Cattle-based Manure Management System for Soil Fertilization

Team Cattle Can Help

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Agenda

1. Problem Statement
2. Solution
3. Methodology
    - Wiring Diagram
    - System Architecture
4. Experiment
5. Conclusion and Future Plan

1

Problem Statement

Problem Statement

Farmers around the world

In Indiana,
more than

80%

of the land is used as
Farms and Forests

*https://www.in.gov/isda/

Problem Statement

Farmers' tasks cannot be done without..

Constant care and attention

Agricultural Expertise

Time-Intensive Menial Labor

Problem Statement

Manure Management

Collecting Manure Everyday

Pollution

Health Problems

Distributing Manure Evenly

Soil Fertilization Process

Problem Statement

Manure Management

Collecting Manure Everyday

Distributing Manure Evenly

UNTIL NOW.

Pollution

Health Problems

Soil Fertilization Process

2

Solution

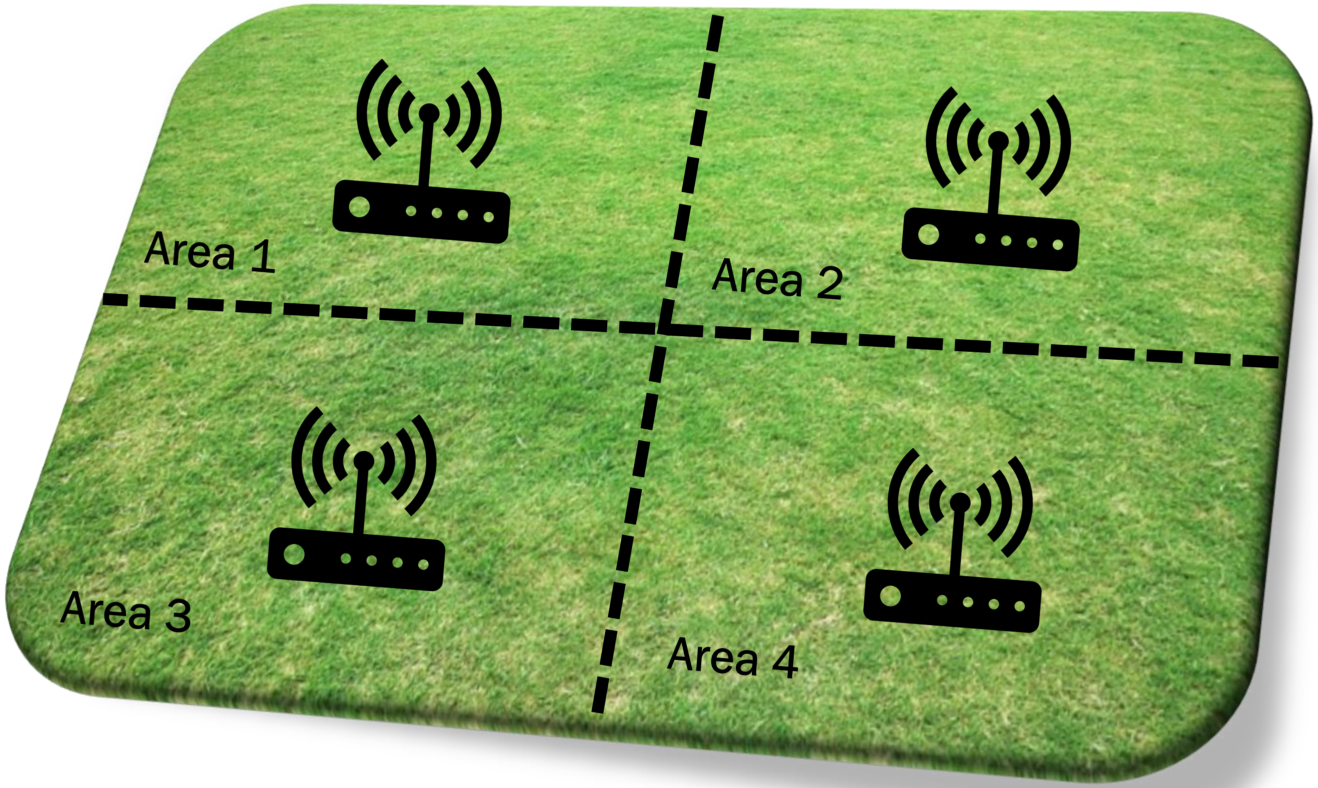
Our Solution

What if cows go poop in low nutrient areas?

‘ Is it possible?’

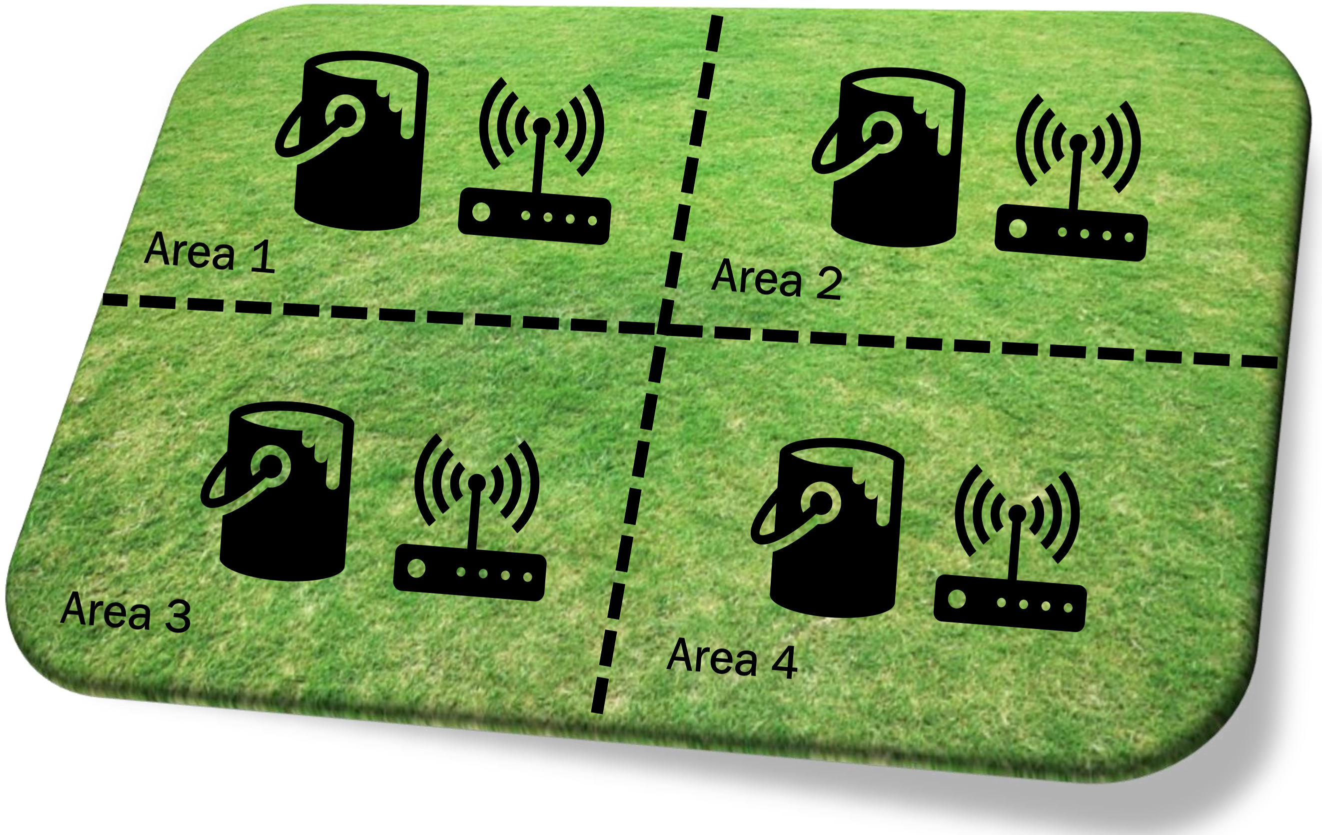
Our Solution

Soil Nutrient Sensors



Our Solution

Soil Nutrient Sensors & Feeders



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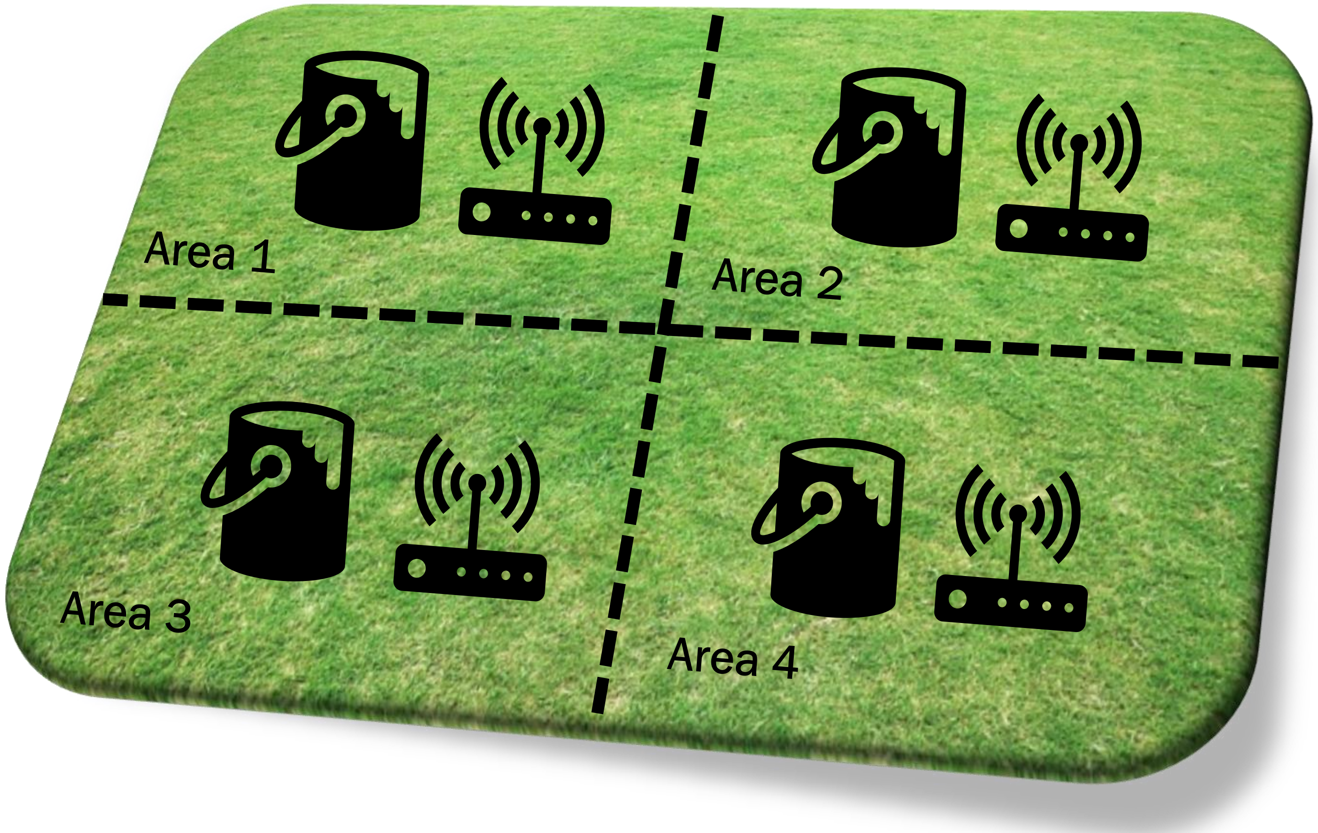
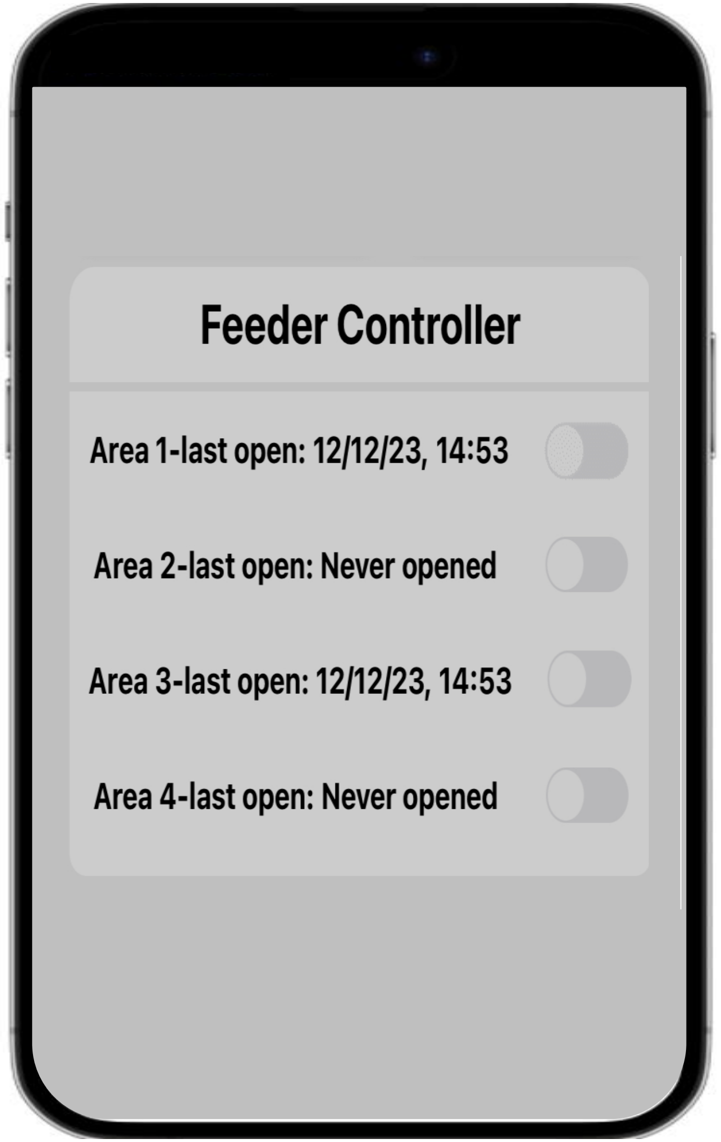
Our Solution

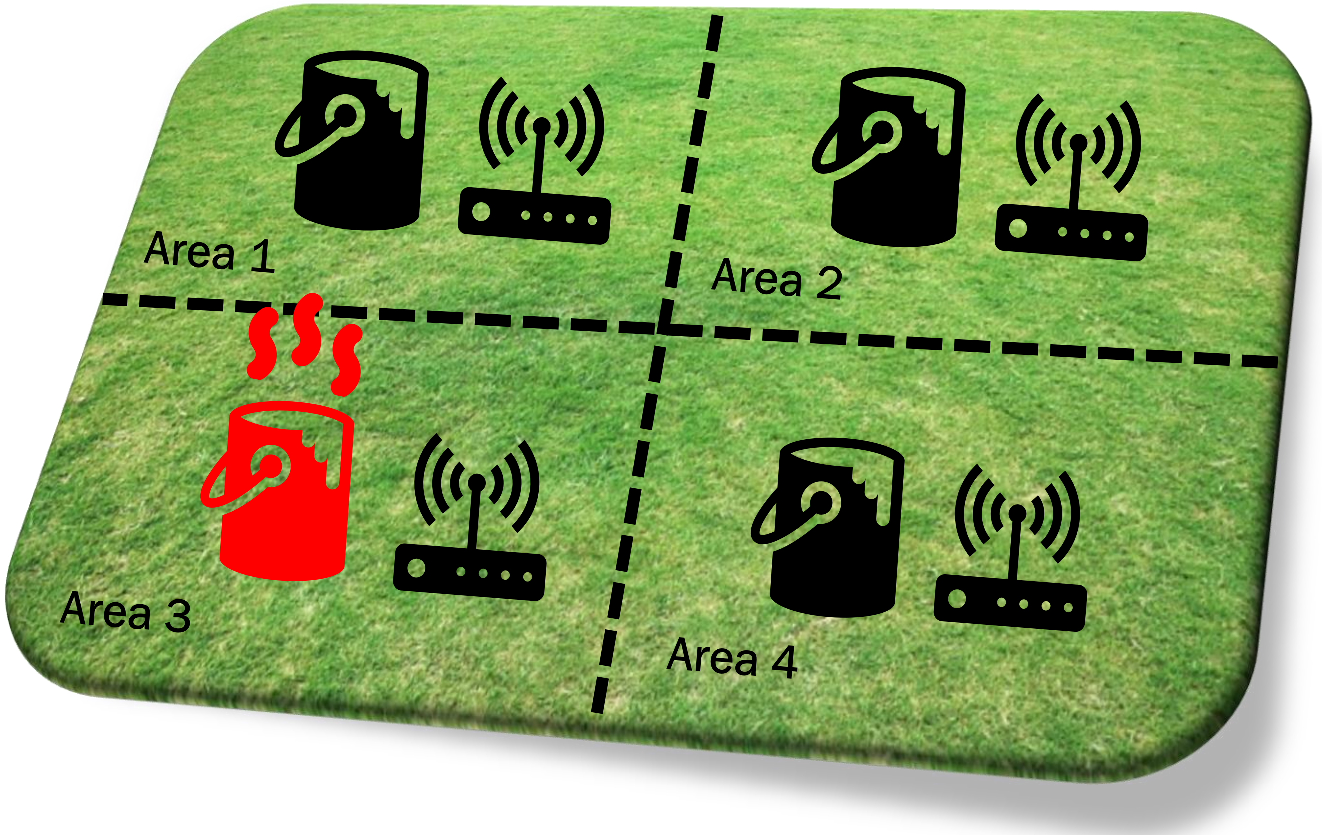
Soil Nutrient Sensors & Feeders

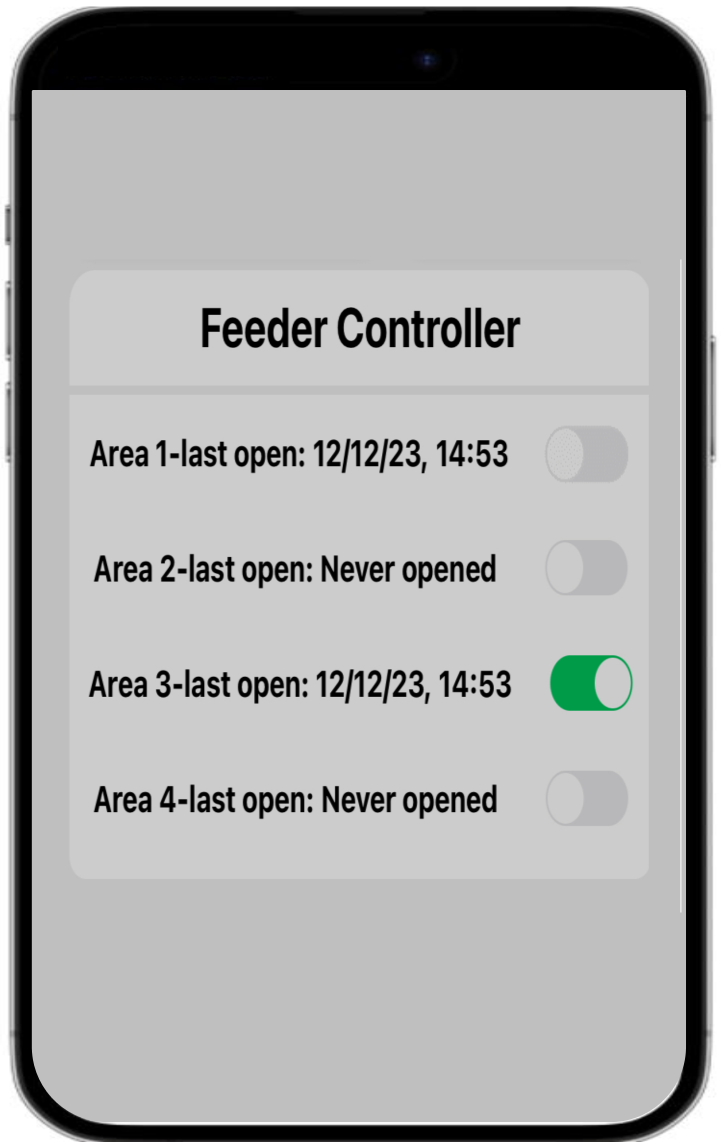




Our Solution

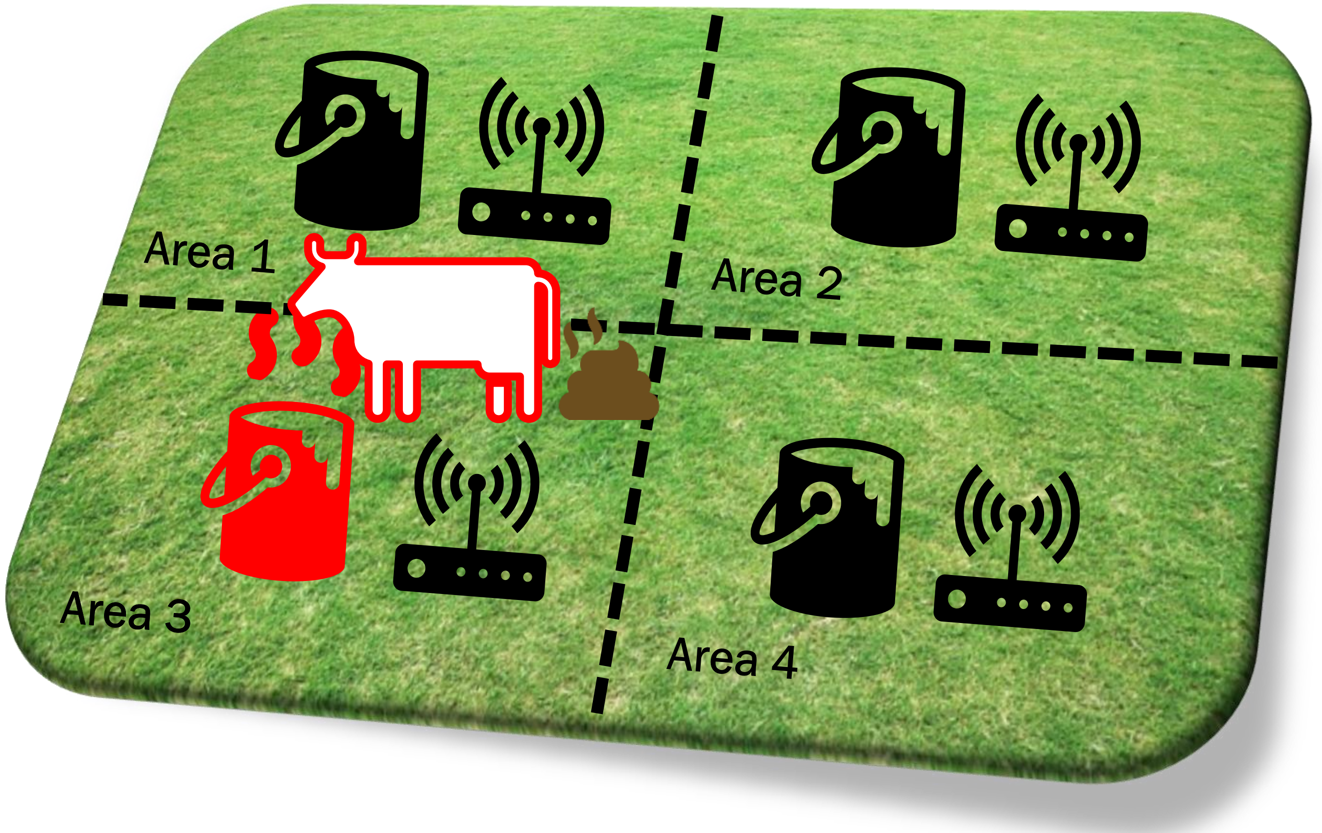
Feeder is activated

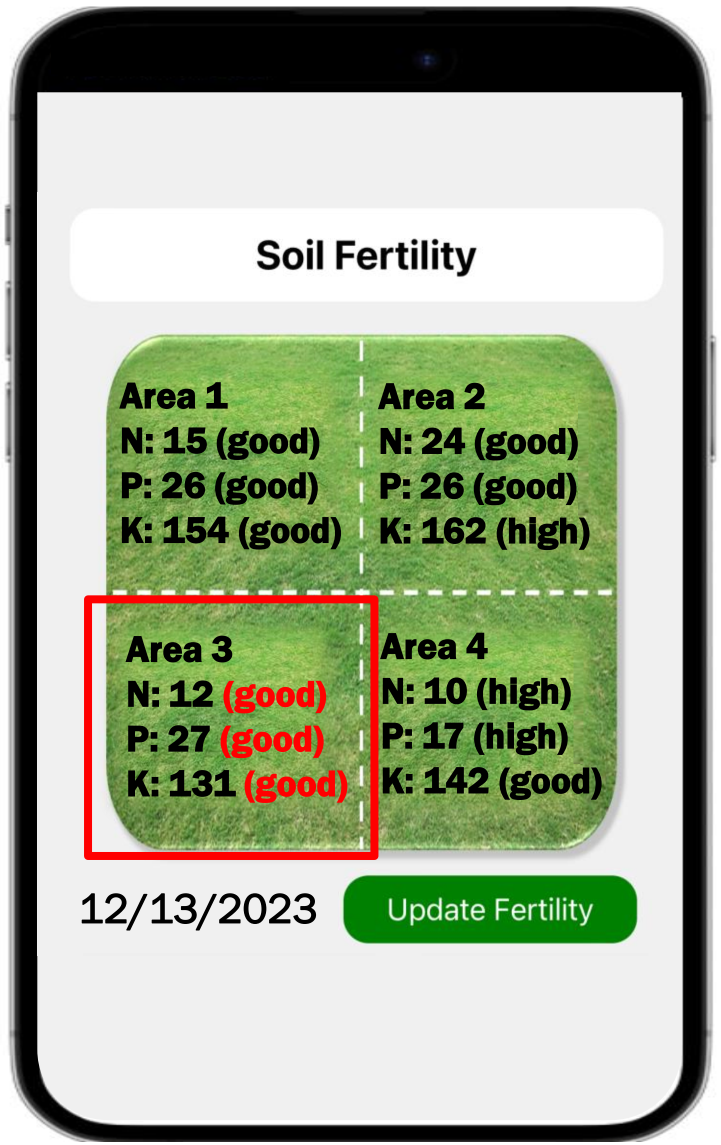




Our Solution

Cattle in action!





Novelty

Novelty

Different perspectives on 'problem statement'

"To achieve higher crop yield "

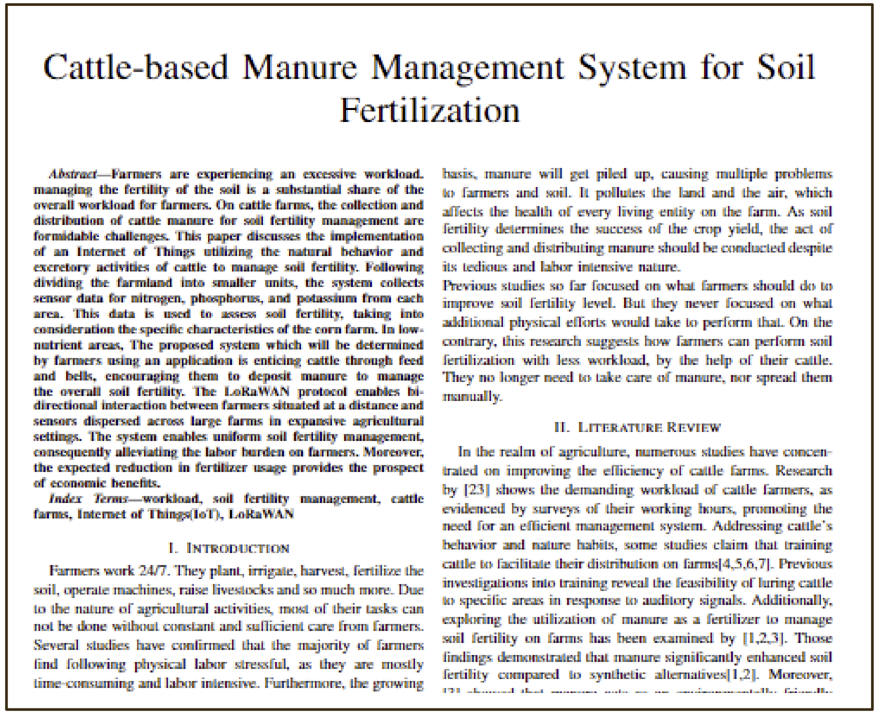
Dairy manure and Synthetic Fertilizer: A meta-analysis of crop production and environmental quality (2019).

Nitrogen, phosphorus, and potassium nutrient effects on grain filling and yield of high-yielding Summer corn (2011).

Soil properties as influenced by phosphorus- and nitrogen-based manure and compost applications (2002).

Soil macronutrient sensing for precision agriculture (2009).

"To improve farming experience"



Cattle-based Manure Management System for Soil Fertilization

Abstract—**Farmers are experiencing an excessive workload. managing the fertility of the soil is a substantial share of the overall workload for farmers. On cattle farms, the collection and distribution of cattle manure for soil fertility management are formidable challenges. This paper discusses the implementation of an Internet of Things utilizing the natural behavior and excretory activities of cattle to manage soil fertility. Following dividing the farmland into smaller units, the system collects sensor data for nitrogen, phosphorus, and potassium from each area. This data is used to assess soil fertility, taking into consideration the specific characteristics of the corn farm. In low-nutrient areas, The proposed system which will be determined by farmers using an application is enticing cattle through feed and bells, encouraging them to deposit manure to manage the overall soil fertility. The LoRaWAN protocol enables bi-directional interaction between farmers situated at a distance and sensors dispersed across large farms in expansive agricultural settings. The system enables uniform soil fertility management, consequently alleviating the labor burden on farmers. Moreover, the expected reduction in fertilizer usage provides the prospect of economic benefits.**

Index Terms—**workload, soil fertility management, cattle farms, Internet of Things(IoT), LoRaWAN**

I. INTRODUCTION

Farmers work 24/7. They plant, irrigate, harvest, fertilize the soil, operate machines, raise livestocks and so much more. Due to the nature of agricultural activities, most of their tasks can not be done without constant and sufficient care from farmers. Several studies have confirmed that the majority of farmers find following physical labor stressful, as they are mostly time-consuming and labor intensive. Furthermore, the growing basis, manure will get piled up, causing multiple problems to farmers and soil. It pollutes the land and the air, which affects the health of every living entity on the farm. As soil fertility determines the success of the crop yield, the act of collecting and distributing manure should be conducted despite its tedious and labor intensive nature.

Previous studies so far focused on what farmers should do to improve soil fertility level. But they never focused on what additional physical efforts would take to perform that. On the contrary, this research suggests how farmers can perform soil fertilization with less workload, by the help of their cattle. They no longer need to take care of manure, nor spread them manually.

II. LITERATURE REVIEW

In the realm of agriculture, numerous studies have concentrated on improving the efficiency of cattle farms. Research by [23] shows the demanding workload of cattle farmers, as evidenced by surveys of their working hours, promoting the need for an efficient management system. Addressing cattle's behavior and nature habits, some studies claim that training cattle to facilitate their distribution on farms[4,5,6,7]. Previous investigations into training reveal the feasibility of luring cattle to specific areas in response to auditory signals. Additionally, exploring the utilization of manure as a fertilizer to manage soil fertility on farms has been examined by [1,2,3]. Those findings demonstrated that manure significantly enhanced soil fertility compared to synthetic alternatives[1,2]. Moreover,

3

Methodology

- Wiring Diagram
- System Architecture

End Node

Wiring Diagram

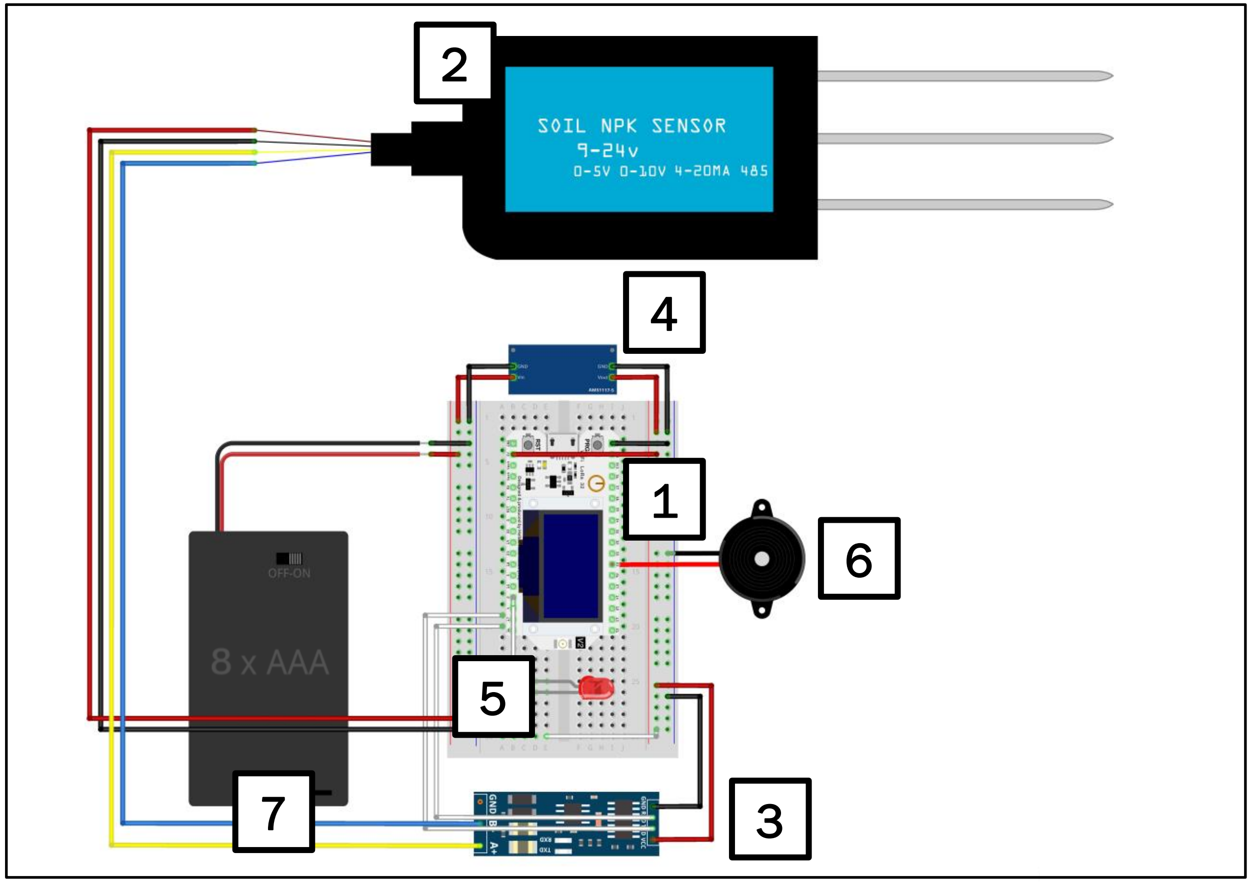


Fig 1. End node wiring diagram

1 ESP32

2 NPK sensor

3 RS485 to TTL Converter

4 DC-DC Converter

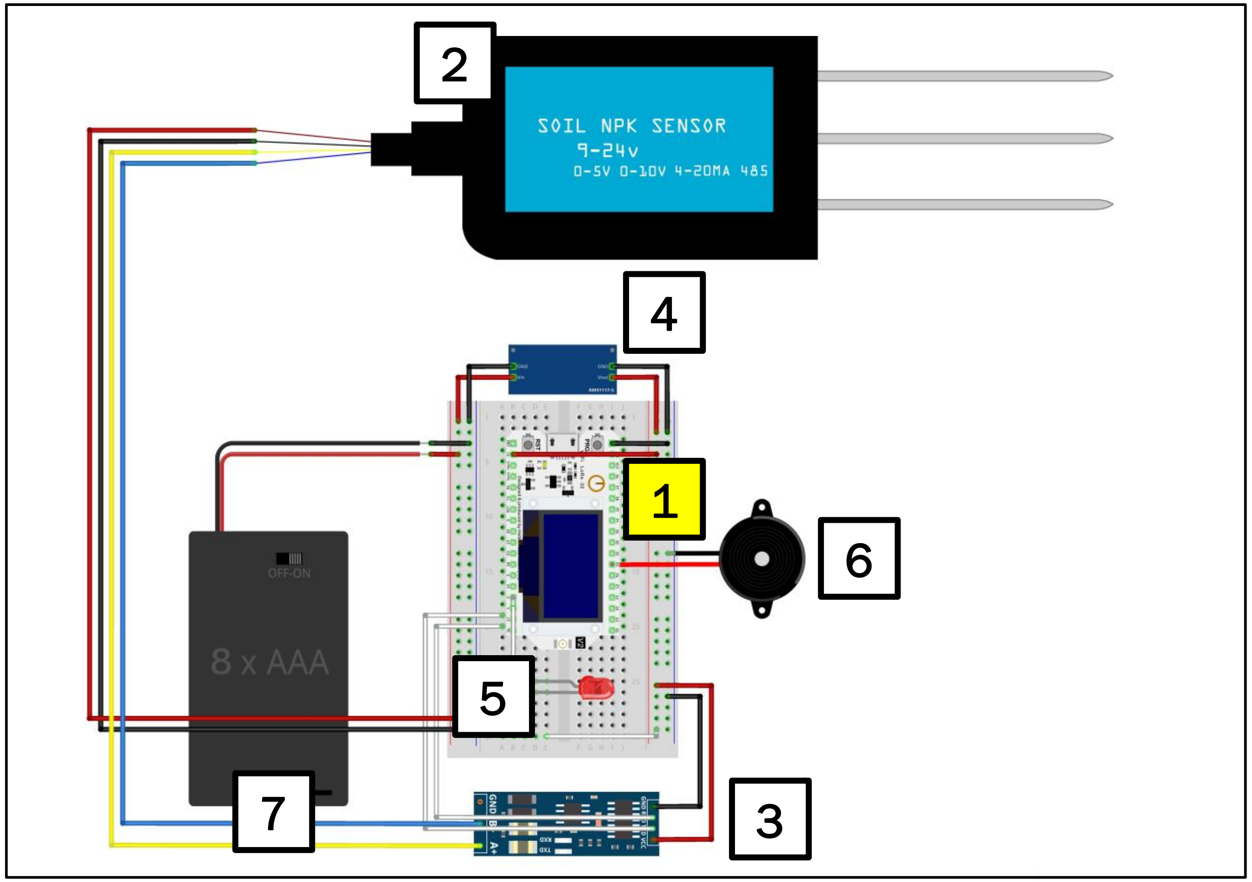
5 LED

6 Sound Sensor

7 Battery

End Node

Wiring Diagram



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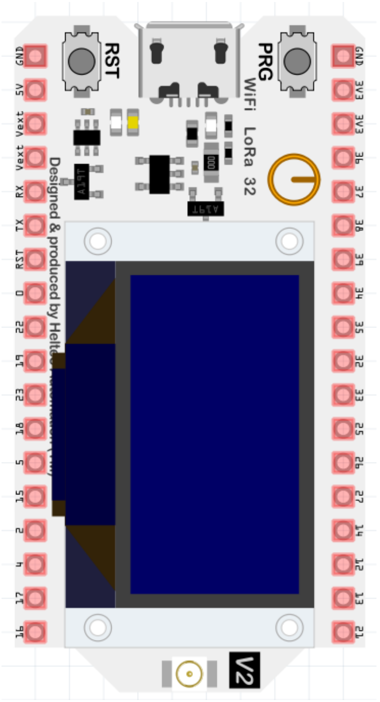
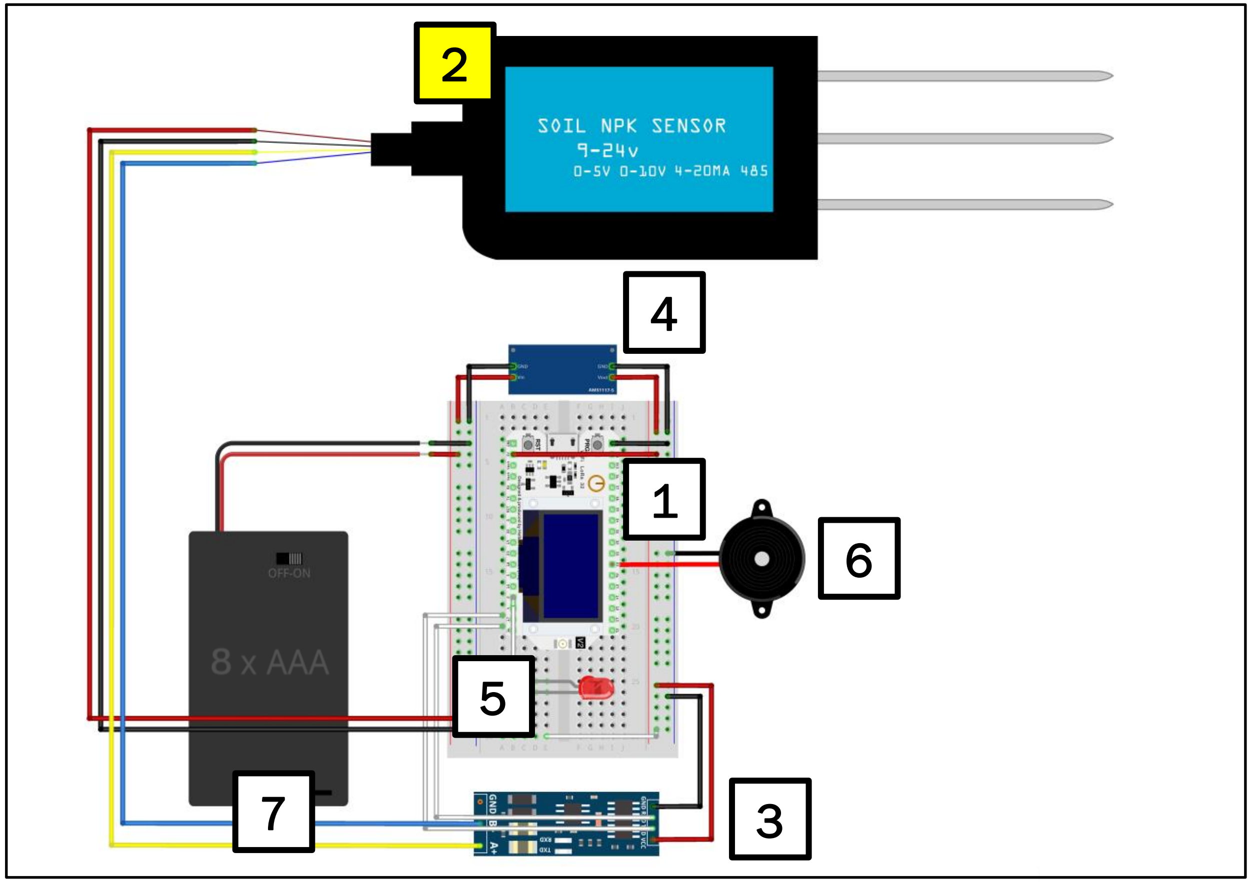


Heltec WIFI esp32 V2

End Node

Wiring Diagram



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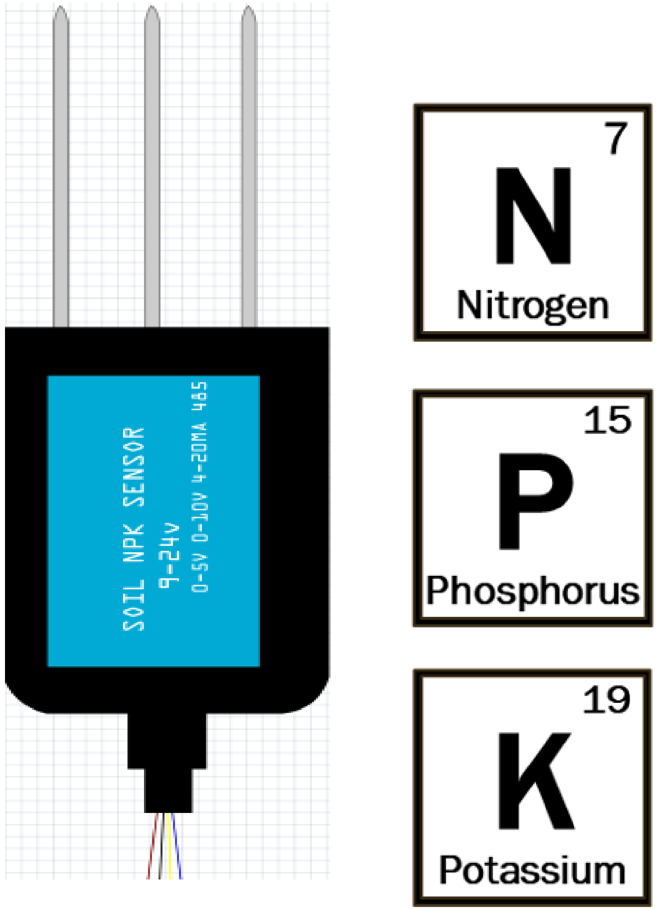
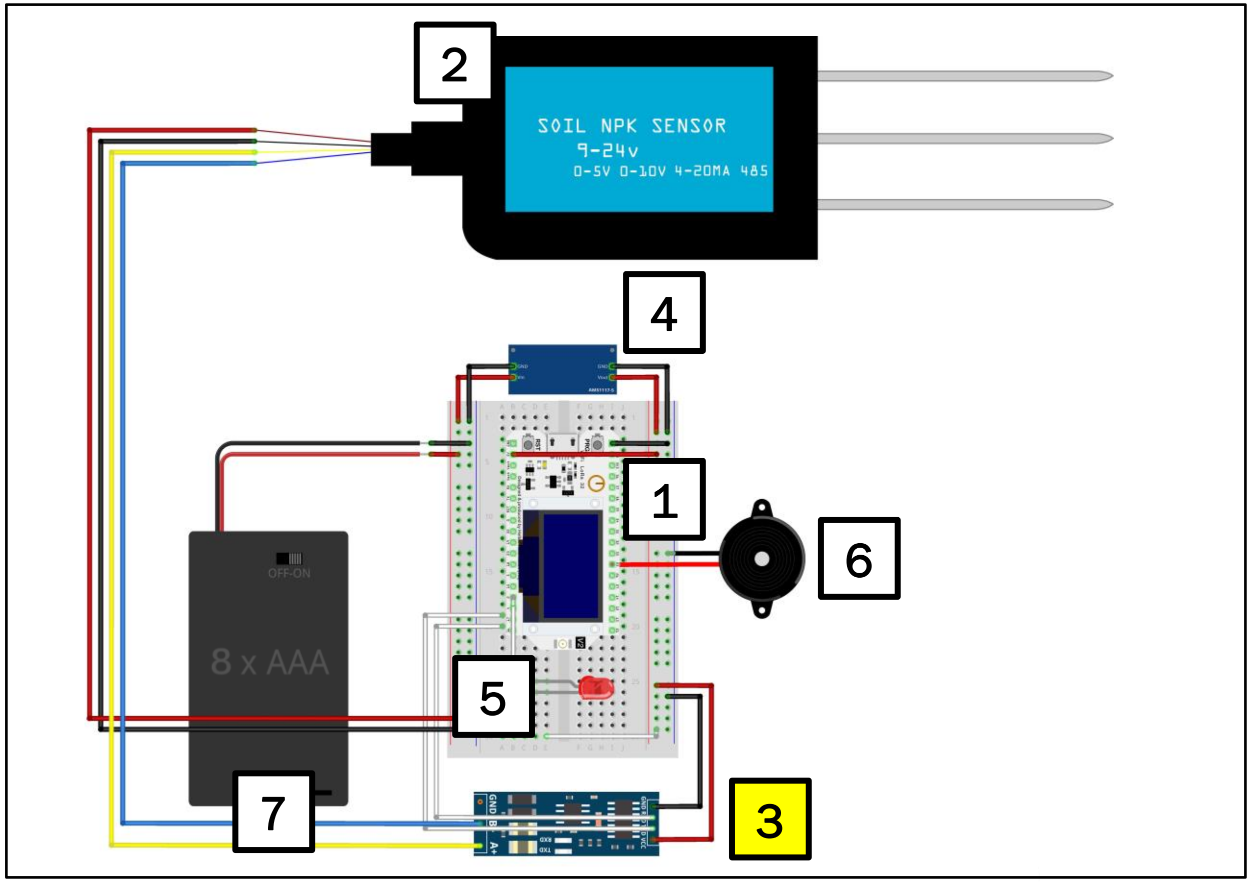


NPK Sensor

End Node

Wiring Diagram



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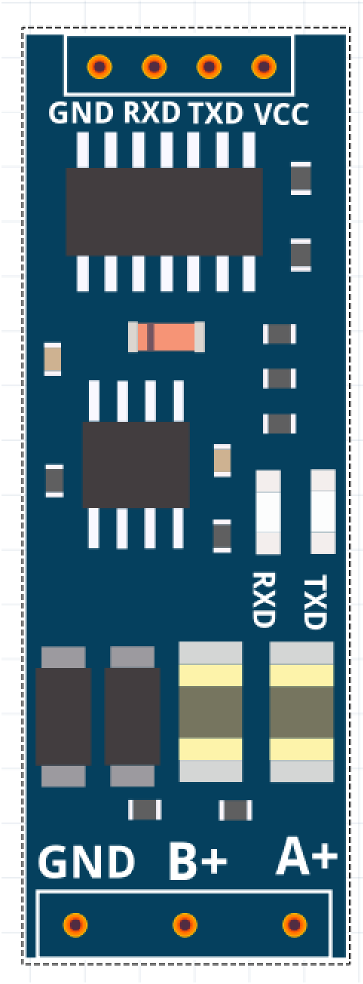
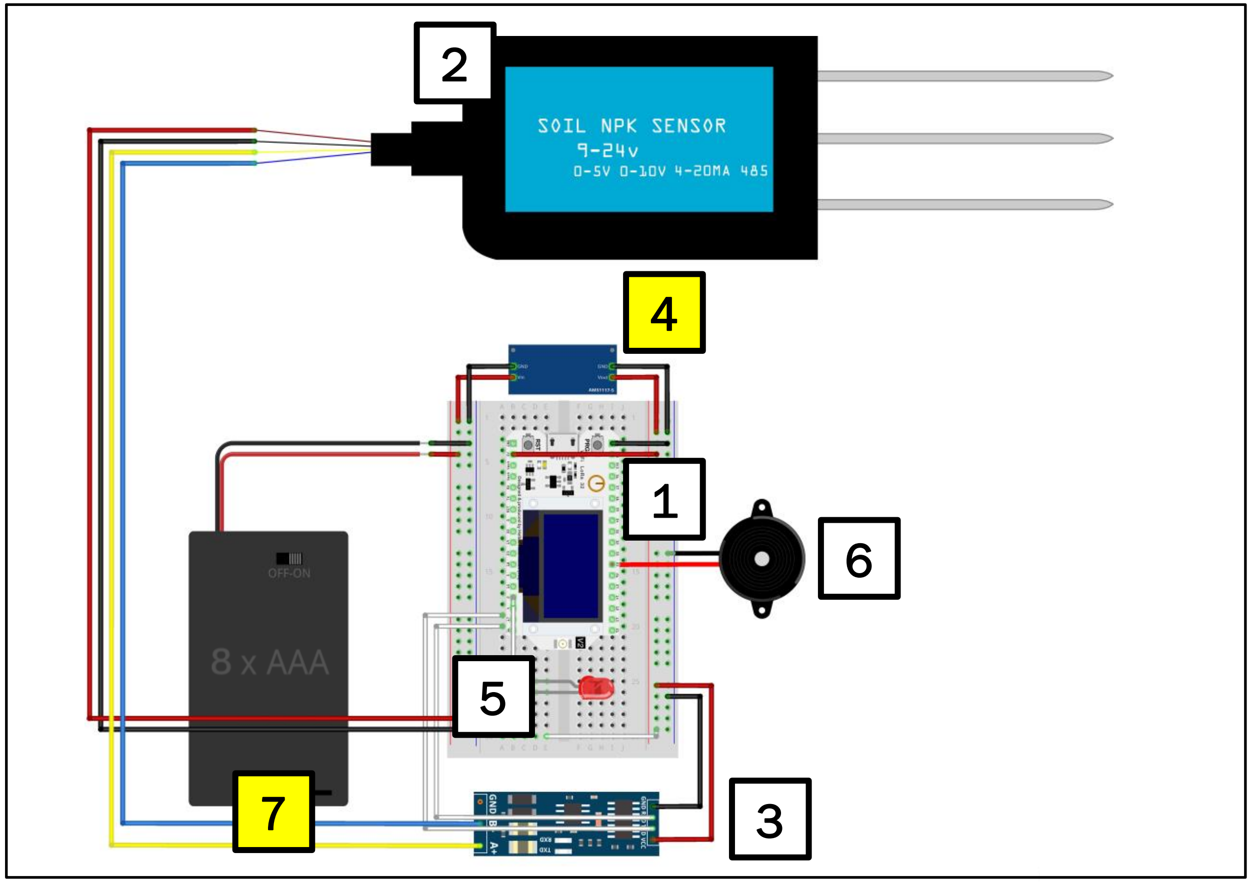


SMAKN SCM
RS485 to TTL Converter

End Node

Wiring Diagram



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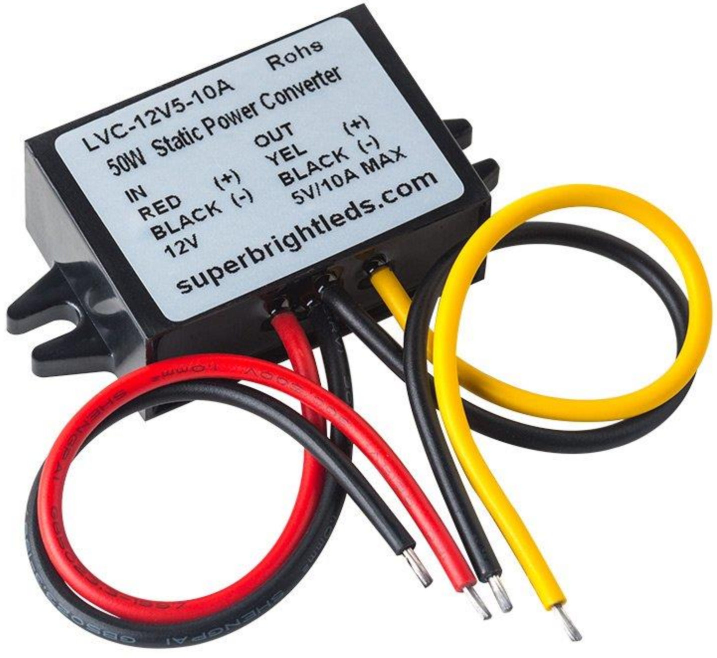
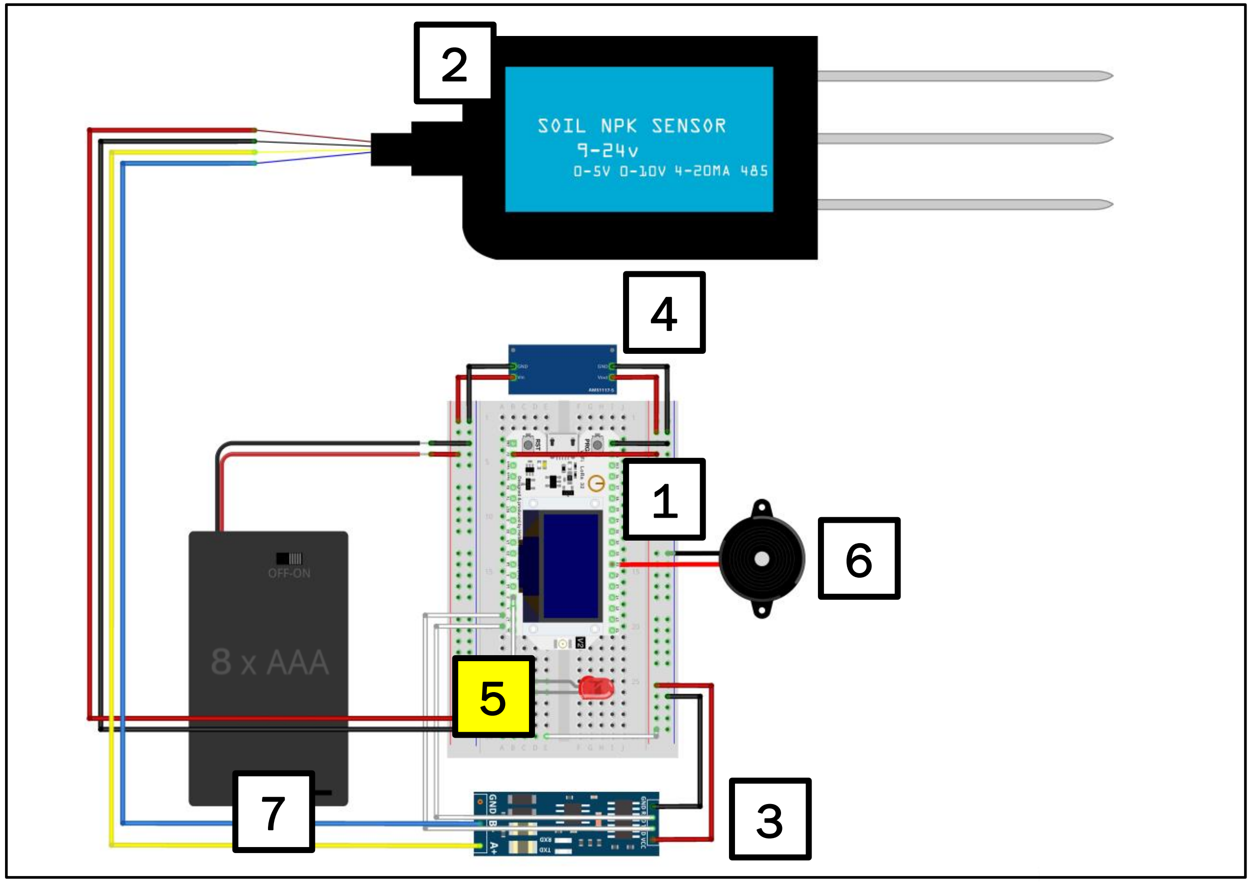


DC-DC Converter

Wiring Diagram



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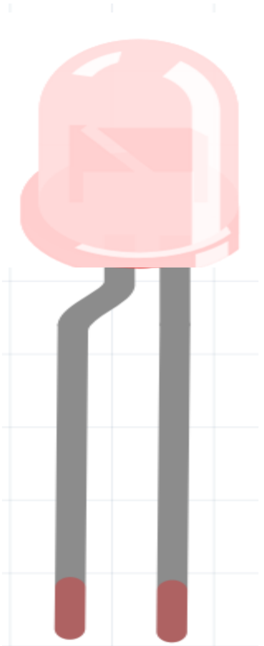
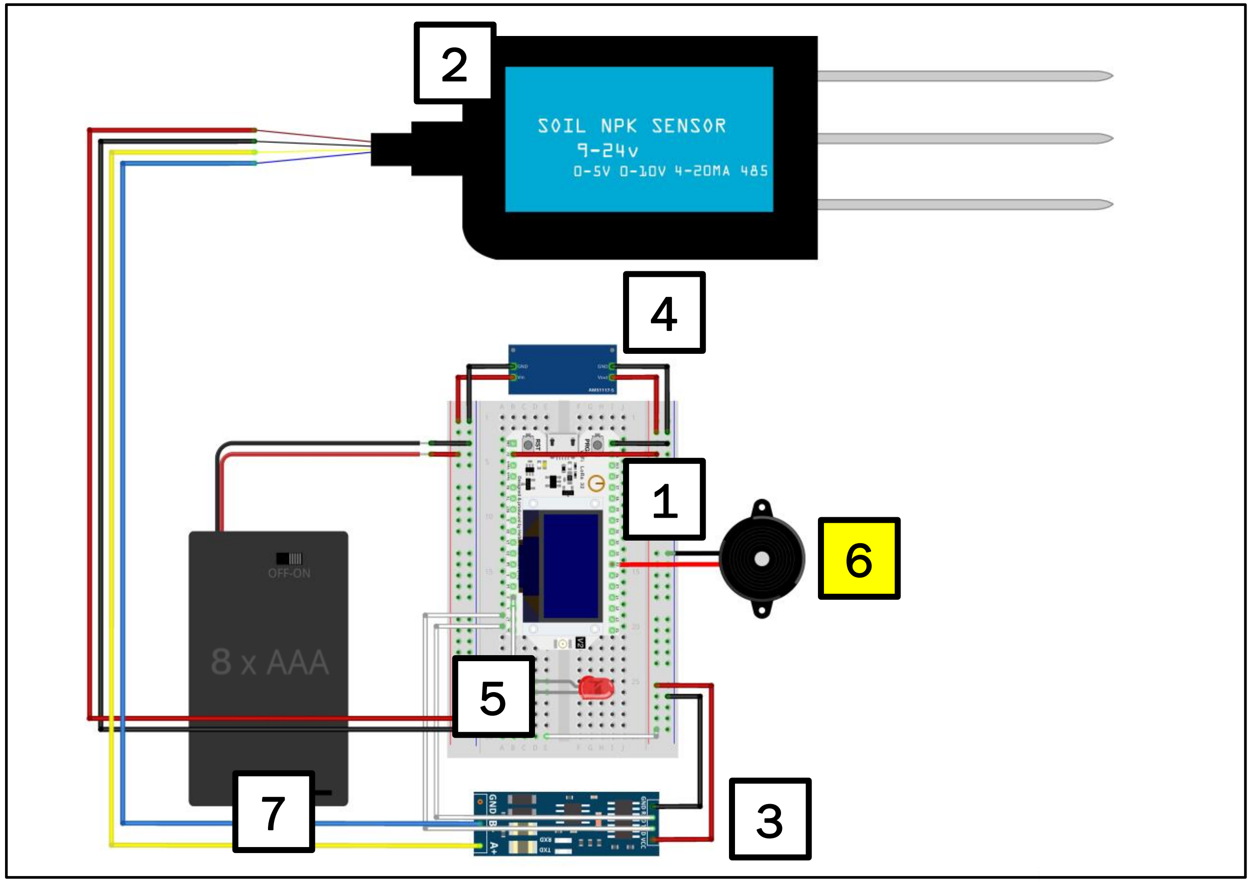


LED ON/OFF

End Node

Wiring Diagram



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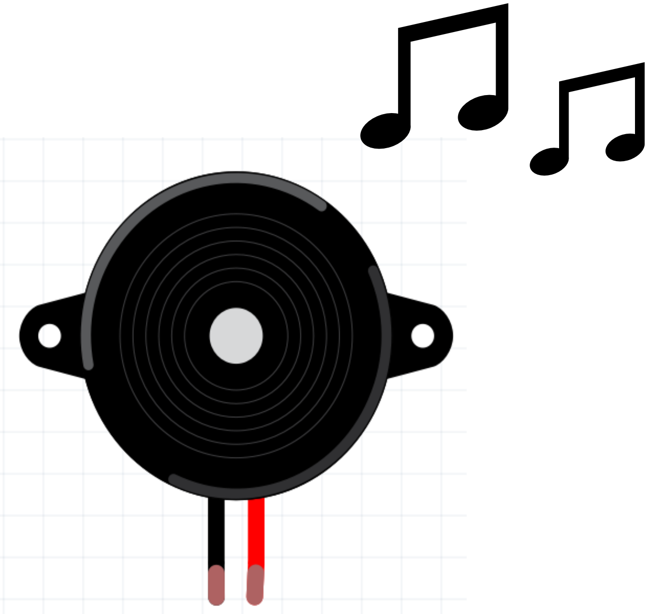


Sound Sensor

System Architecture

Main flow of our system

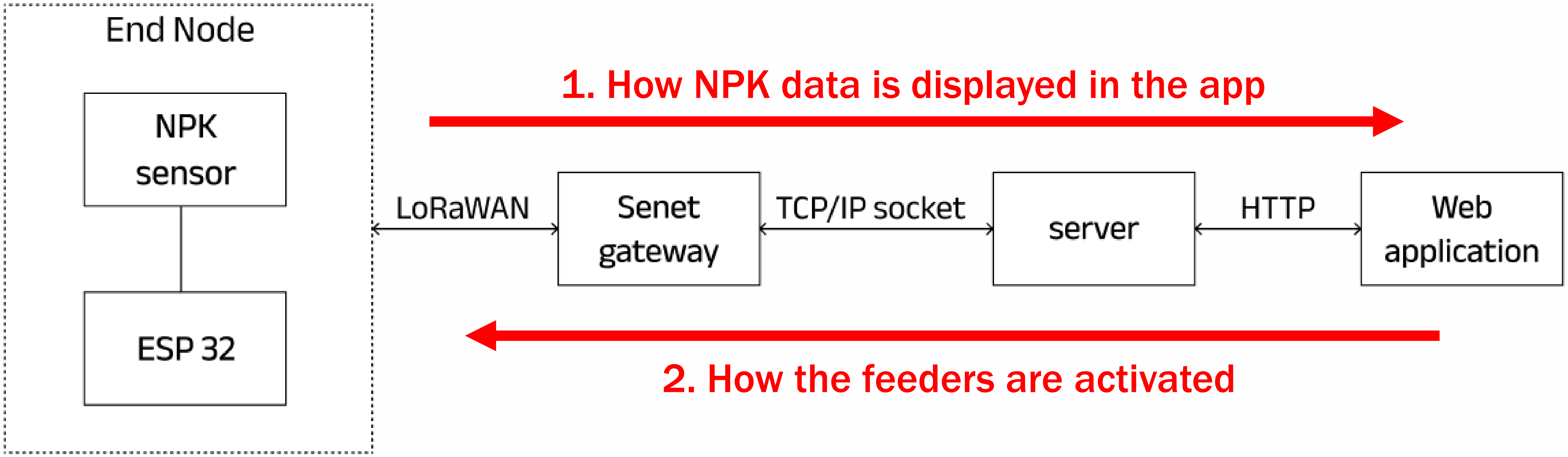
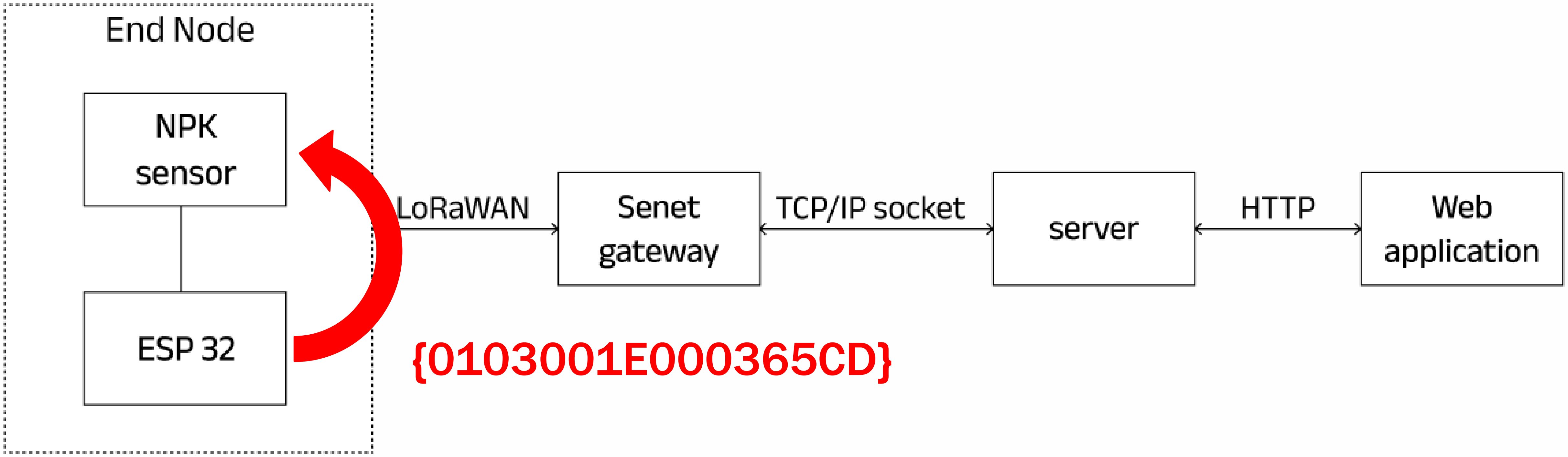


Fig 2. system architecture

System Architecture

1. How NPK data shows up in the app



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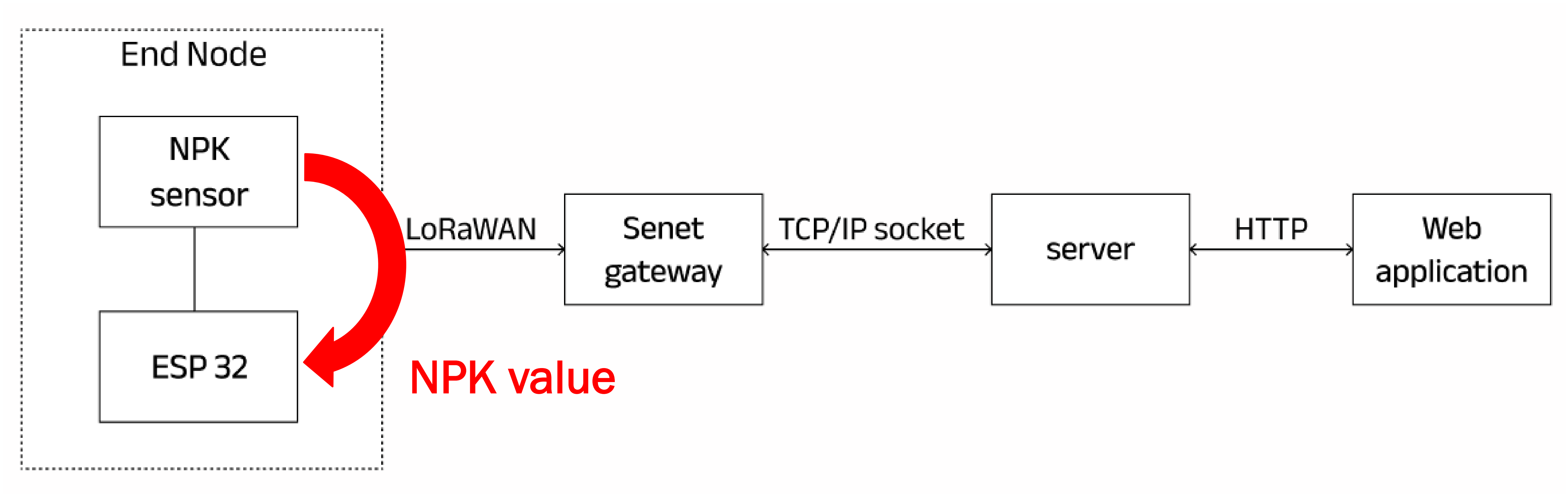

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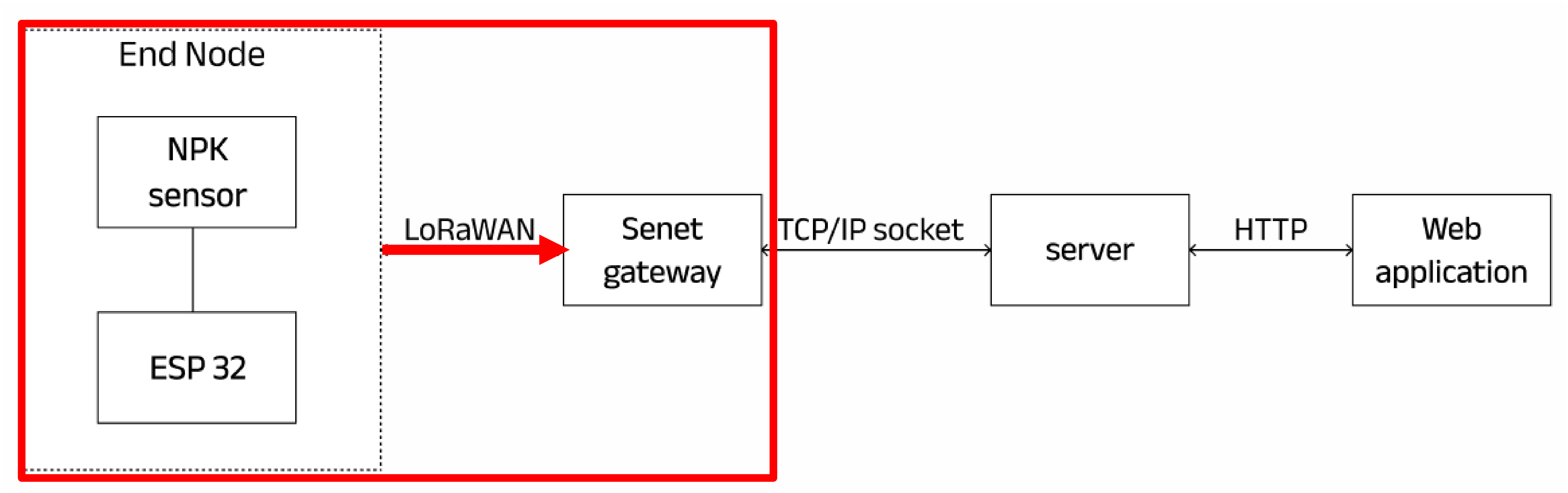

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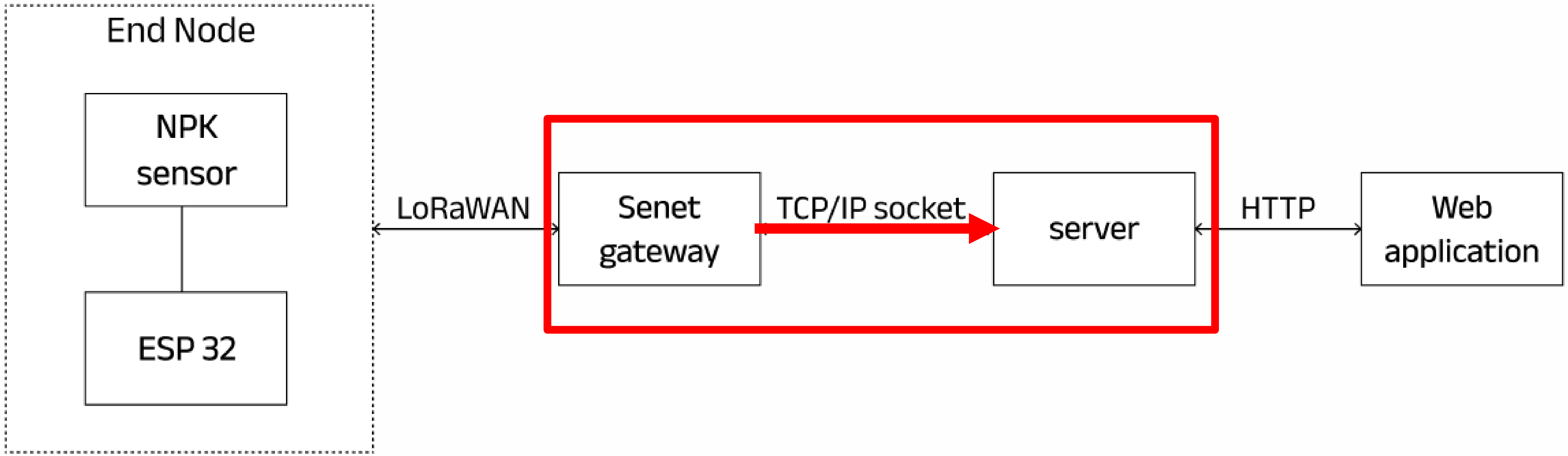

Fig 2. system architecture

System Architecture

Ideal NPK value

techniques, may make implementation of a variable-rate fertilizer application system impractical.[12] In this situation, on-the-go real-time sensors could be useful to allow the collection of geographically referenced data on a much finer spatial resolution than is currently feasible with manual and/or laboratory methods. These automated sensor measurements can provide the benefits from the increased density of measurements at a relatively low cost.[13]

Soil fertility research has identified levels of macronutrient concentrations in the soil that are sufficient for field crop production without further additions. For example, Midwestern US Cornbelt research[9,10] suggested that soil with a residual nitrate level below $10\ \mathrm{mg\ kg^{-1}}$ would require a full-rate nitrogen application rate to achieve a 100% corn yield goal. Residual nitrate levels above $30\ \mathrm{mg\ kg^{-1}}$ would require no additional fertilizer. Similarly, for corn production, soils having plant-available phosphorus and exchangeable potassium levels of $27.5\ \mathrm{mg\ kg^{-1}}$ and $150\ \mathrm{mg\ kg^{-1}}$, respectively, would be considered adequate to support crop production if the amounts removed by the crop each year were replaced.[14] Ideally, real-time sensors would be able to accurately sense macronutrient levels in these ranges, and allow perhaps six finite application rates over the range of zero to

Table 1. Phosphorus recommendations for corn production utilizing various extraction methods.

	PPM				
	Very Low	Low	Optimum*	High	Very High
Bray P and Mehlich-3 P	0-8	9-15	16-20	21-30	31+
Olsen P	0-5	6-9	10-13	14-18	19+
	P_2O_5 (lb/acre) to apply to corn				
	100	75	58	0	0

Table 2. Potassium recommendations for corn production using the ammonium acetate and Melich-3 Extractable K method.

	Ammonium Acetate and Mehlich-3 Extractable K (PPM)				
	Very Low	Low	Optimum*	High	Very High
Dry	0-120	121-160	161-200	201-240	240+
Field-moist and Slurry	0-50	51-85	86-120	121-155	156+
	K_2O to apply (lb/acre)				
Fine Textured	130	90	40	0	0
Sandy Textured	110	70	40	0	0

Web application

[1] Kim HJ, Sudduth KA, Hummel JW. Soil macronutrient sensing for precision agriculture. J Environ Monit. 2009 Oct;11(10) 1810-1824. doi:10.1039/b906634a. PMID: 19809703.

[2] Image from: https://www.cropscience.bayer.us/articles/bayer/reading-interpreting-soil-test

System Architecture

Ideal NPK value

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Table 1. Phosphorus recommendations for corn production utilizing various extraction methods.

Fine Textured	130	90	40	0	0
Sandy Textured	110	70	40	0	0

	Low	Good	High
N	0 ~ 10	11 ~ 30	31+
P	0 ~ 20	21 ~ 30	31+
K	0 ~ 120	121 ~ 155	156+

Table 1. Ideal NPK range

Web application

[1] Kim HJ, Sudduth KA, Hummel JW. Soil macronutrient sensing for precision agriculture. J Environ Monit. 2009 Oct;11(10) 1810-1824. doi:10.1039/b906634a. PMID: 19809703.

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System Architecture

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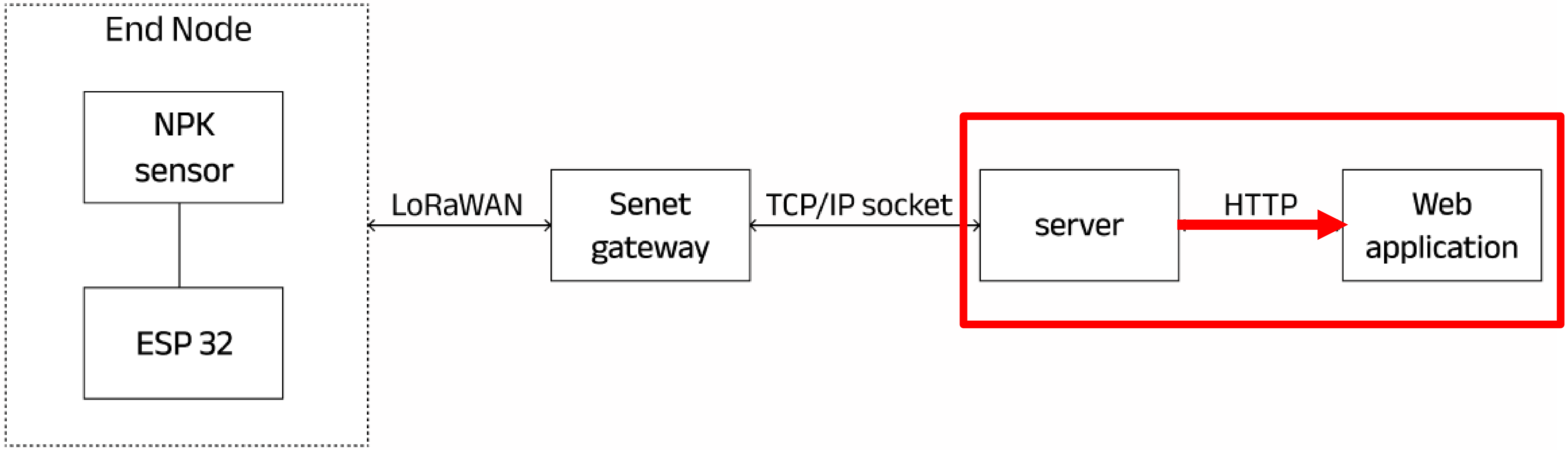


Fig 2. system architecture

System Architecture

2. Process of farmers controlling the feeder

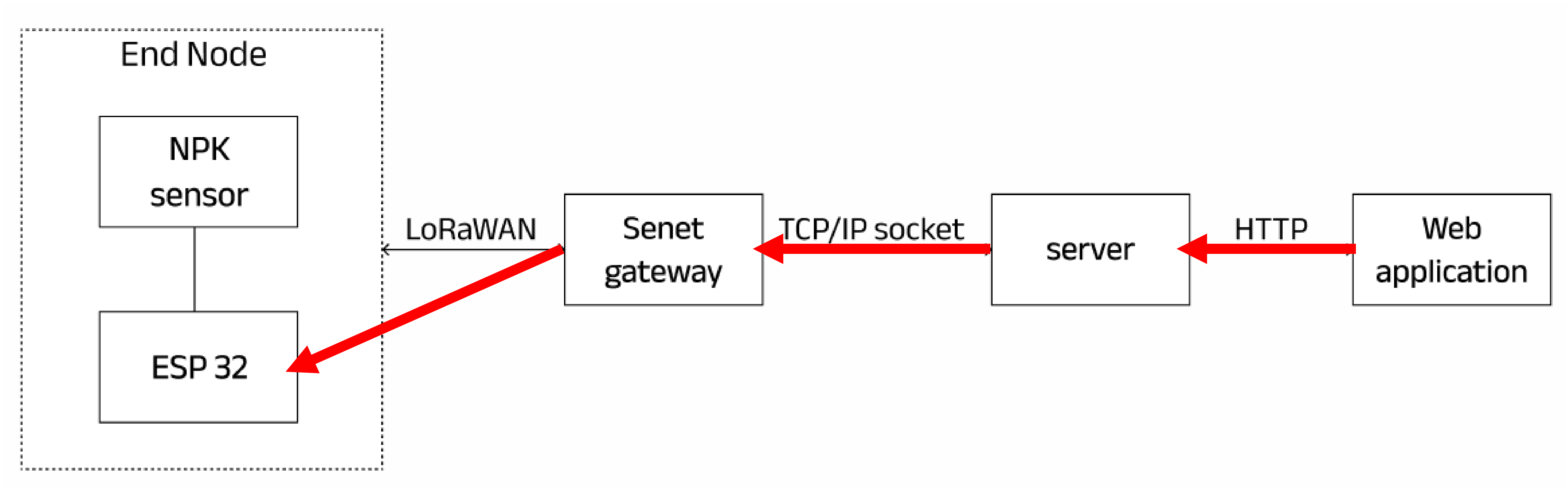
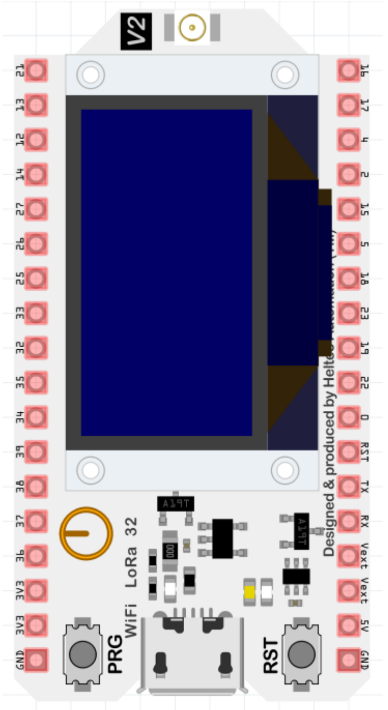


Fig 2. system architecture

2. Process of farmers controlling the feeder



ESP 32

Sending Signal

Open the feeder

Ring a bell

System Architecture

2. Process of farmers controlling the feeder

1. **Cattle will continue to excrete near it, which can be overfertilized.**

2. **Cattle's manure is not immediately absorbed into the soil.**

2. Process of farmers controlling the feeder

Decide after seeing
how much fertility rises after the closure.

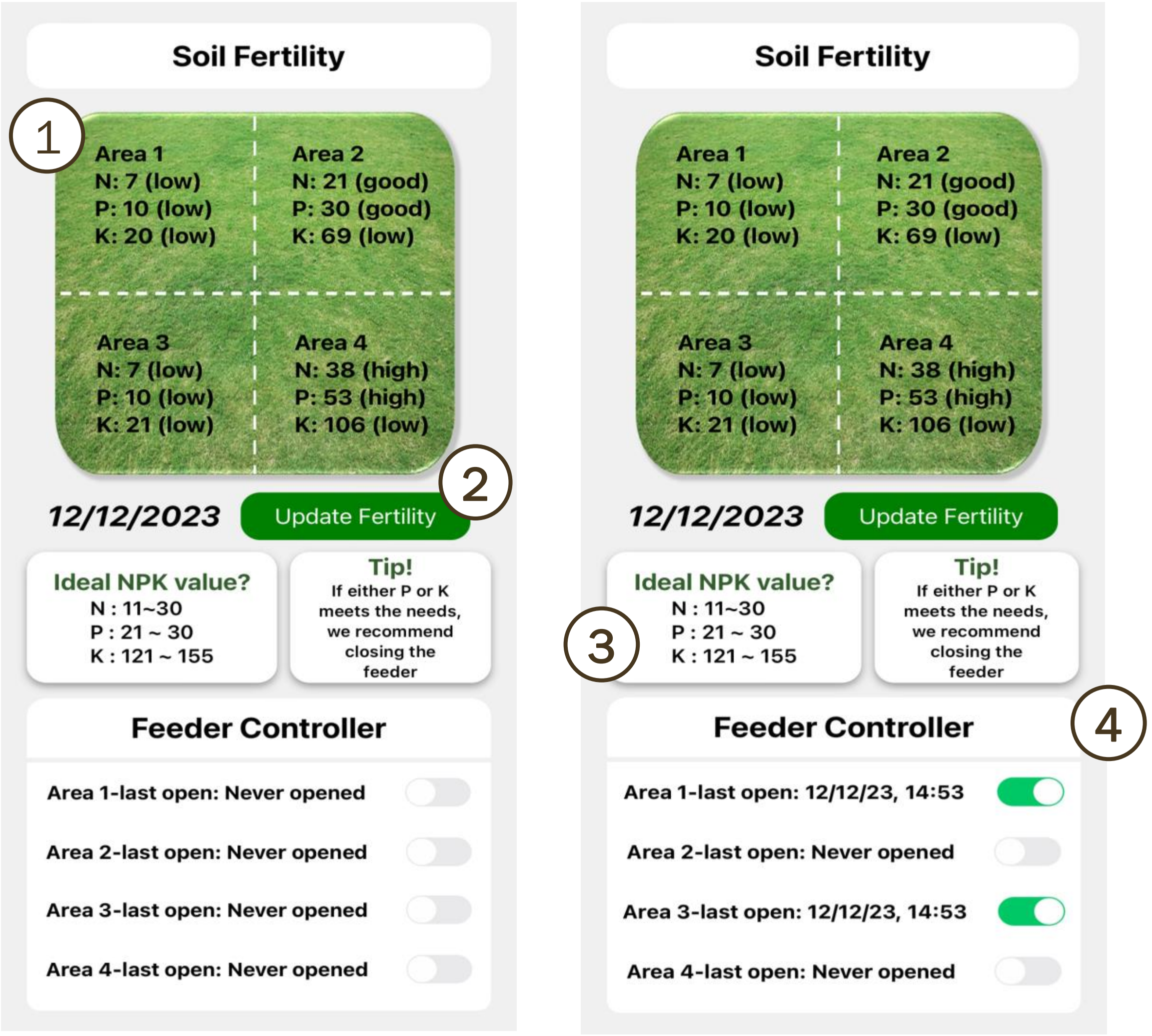
4

Experiment

Experiment Setting

Application Functions

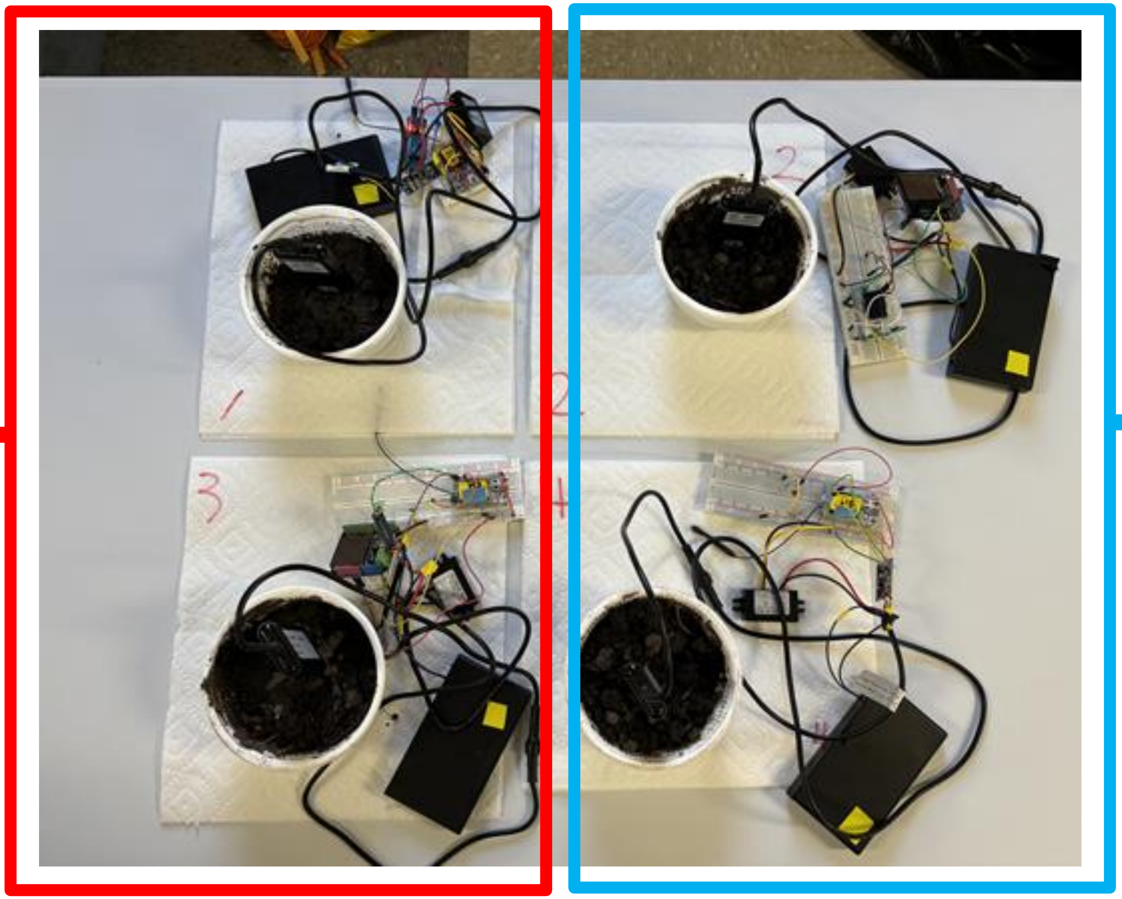
1. **Farm view**
2. **Today's Date & Update Button**
3. **NPK information**
   - Ideal NPK value
   - Tip for choosing feeder
4. **Feeder Controller**
   - Feeder Control Button
   - Last Time Feeder was Opened



Pic 1. Application Screenshots

Experiment (Demo)

Low fertility



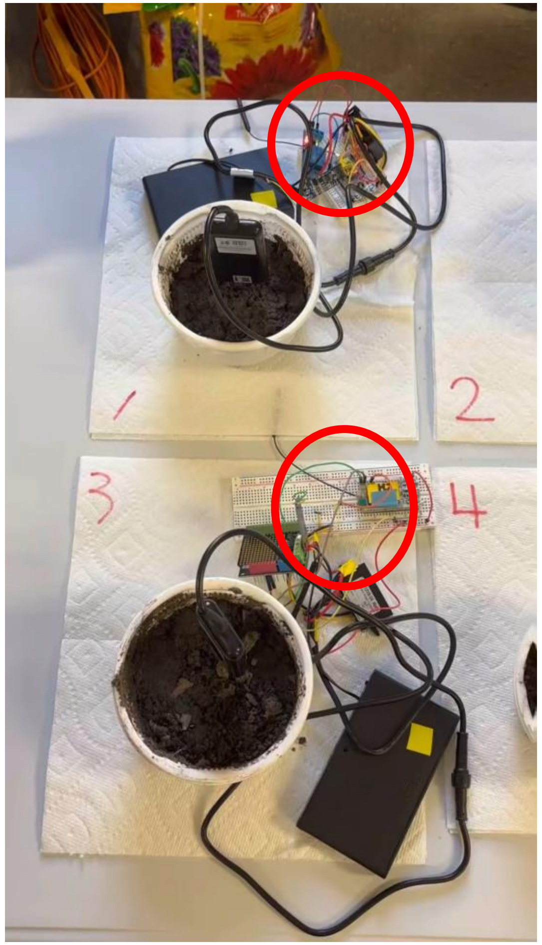
Good fertility

Pic 2. Experiment setting

Experiment (Demo)

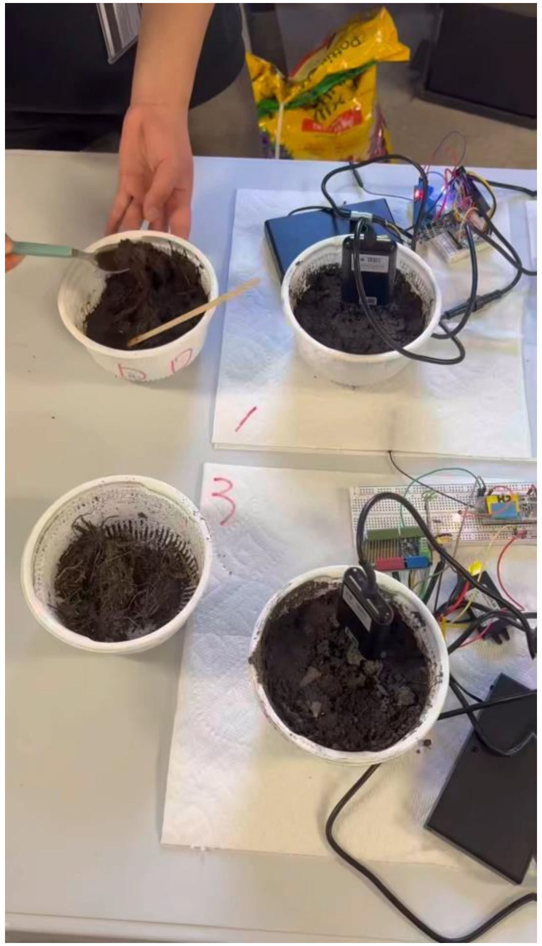
12/12 In the Morning

User can check nutrient levels of each area through the application.



In the application, when a user activate the feeders in area 1 and 3, you can see the LED light up and ringing a bell.

Experiment (Demo)



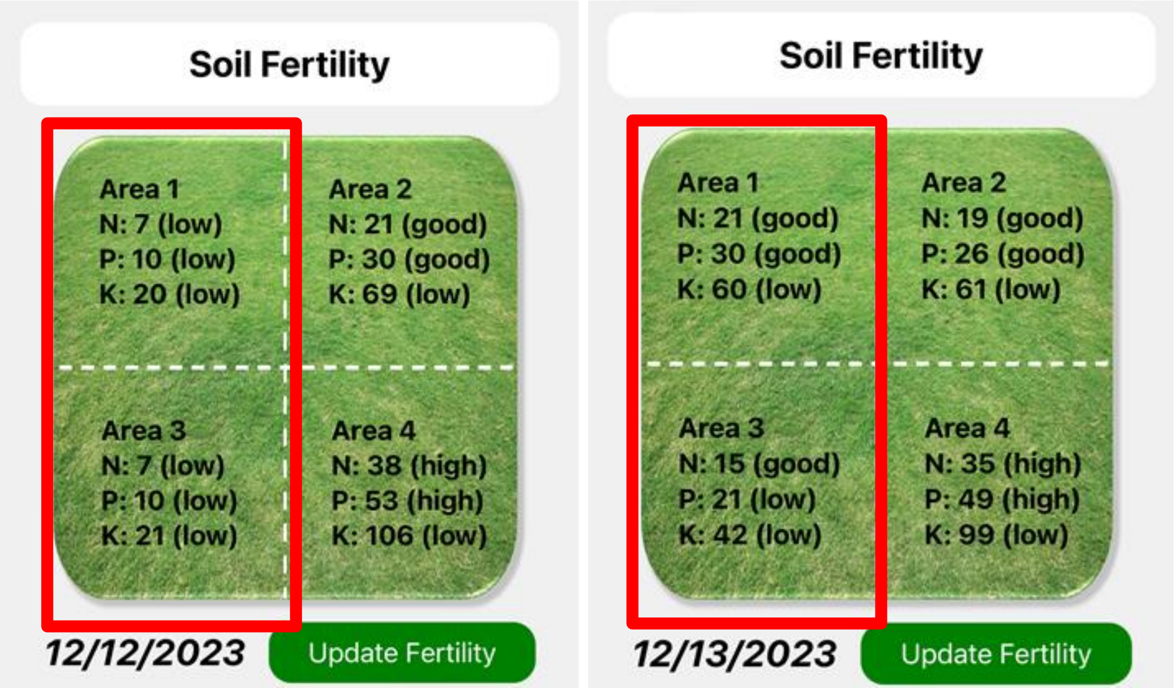
12/12

- Replaced by us spraying the manure

- Applied slurry manure for area 1, dry manure for area 3.

- After 3 hours, the feeders are automatically closed.

Next Day 12/13

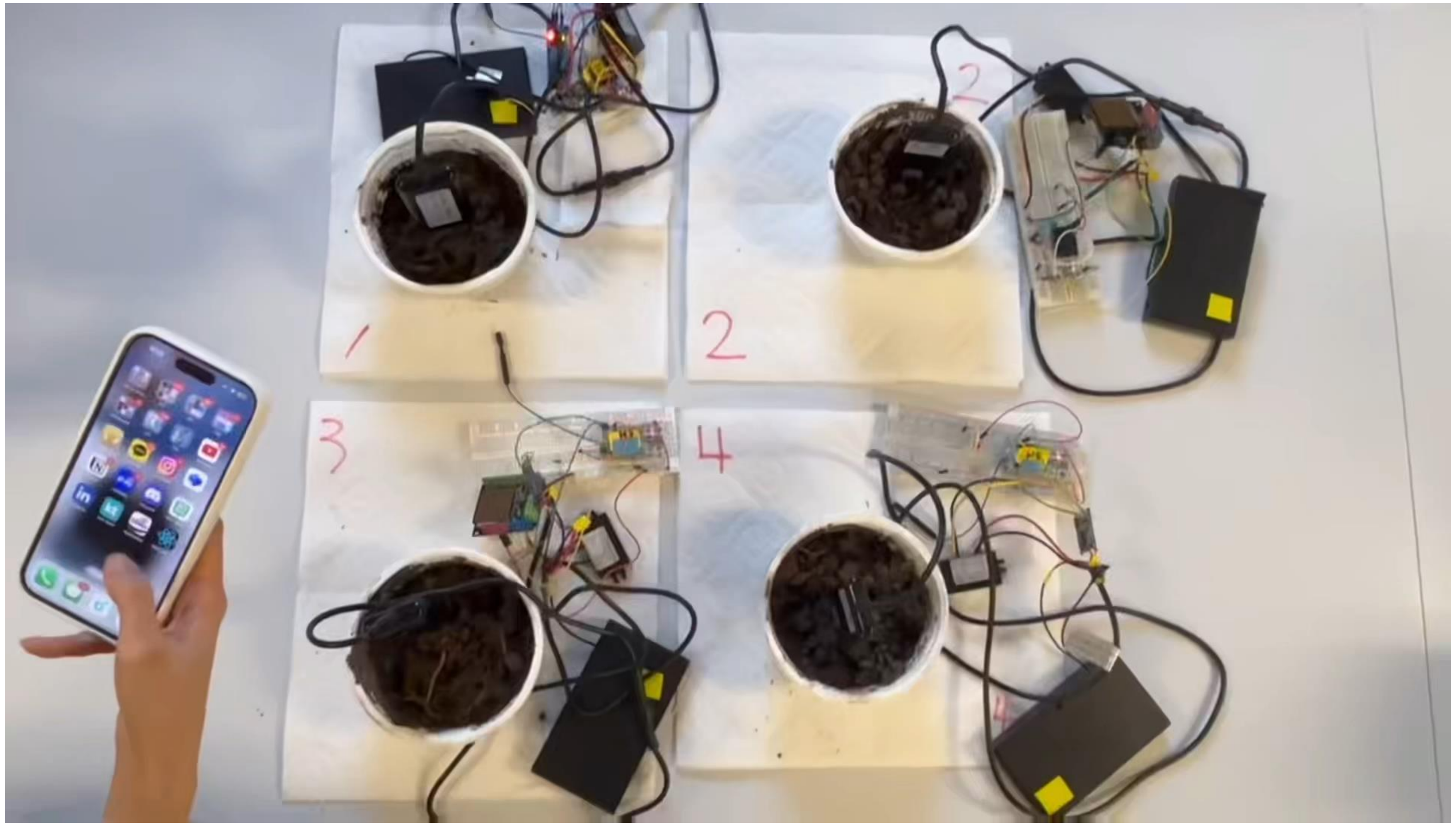


Fertility of area 1 and 3 have increased

Pic 3. Application Screenshot after applying manure

Experiment (Demo)

After several iterations



Result

Trending Graph

1. The fertility of the area where manure has been spread increases over time

   ✓ slurry manure, closer to the actual manure of cows, is more effective in enhancing fertility

2. The fertility of the two areas, where nothing has been done, gradually decreased over time

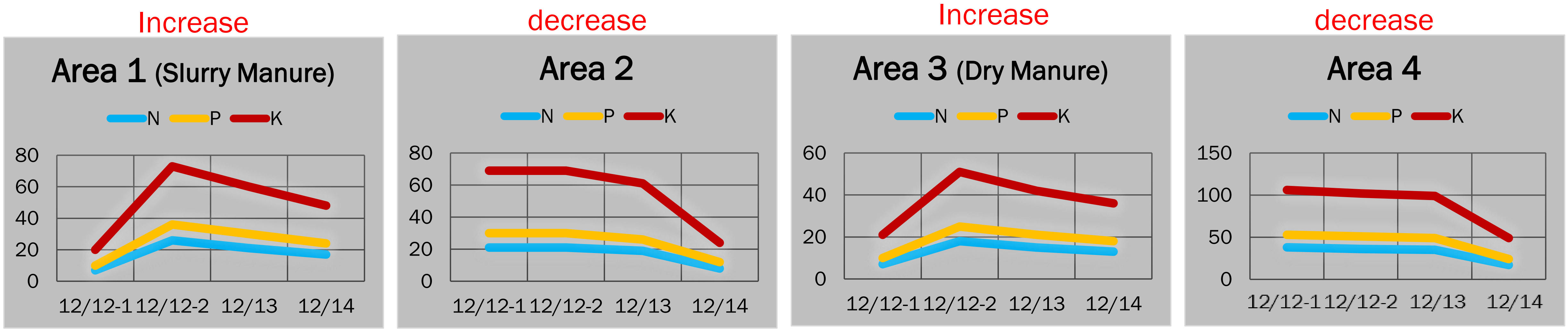


Fig 3. Result Graph

5

Conclusion

Conclusion and Future Plan

Conclusion

New Method	This project shows a way to maintain & manage soil fertility evenly with an application using IoT systems and cow habits
Long Distance	Soil nutrient data is transmitted via LoRaWAN to provide remote user who lived far away from the farm
Reduce Workload	This solution can reduce the physical burden on the farmer by delegating menial labor to cattle
Practical	It is practical as it achieves its purpose by using what cows do naturally

Conclusion and Future Plan

Future plans

- The optimal concentration of N, P, and K for a farm can differ based on

  Soil Type | Crop Type | Moisture Level | Farm Size | PH Level

- We can expect better results when all the conditions are taken into account, and a formula derived through scientific experimentation incorporates every variable.

  N P K + α

Thank you

Q&A