Smart Farmging gGmbH

Activity Report 2024 – with updates through September 2025

This activity report documents the work of Smart Farming gGmbH in 2024. To provide a transparent picture of our current progress, it also includes key developments up to September 2025. For formal reporting to authorities and the tax office, the Activity Report 2024 (01.01.–31.12.2024) remains valid. The present version is intended primarily to inform our supporters, partner organizations, and interested stakeholders.

The experiences and insights gained from the visits to India in 2023 have highlighted the great need for practical tools for smallholder farmers. A soil monitoring system can play a key role in this by providing precise data for targeted irrigation and fertilization, thus improving soil quality, yields, and biodiversity. Against this backdrop, the goals and activities of Smart Farming gGmbH will be clarified.

Objectives and activities

Smart Farming gGmbH aims to support **smallholder farmers** in the Global South. They play a key role in times of climate change, crop uncertainty, and rising costs. Their work makes a crucial contribution to preserving our livelihoods.

Studies clearly show: **Regenerative agriculture**, as practiced or revived by smallholder farmers in many places, is the most effective way to preserve and expand the humus layer, one of the Earth's **largest carbon stores**. Healthy, humus-rich soil not only stores many times more carbon, but also ensures greater water retention capacity, improved soil fertility, and increased biodiversity. Smallholder farmers thus make an indispensable contribution to both food security and global climate protection.

To leverage this potential, Smart Farming gGmbH is developing a **soil monitoring device**. This device enables the regular measurement of the soil's key parameters such as nutrients, moisture, pH, and temperature. The data obtained provides smallholder farmers with a basis for targeted decisions: when and how to irrigate or fertilize – all while using as few resources as possible.

The Soil-Monitoring-Device is intended to become a **practical tool** that enables smallholder farmers to manage their fields more sustainably, stabilize their yields, and simultaneously improve soil quality in the long term. The goal is to design technological support in such a way that it belongs to the farmers, can be understood, and further developed by them – an approach that strengthens their independence and recognizes their role in society as custodians of the soil and the humus layer.

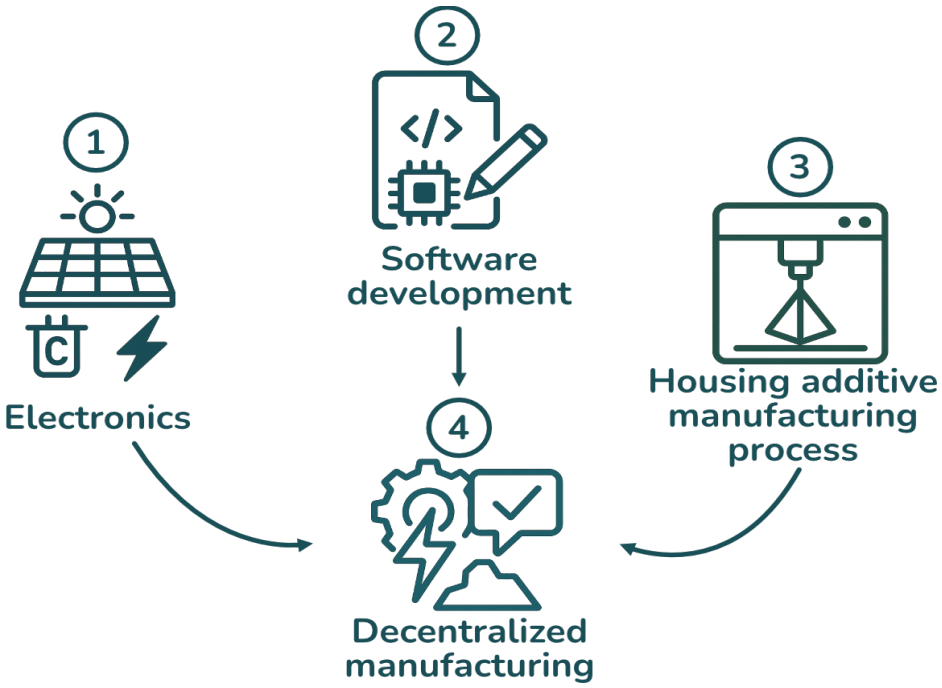
Challenges

The first step involved developing a detailed concept. This involved systematically analyzing the requirements for a soil monitoring system: energy self-sufficiency through solar cells, robust construction for field use, ease of use, and flexible deployment in different countries.

The following points were particularly important in this regard:

1. **Development of electronics** for a stable, self-sufficient power supply, standard interfaces for sensors, and a versatile open communication platform.
2. **Development of free** software for use in the cloud and for microcontrollers. Use of exclusively freely available development tools.
3. **Design of a housing** suitable for countries with different climatic conditions.
4. **Decentralized manufacturing** as a goal, so that devices can be produced and maintained directly on site.

Addressing these issues was time-consuming, but crucial for practical applicability.



4-point requirements for the soil monitoring device

From Concept to Practice

1. Electronics

1.1. Technical Requirements

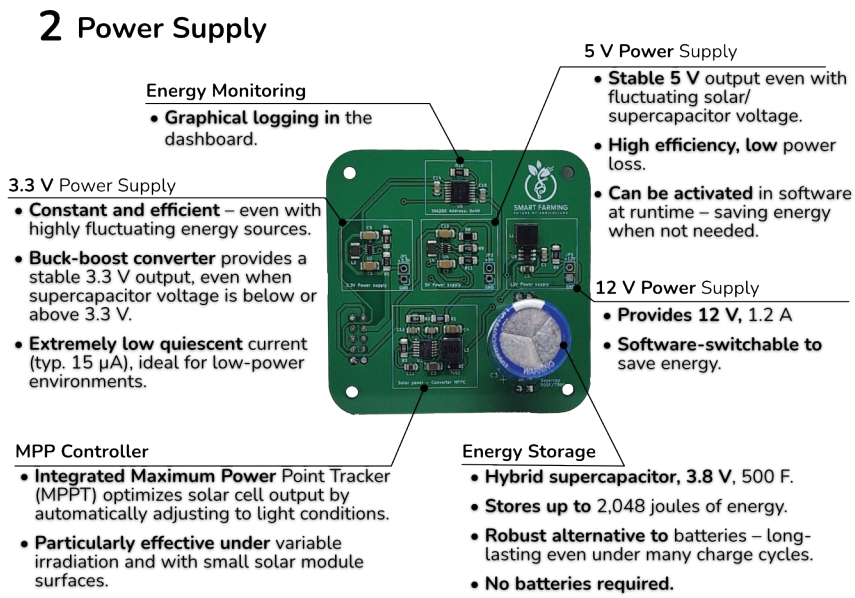
a) Power supply without batteries,

b) Stable voltage regulation for different supply voltages,

c) Multiple wireless connectivity options: GSM, LoRa, WiFi.

1.2. **Power Supply Without** Batteries

The electronics were designed so that the Soil Monitoring Device can operate autonomously with solar cells and supercapacitors – without batteries. A special charge controller with a Maximum Power Point Tracker (MPPT) ensures optimal energy yield. The power supply was designed to be flexible, providing stable 3.3 V, 5 V, and 12 V for different sensors and modules.



1.3. **Variety of Interfaces** for Sensors: I²C, SPI, Modbus

The circuit board provides three key interfaces for connecting sensors. With I²C, SPI, and Modbus, the Soil-Monitoring-Device covers the full range of sensor options: from small, low-cost sensors to powerful expansion modules and robust industrial field sensors.

a) This makes the system:

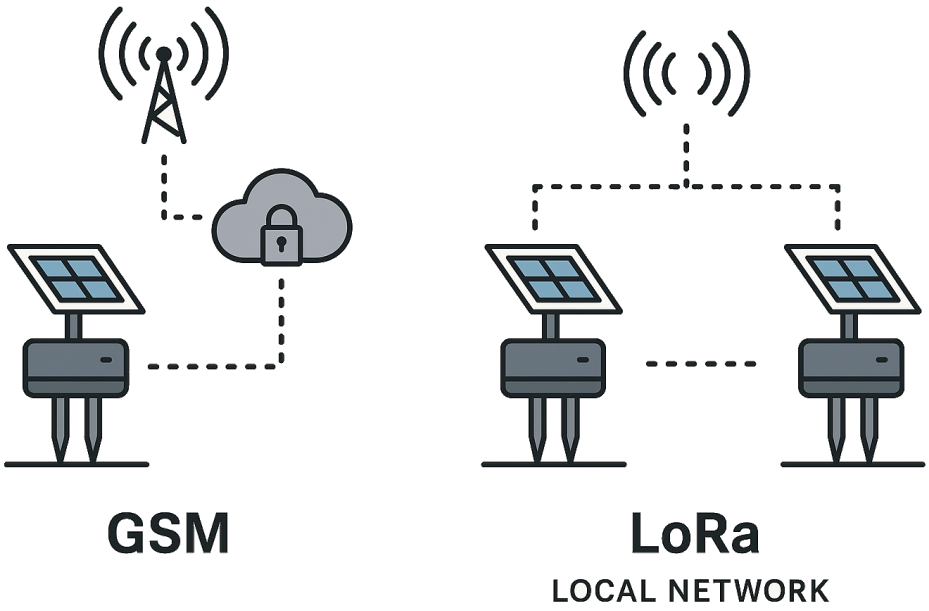
- modular – different sensors can be flexibly combined,
- future-proof – even future sensors and extensions can be integrated,

- practical – it adapts to field conditions, from research environments to the daily reality of smallholder farmers.

1.4. Communication Technology

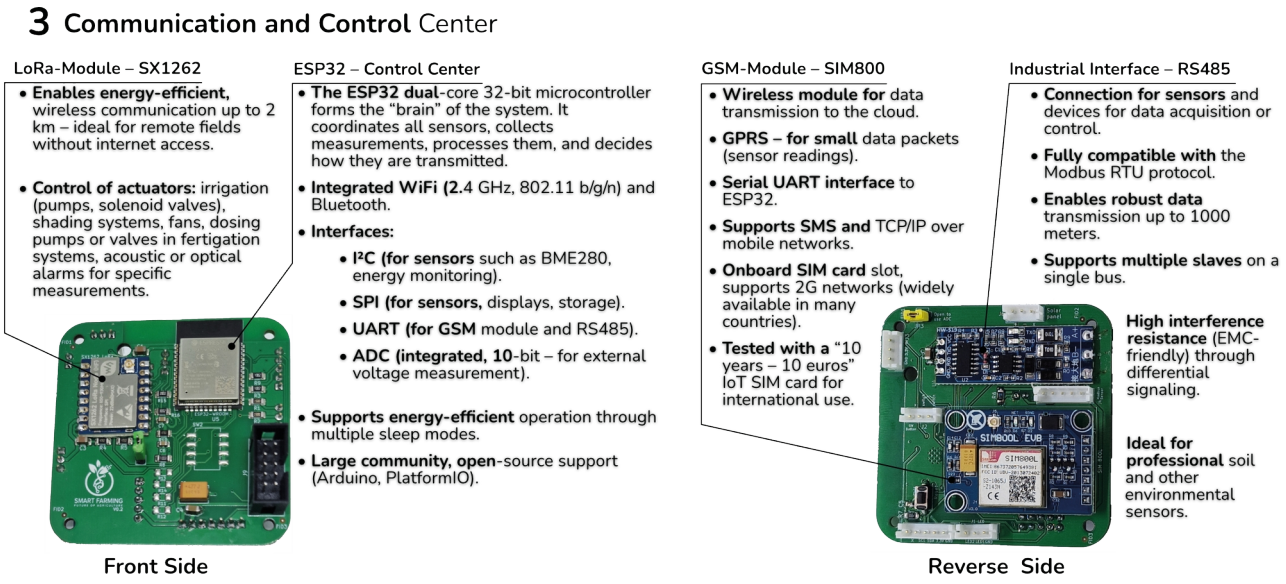
Another important aspect is communication technology: In addition to **GSM** with **SIM** card, **LoRa** (Long-Range Wide-Area Network) has been integrated into the hardware from the start, enabling **wireless connections of up to 2 km**. With the SX1260 module, **all frequencies** permitted in different countries are covered. This makes the Soil-Monitoring-Device usable even in regions without GSM coverage.

In the long term, this opens the possibility of building an **internet-independent** local LoRa network that connects several sensor nodes and a local web server.



Communication with cloud web server via GSM or via LoRa with local web server

To reduce hardware costs, individual modules (GSM, LoRa, Modbus) that are not required can simply remain unassembled on the circuit board.



***Design plans for** housings and circuit boards are freely available under the Open Hardware License (CERN-OHL).*

Control and communication unit of the Soil Monitoring Device

Development Tools

For circuit design, PCB layout, and routing, the **open-source software KiCAD** was used.

2. **Software Development** for Cloud & Microcontroller

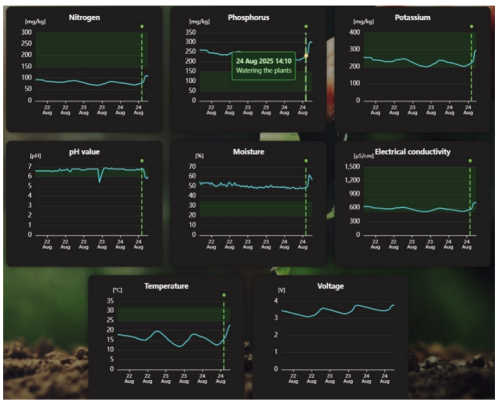
Parallel to hardware development, intensive work was carried out on the software. A key outcome was the creation of a secure cloud platform enabling encrypted data transfer and analysis of measurement values. The software was developed along two tracks.

2.1. Cloud-Plattform: A **database concept** was created that allows online configuration of **sensor nodes** connected to the Soil-Monitoring-Device. Sensors can be assigned to individual fields, **crop types**, or **soil textures**, enabling differentiated evaluation of the data.

2.2. Visualization and Analysis: Measurement values are visualized graphically and can be accessed from anywhere with internet access. This creates a flexible tool for farmers, researchers, and organizations to monitor and analyze soil data.



Current readings



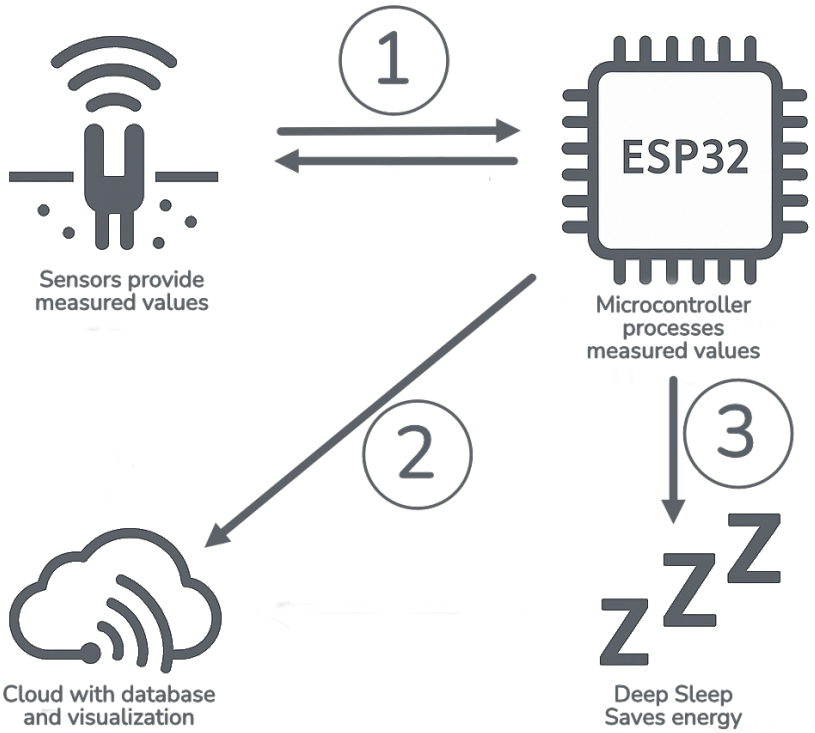
Line charts for historical values

2.3. Programming the Microcontroller

Programming the ESP32 microcontroller was a key part of the work in 2024. The aim was to ensure that the device could be operated autonomously, flexibly, and securely.

- **Energy optimization**: The ESP32 was programmed to remain in deep-sleep mode most of the time and only wake up for measurement and data transmission. This makes it possible to reliably operate the Soil-Monitoring-Device with solar energy and supercapacitors – completely without batteries.
- **Modular architecture**: The software is modular. Different sensors with interfaces such as I²C, SPI, and Modbus can be integrated via drivers. This allows quick adaptation to regional conditions and new sensors.
- **Secure communication**: AES encryption is used for data transfer, ensuring the confidentiality of the collected measurement data. Supported transmission paths include GSM, WiFi, and LoRa.

- **Time management**: By regularly synchronizing with the server, the ESP32 ensures that measurements are stored with precise timestamps – a central prerequisite for analysis and comparisons.



***1** Measurement & Processing · **2** Storage & Visualization · **3** Energy Saving*

- **Open development environment**: Only open-source tools are used for programming, particularly PlatformIO and C++ for the microcontroller, and PHP, ECharts, HTML, and JavaScript for the cloud platform. The source code will be **openly documented** after release, ensuring it is transparent, adaptable, and extendable.

Thus, programming the microcontroller forms the **technical heart** of the Soil-Monitoring-Device, linking the developed electronics with the cloud platform into a functional overall system.

3. Housing

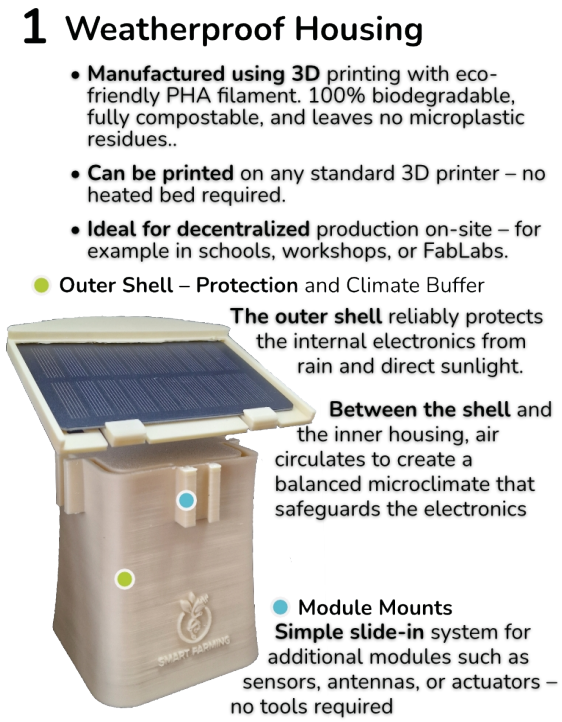
3.1. Two-Layer Design

The housing was another major focus in 2024. A **two-layer** design was created: an inner housing protects the electronics, while an outer shell provides additional weather protection and regulated air circulation.

In **decentralized** 3D-printing trials, eco-friendly, compostable materials without microplastic residues (PHA filament) were tested. These materials also met the requirements for high stability and durability in field use.

3.2. Open Tools

In all development phases, it was decided to use only **open-source tools**. For housing design, **FreeCAD** was employed.



Housing with 3D printing and compostable material, without microplastic residues.

4. Decentralized Manufacturing

A central element of the concept is the possibility of manufacturing the Soil Monitoring Device **decentrally**. This decision has far-reaching benefits that extend well beyond the purely technical domain:

4.1. Knowledge and Opportunities in Rural Areas
Local production builds know-how in rural regions. Young people gain practical skills in electronics, software, and 3D printing. This knowledge remains within communities, opening new perspectives and reducing rural-to-urban migration.

4.2. Local Value Creation and Service
Transport routes are shortened or eliminated, as devices and spare parts can be produced locally. Support and service are directly available nearby. This creates a local, independent ecosystem that meets the needs of the community – without dependence on large corporations.

4.3. Adaptability and Custom Solutions
Local manufacturing allows devices to be more easily tailored to specific conditions – such as climate, field sizes, or preferred crops.

4.4. Sustainability and Resource Efficiency
Decentralized production avoids long supply chains and reduces the ecological footprint. Regional materials can be used, and 3D printing enables resource-efficient manufacturing with minimal waste.

4.5. Strengthening Community and Self-Determination
Communities gain the ability to control and further develop their own technology. This fosters independence and self-determination among smallholder farmers, making the technology a part of the community rather than a product imposed from outside.

4.6. Resilience and Crisis Resistance
In times of disrupted supply chains (e.g. pandemics, geopolitical conflicts), decentralized manufacturing ensures greater resilience. Devices and spare parts can be produced even when international supply routes are blocked.

Thus, **decentralized** manufacturing becomes not just a technical advantage but a **strategic key** for sustainable development and social stability.

Summary

The progress made in 2024 laid a decisive foundation for deploying the Soil-Monitoring-Device in practical use in the coming years, providing smallholder farmers worldwide with an **open, sustainable technology**. The Soil-Monitoring-Device is more than just a technical tool. It is designed to foster agriculture that works in harmony with natural cycles – preserving and regenerating soil instead of exhausting it.

Through precise data, smallholder farmers can manage their fields so that nutrients, water, and energy are used efficiently and responsibly. This improves soil fertility, increases yields, and simultaneously strengthens biodiversity.

The Soil-Monitoring-Device thus supports the transition to a **resilient**, **regenerative agriculture** that safeguards the livelihoods of future generations and makes an active contribution to climate protection.

Our **heartfelt thanks to all supporters** who helped us in **2024**.

Senden, 20. Dec. 2024

Achim Giebler, Geschäftsführer