributes to digital skills and literacy to not only assess existing technologies but also conceive of new technologies that serve their needs rather than those of technology corporations.

Second, as a research-through-design project, it seeks to facilitate critical discussion around the use of digital sensing, machine learning, and generative AI on farms. It deliberately avoids the common technological trend to use AI to support or automate decision-making. It opens a design space for alternative uses of digital sensing and AI – for community engagement and advocacy. Yet, to be clear, we do not necessarily advocate for Soil Stories as a solution or product. It is critical design prototype to engage farmers shared knowledge production on digital farming.

V. Author Bios and Experiences

Sebastian Prost is a Lecturer in the Centre for Human-Computer Interaction Design at City St George's, University of London. He has developed a critical research agenda at the intersection of food and technology, exploring socio-digital innovation to support local food networks and smallholder farms (e.g. [8]). He has published in leading HCI venues, including CHI, CSCW, and DIS. He is motivated to turn the creative visions developed in his research into tangible prototypes. He hopes to further develop his skills in physical prototyping and making at the summer school.

Nick Taylor is a Senior Lecturer in Open Lab at Newcastle University. He has a long-held interest in using technologies to support communities and especially in empowering communities to harness technology through maker/DIY approaches, often including physical computing and IoT.

Jon Rogers is a Professor of Creative Technology in the school of design at Northumbria University. He has been making (and breaking) things that explore the health of the relationship between people and the internet for over 30 years. Most recently he has developed pegBits [9] as a system for prototyping open hardware in hopefully more accessible way.

VI. Acknowledgements

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