Software Engineering for IoT Project
Aquaponics Monitoring System
Team "The farmers"

Submitted To

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Introduction

What is Aquaponics?

According to Wikipedia **Aquaponics** "is a food production system that couples aquaculture (raising aquatic animals such as fish, crayfish, snails or prawns in tanks) with hydroponics (cultivating plants in water) whereby the nutrient-rich aquaculture water is fed to hydroponically-grown plants, where nitrifying bacteria convert ammonia into nitrates."

Aquaponics is a very interesting farming technique that combines two different farming types and ecosystems: aquaculture and hydroponics(soilless) farming in a closed-loop system. The animals provide nutrients in the form of broken-down excretions, which allow the plants to grow.

Aquaponics farms in a controlled-environment greenhouse can be a source of **consistent quality** veggies and **all-round year** harvest as they are weatherproof and contamination-free.

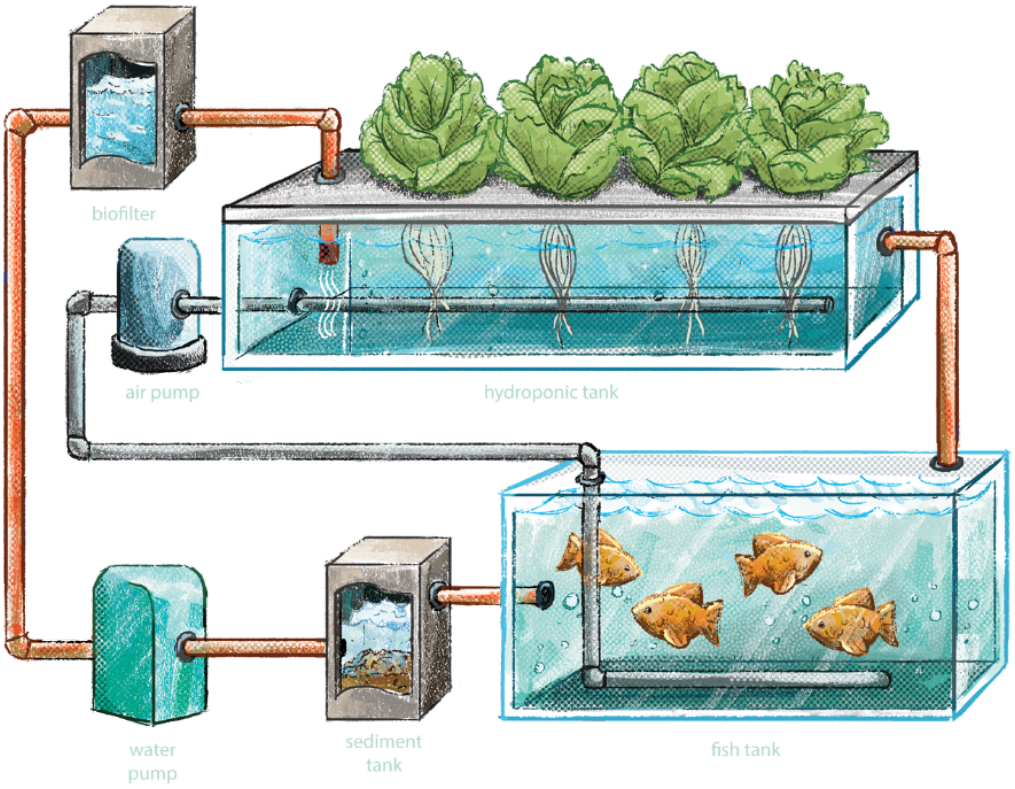


Fig 1: Aquaponic System

Image source: https://ag.purdue.edu/envision/the-big-idea-hydroponics-aquaponics/

Operational Features of Aquaponics

These types of farms have three important components that determine the efficiency of the system. Those Are:

- **The Fish Tank:** the fishes grow in a container/tank that is made for these types of farms. The breeds of fishes we use depend on the availability of the breed we can easily get, but generally, freshwater fishes are the desired ones. Usually, we use Blue Nile Tilapia, and the feed we give them also determines their growth and the waste/ammonia we get from the tanks.
- **The Filters:** The main purpose of this section of the system is to remove unwanted parts of the liquid we get from the tankers before we release them to the growing bed. So, for this purpose, we need two types of filters
  - **The Solid Filter:** In this section, we avoid the solid dirt from the fluid we got from the tanks.
  - **The Biological Filter:** this is a very important part of the system, where the fluid changes form due to the **naturally** occurring bacteria in our biological filter. This filter, also known as the **Rock Media Bed, creates** favorable conditions for the bacteria to survive and they change the Ammonia to a Nitrate, which is the main ingredient in fertilizers that our veggies need.
- **Growing Beds:** In this system, we are considering a deep water growing bed. The veggies use the deepwater beds as a growing medium. The plants will consume the nitrates and give us freshwater which will be **recirculated** to the fish tank for the fishes to use. Which makes the farm use less than 95% of water for diverse and far more harvest compared to other forms of farming.

Main Constraints to consider

- The sensors in the tank need to monitor the acidity(pH Level), temperature, and oxygen level of the tanks in order to **keep all the metrics healthy** enough to keep the fishes safe and grow better.
- The Sensors in the growing beds need to monitor the amount of nitrate in our growing beds and if it is underutilized, it **creates algae** that compete for nutrients with our plants. So, we have to **plan for optimum utilization**.

Controlled Environment Design for Aquaponics

The controlled environment is designed to entertain a change in the number of fish tanks and grow-beds, So our monitoring system needs to be scalable to accommodate change, without breaking the already existing system. To make the whole plant an energy-efficient farm, we will use gravity to manage water flow from the fish tanks to the grow bed, we will only use electricity to pump the freshwater from the grow beds back to the fish tanks.

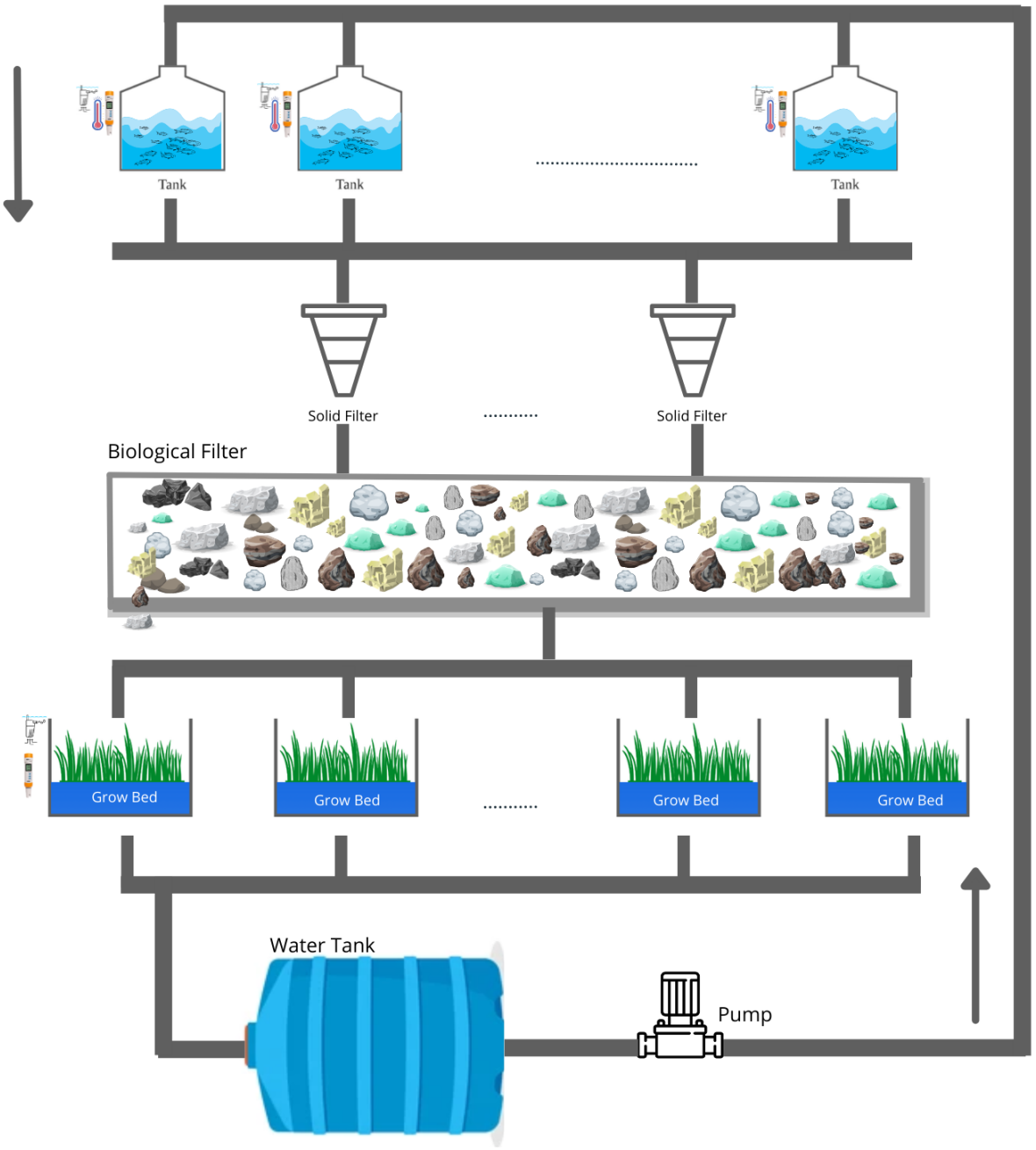


Fig 2: Controlled Environment design for Aquaponic System

Features

- Monitor and control oxygen levels in the fish tank and hydroponic grow beds
- Monitor and control pH value of water in the fish tank and hydroponic grow beds
- Monitor and control temperature of the fish tank
- Monitor and control water-level in different tanks and grow beds

Final Goal

What we aim to achieve finally is a controlled environment aquaponics that is managed by an almost real-time monitoring system that controls each metric using different sensors and actuators. And the farm will need 1 or a maximum of 2 people to run the whole farm operations, starting from seeding and harvesting.

System Components

The types of sensors and actuators we implemented for simulation are as follows.

- **Hardware**
    - **SENSORS / Simulated**
        - Ultrasonic sensor(Water-Level Sensor)
        - pH sensor
        - Dissolved Oxygen Sensor (PPB) ->(1mg/L=1000ppb)
        - Waterproof Temperature sensor
- **Software & Protocol**
    - MQTT
    - Kafka<-->Zookeeper
    - InfluxDB
    - Portainer Docker Image Manager
    - Android (FrontEnd)
    - NodeJS(BackEnd)
    - Python (Broker)
    - Node-Red Dashboard
    - Web Interface and UI(Graphana)

General Architecture of Our System

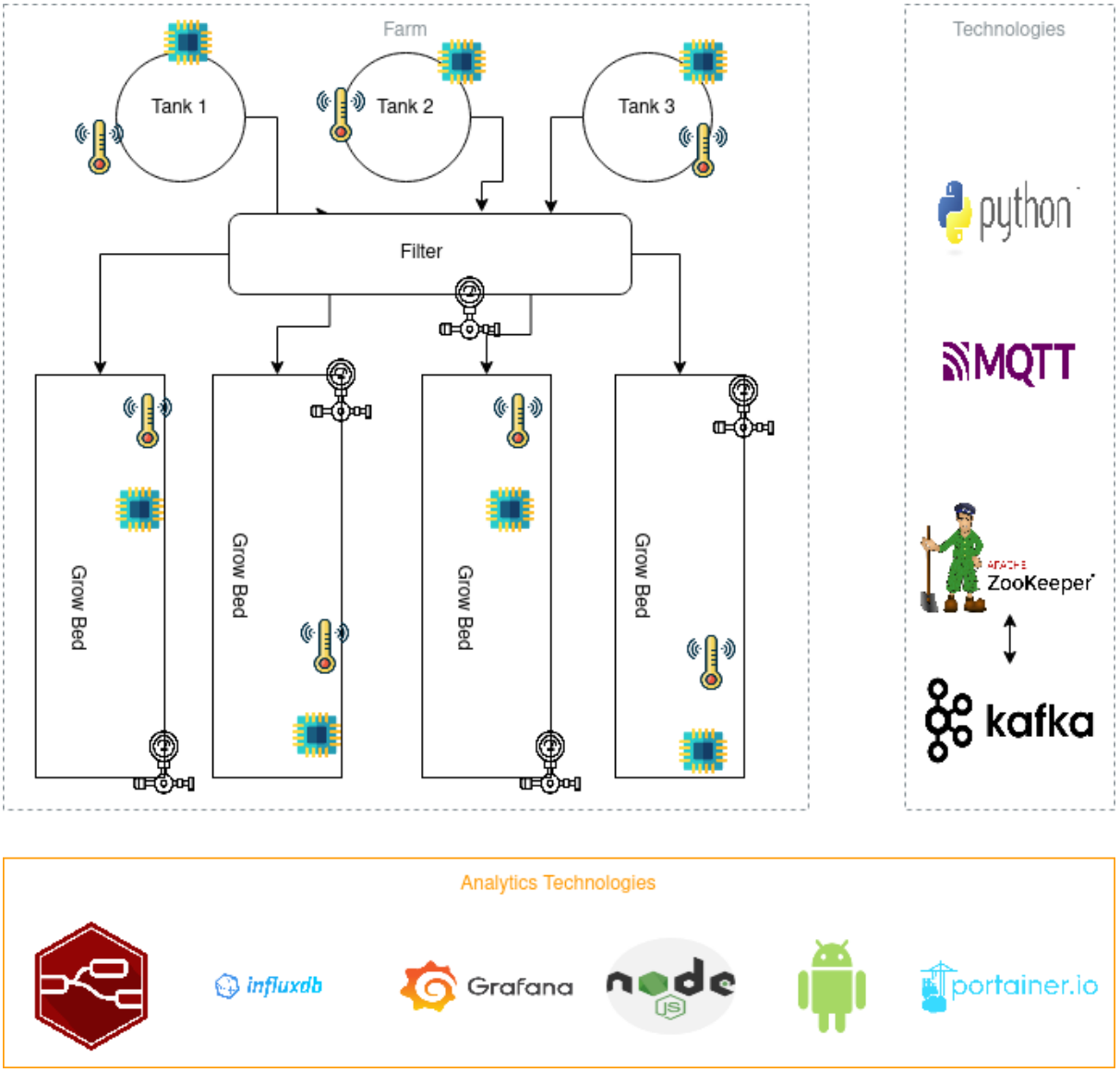


Fig 3: General Architecture of our system

DataFlow Diagram of the Aquaponics System

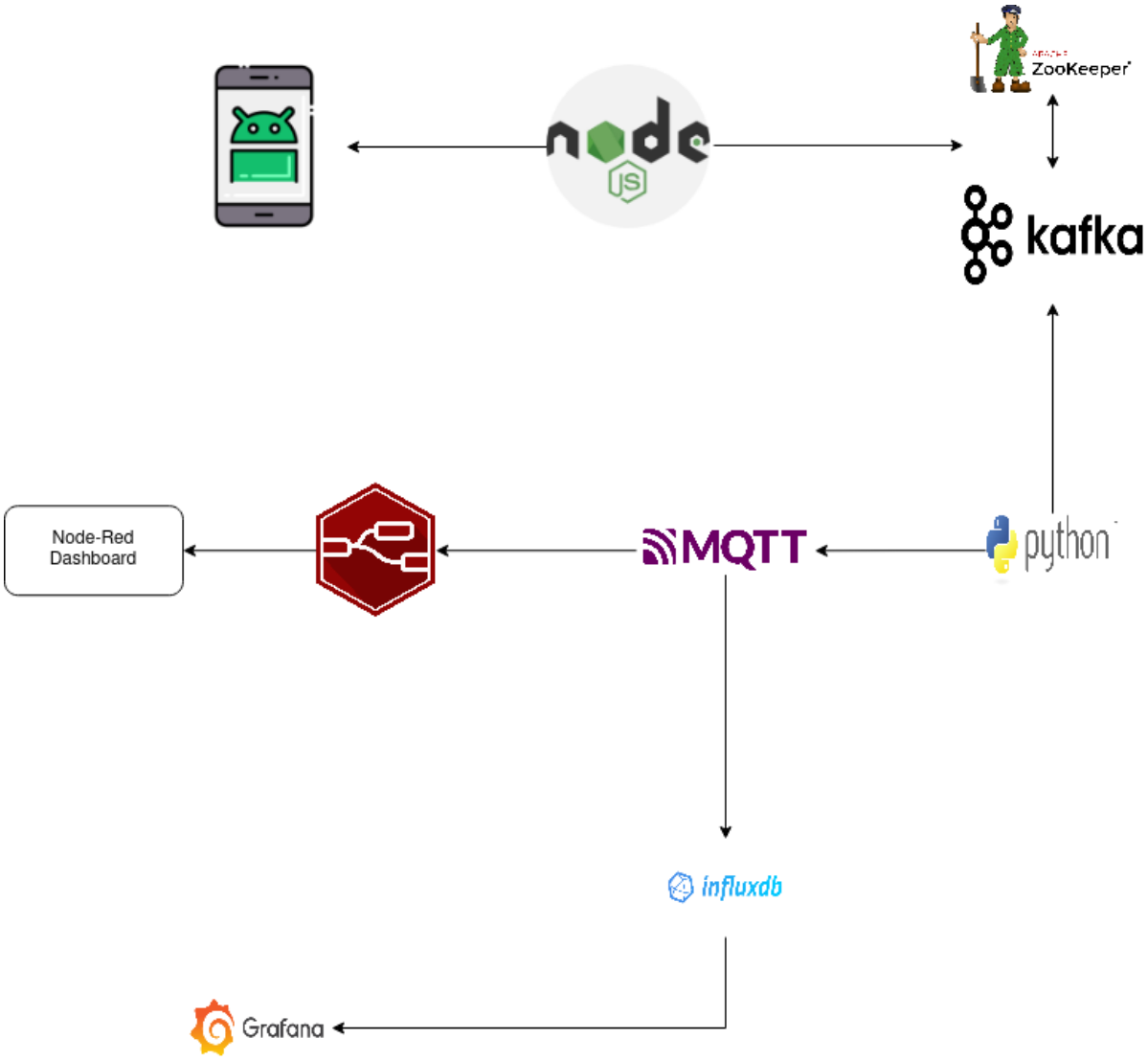


Fig 4: Data Flow Diagram of our Aquaponic System

UseCases

- ☐ When the metrics are abnormal (higher or lower) our Aquaponics Controlled Environment system will trigger the specific Actuator to adjust the specific metric under monitoring
    - Tank - when the tank water temperature goes down less than 10 trigger action on the temperature heater
    - Grow-Bed - When the Grow-Bed water temperature goes down less than or more than the accepted temperature, it will trigger action on the temperature heater

- ☐ Those Behaviours are considered on the code simulating the sensor data and when the abnormal temperatures are reached it will simulate the behavior of the actuator by self-regulating itself.

- ☐ Our Aquaponics Controlled Environment system is divided into two parts, i.e The Fish-Tank and Grow-Bed

- ☐ Our general development approach of this system is considering the following characteristics:
    - ☐ **Scalability**: To this end, our system is designed and developed to accommodate changes in the number of Grow-Beds, Fish-Tanks, Number of Sensors without breaking the whole system. We can add more Fish-Tanks, Grow-Beds, and Sensors and the system will dynamically accommodate the changes made.
    - ☐ **The Realness of Simulated Data:** As anyone who worked with random data simulation might understand, generating data that seems reality is tricky. To avoid such unrealistic data jumps we have put a considerable amount of time and work to make it look more real.

- ☐ We have Provided two types of User Interface to our farmers, using 2 different technologies:
    - ☐ **Component-Oriented View using Node-Red Dashboard:** we have provided this user interface to provide the farmer view to check the status of each tank and grow-bed.
    - ☐ **Metrics-Oriented View using Grafana:** we have provided this view to our farmers to help them check the farm metrics like temperature, PH of all the

components in the same place. This is important for farms that grow multiple crops at the same time.

Component-Oriented View using Node-Red Dashboard

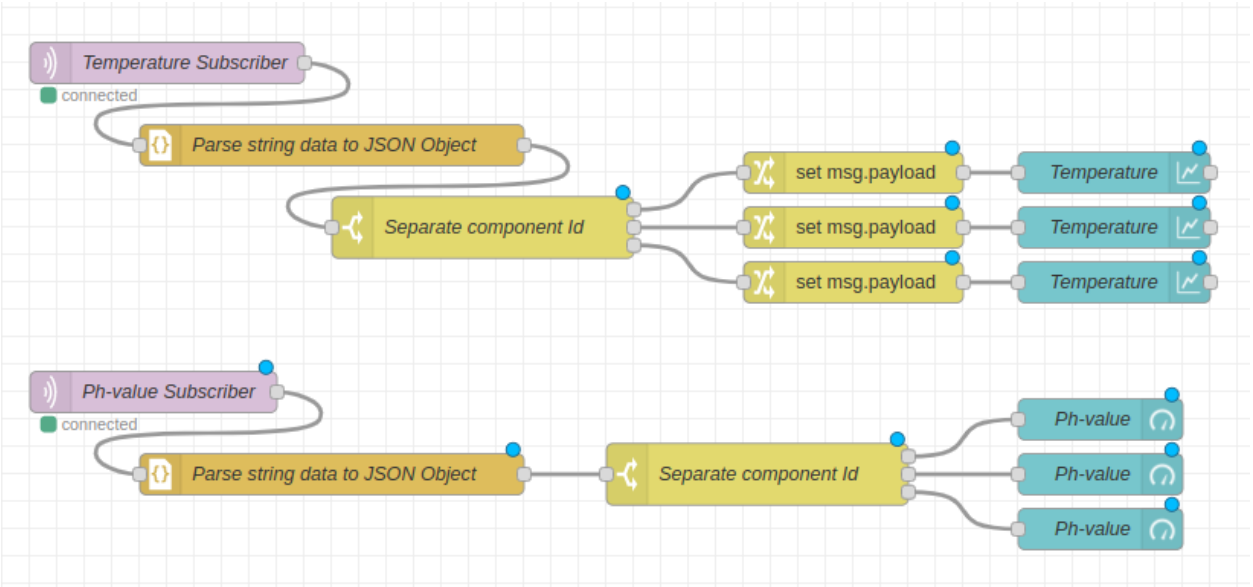
As mentioned above, we have defined two flows for the project.

1. **Tank Flow** - describes the flow of tank system in the aquaponics. Each tank has Temperature Sensor, Ph-Value Sensor, Oxygen level sensor, and water level sensor.
2. **Grow Bed Flow** - describes the flow of grow beds in aquaponics. Each grow-bed has two Temperature Sensors, two Ph-Value Sensors, two Oxygen level sensors, and two water level sensors. The number of sensors can be varied as necessary.

The flows mentioned below have been implemented using node-red and each flow is monitored through the UI provided by the node-red.

- When the temperature is abnormal (higher or lower) then trigger the Air conditioner to adjust the temperature.
- When the Oxygen level is abnormal (lower or higher), trigger the oxygen aerator (adjust the oxygen level)
- When the water level increases,
    - Tank - open the valves and release water to the filters
    - Grow Bed - open the valves and release water to the grow bed
- When the water level decreases – pour in water
- When the PH value changes, adjust the PH Value to the normal range.

Tank Flow



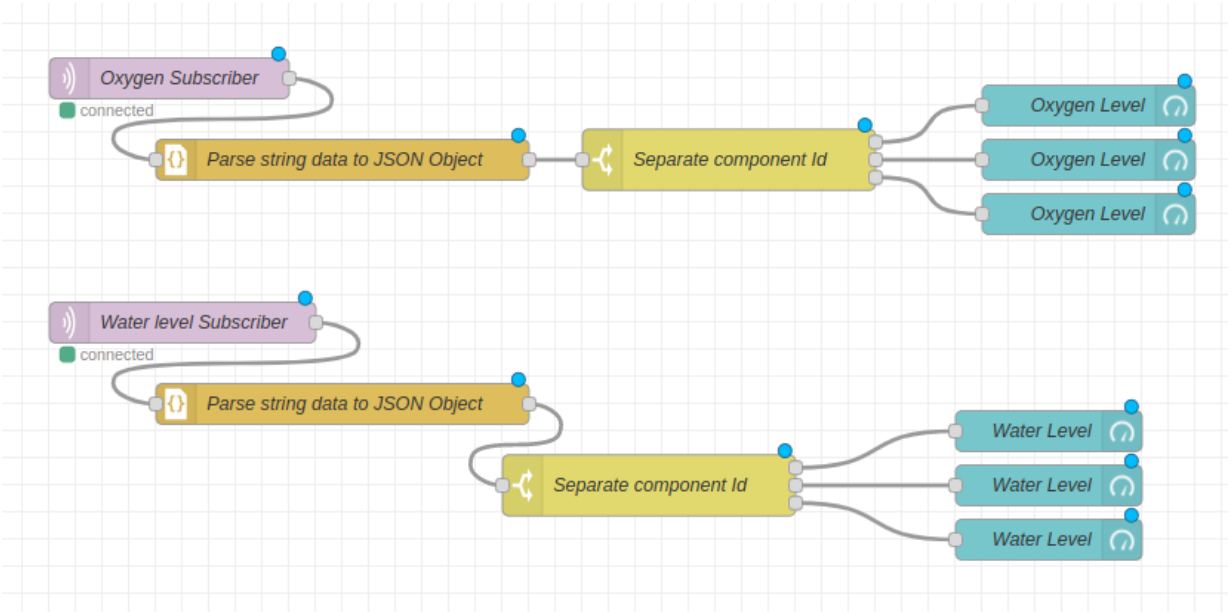


Fig 5: Tank Flow - Temperature, Ph-Value, Oxygen and Water level

Tank monitoring UI

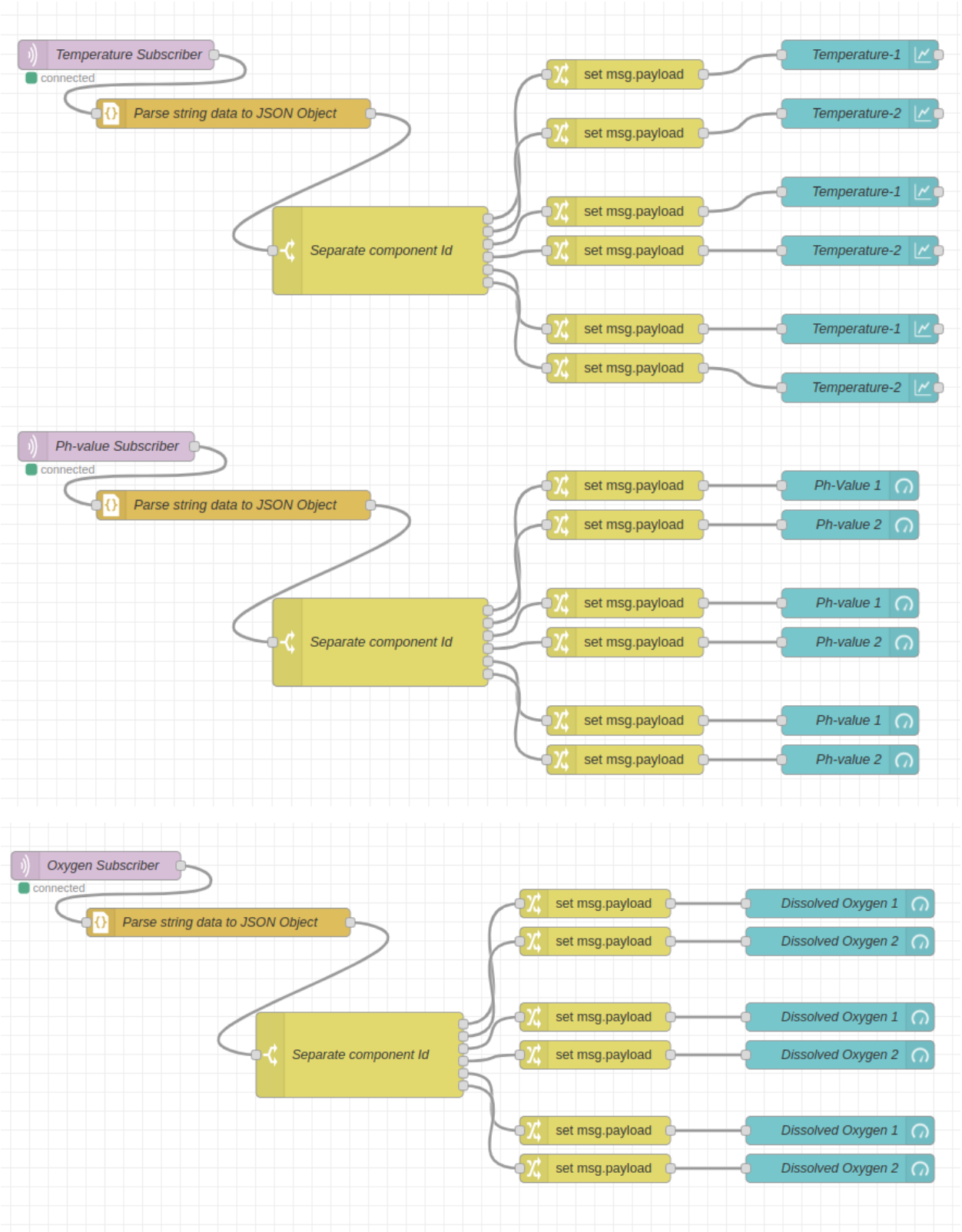
Number of Tanks - 3

Number of Sensors (temperature, ph-value, oxygen level, water level sensor) - 1 per tank

Fig 6: Tank Monitoring (Temperature, Ph-Value, Oxygen and Water level) UI - Nodered

Temperature is monitored using a line chart. A gauge diagram is used to monitor ph-value and dissolved oxygen. Similarly, a level diagram is used to meter the water level.

Grow-Bed Flow



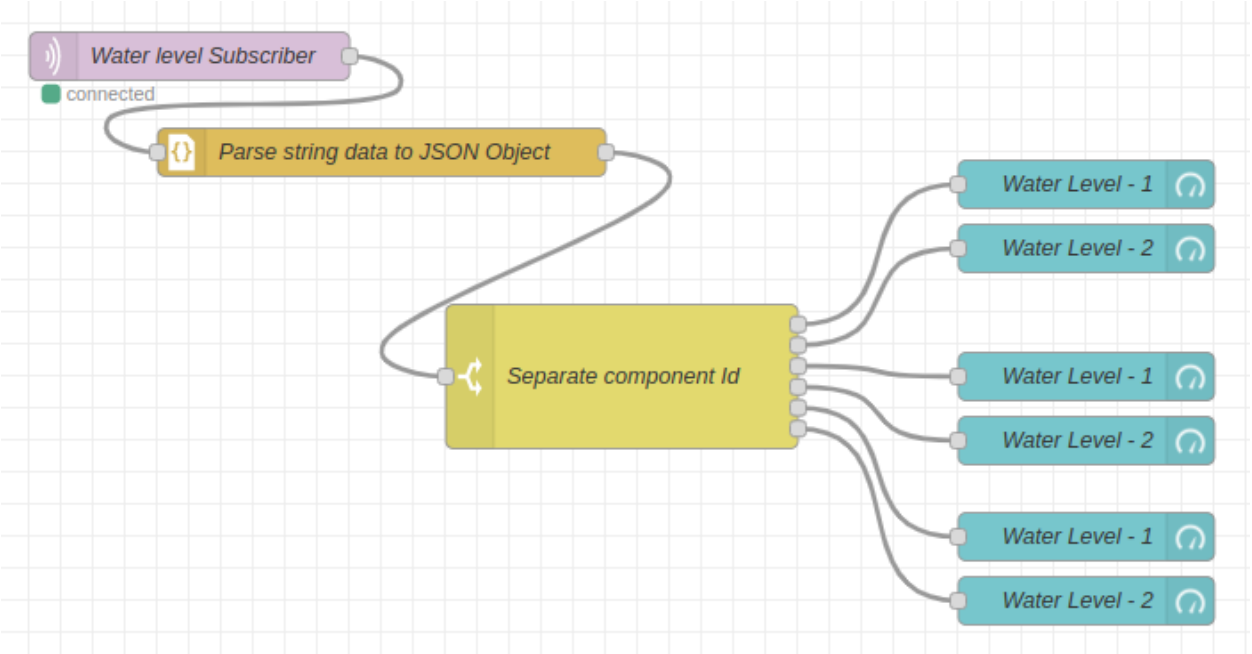


Fig 7: Grow Bed Flow - Temperature, Ph-Value, Oxygen and Water level

GrowBed - monitoring UI

Number of Tanks - 3

Number of Sensors (temperature, ph-value, oxygen level, water level sensor) - 2 per tank

Fig 8: Grow Bed Monitoring (Temperature, Ph-Value, Oxygen and Water level) UI - Nodered

Metrics-Oriented View using Grafana

Fish-Tank Monitoring

Each Fish-Tank is equipped with one of each sensor type, i.e. Temperature, PH, Water-Level, and Oxygen sensors. In this view, the farmer can see the level of each metric in all the fish tanks.

Fig 9: Fish-Tank Monitoring - Grafana

Fish-Tanks PH Monitor

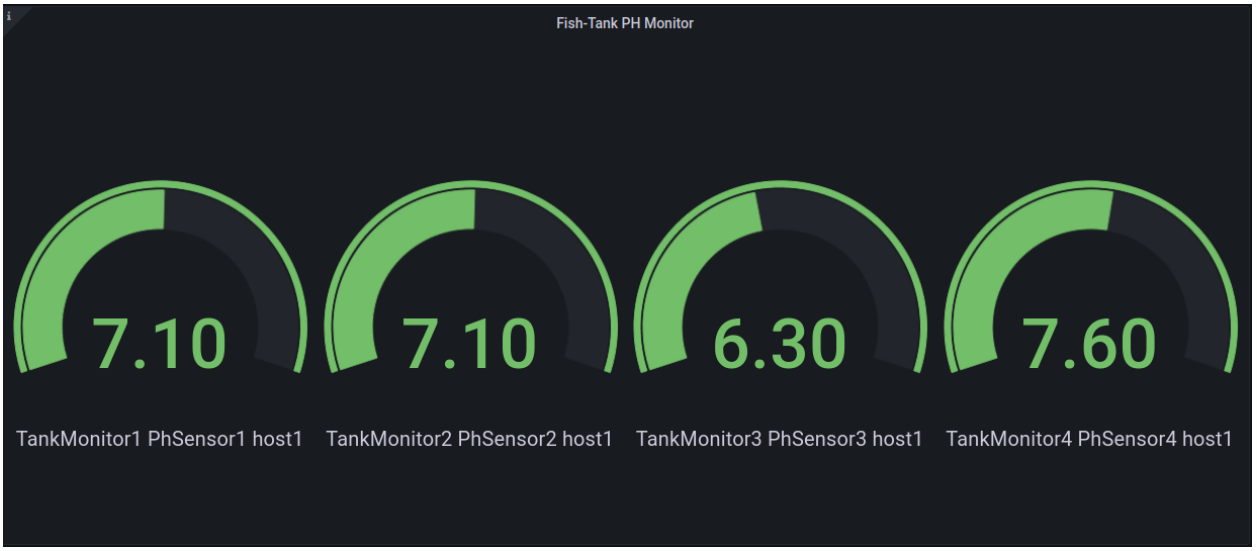


Fig 10: Fish-Tank PH Monitor - Grafana

Fish-Tanks Temperature Monitor

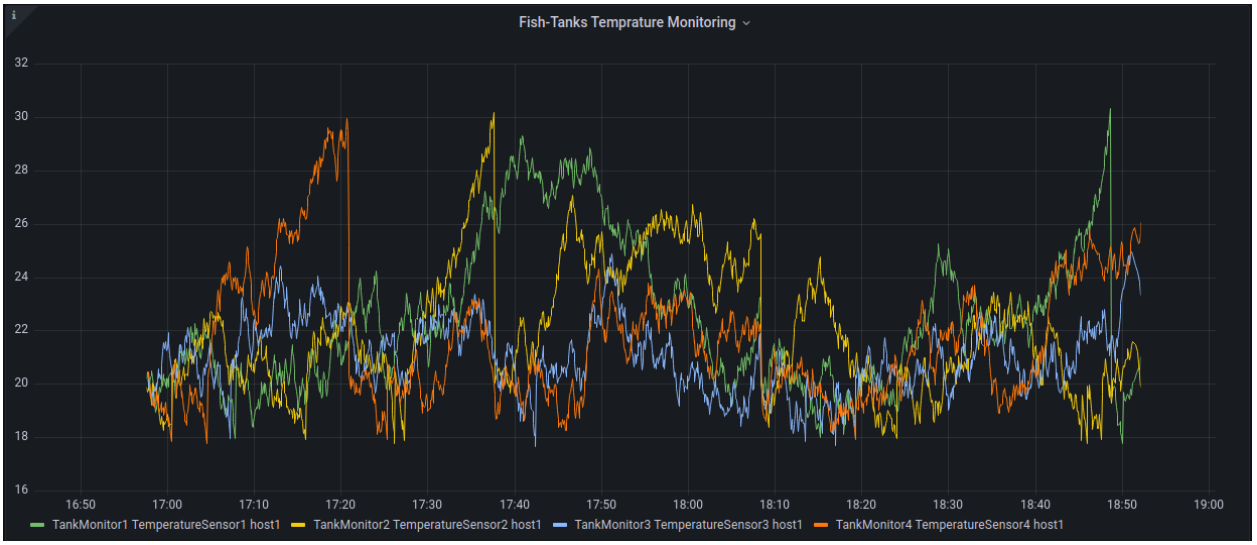


Fig 11: Fish-Tank Temperature Monitor - Grafana

Fish-Tanks Water-Level Monitor

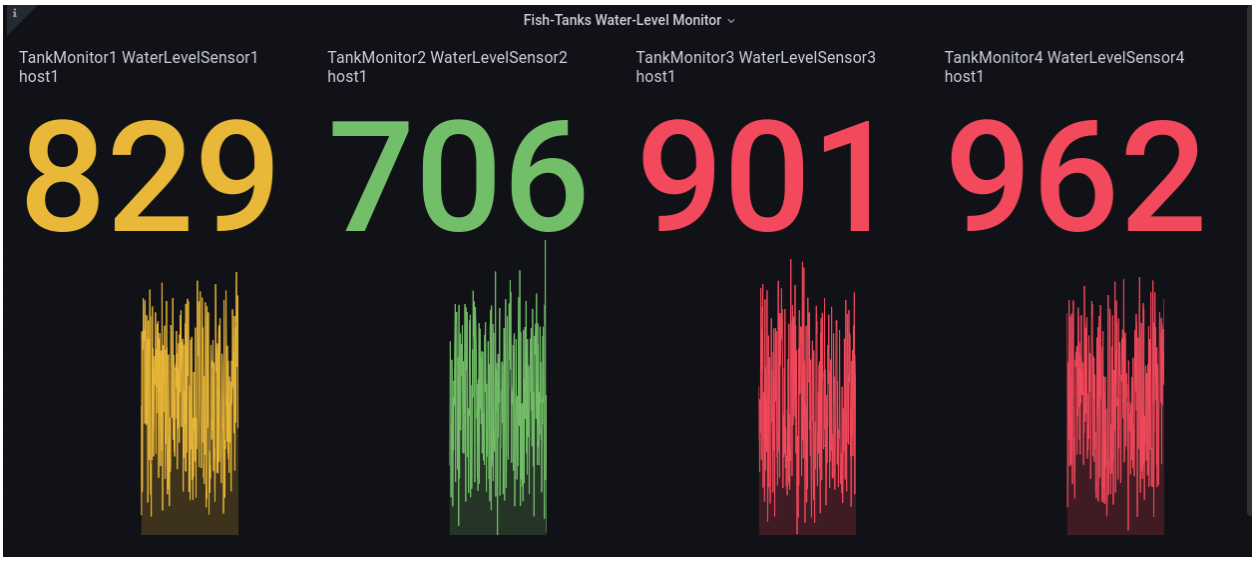


Fig 12: Fish-Tank Water-Level Monitor - Grafana

Fish-Tanks Oxygen-Level Monitor

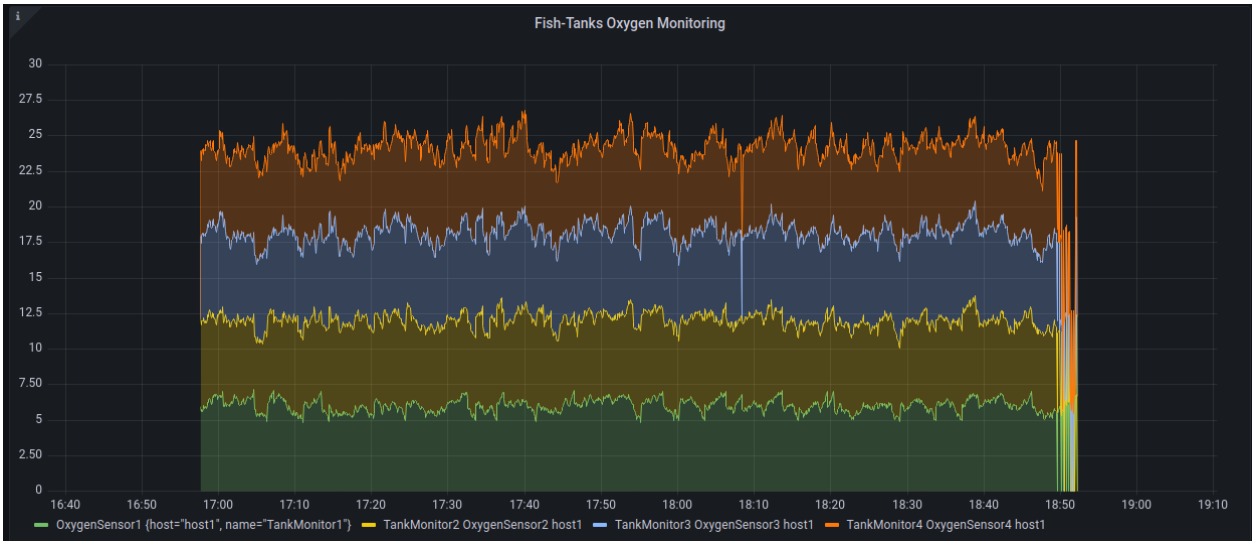


Fig 13: Fish-Tank Oxygen Level-Value - Grafana

Grow-Bed Monitoring

Each Grow-Bed is equipped with two of each sensor type, i.e. Temperature, PH, Water-Level, and Oxygen sensors. Each sensor is placed in the two ends of the grow-beds to measure the healthiness of the grow-beds. In this view, the farmer can see the level of each metric in all the fish tanks.

Fig 14:Grow-Bed Monitoring (Water level and PH) - Grafana

Each grow-bed is monitored using two panels using the sensor data we are gating from both the water entrance and exit of the grow-beds

Fig 15:Grow-Bed Monitoring (Temperature and Oxygen) - Grafana

Grow-Bed PH Monitor

Fig 16: Grow-Bed PH Monitoring - Grafana

Grow-Bed Temperature Monitor

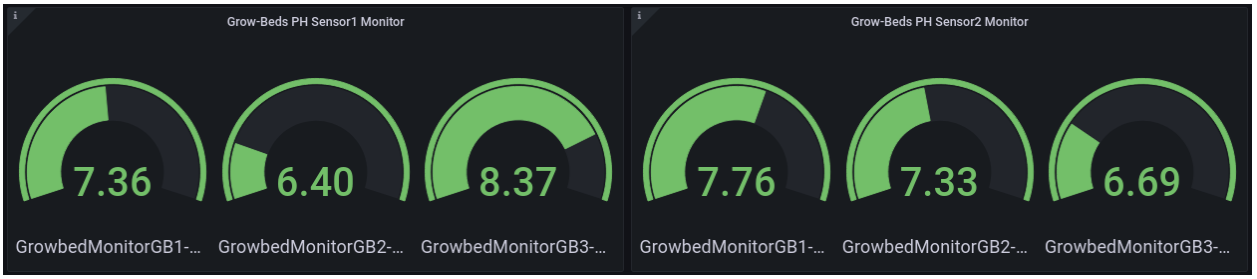


Fig 17: Grow-Bed Temperature Monitoring - Grafana

Grow-Bed Water-Level Monitor

Fig 18: Grow-Bed Water-Level Monitoring - Grafana

Grow-Bed Oxygen-Level Monitor

Fig 19: Grow-Bed Oxygen-Level Monitoring - Grafana

Frontend Application

This module enables end-users to manage their farm using their handheld mobiles. This includes seeing the status of their farm, getting a notification on sensitive conditions, and executing actions.

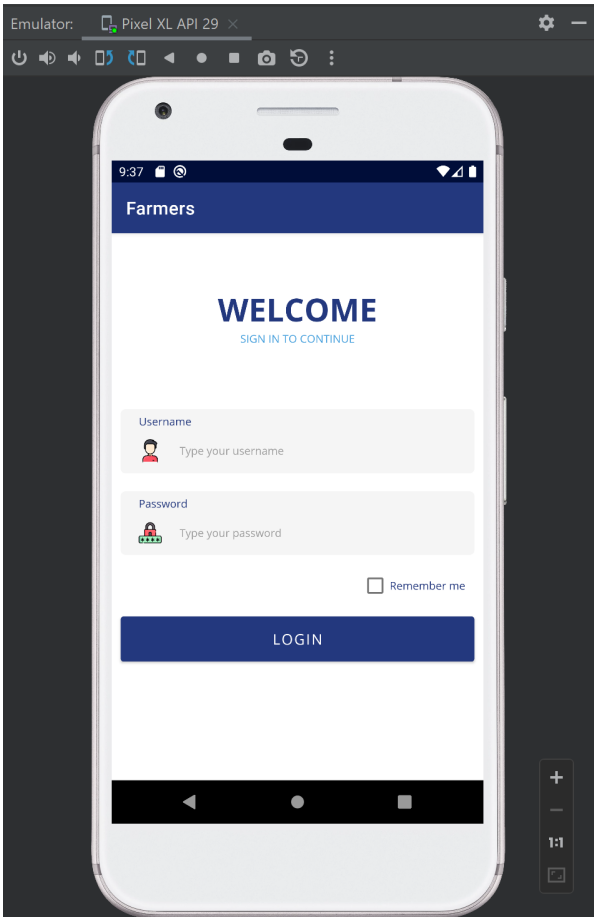


Fig 20: Login screen of the application

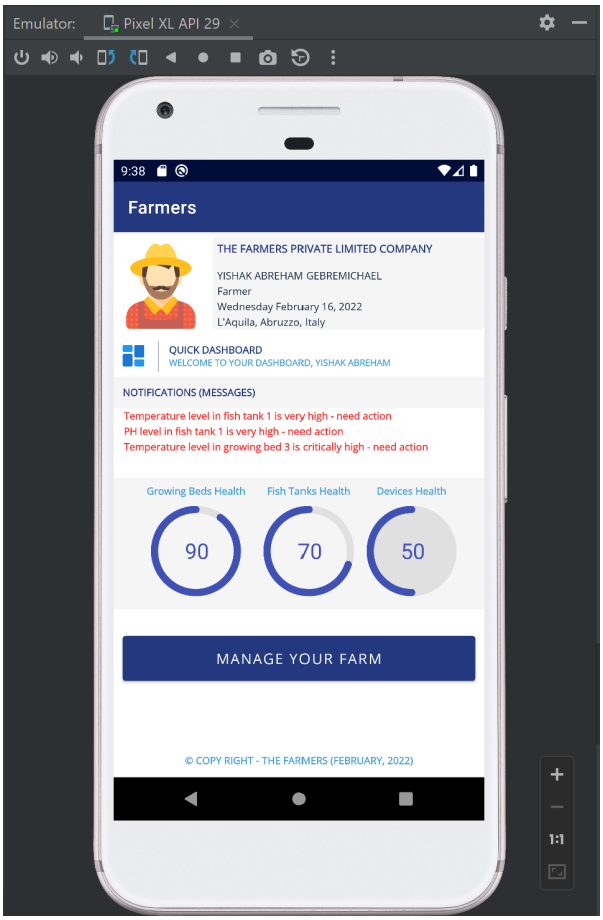


Fig 21: Dashboard of the application

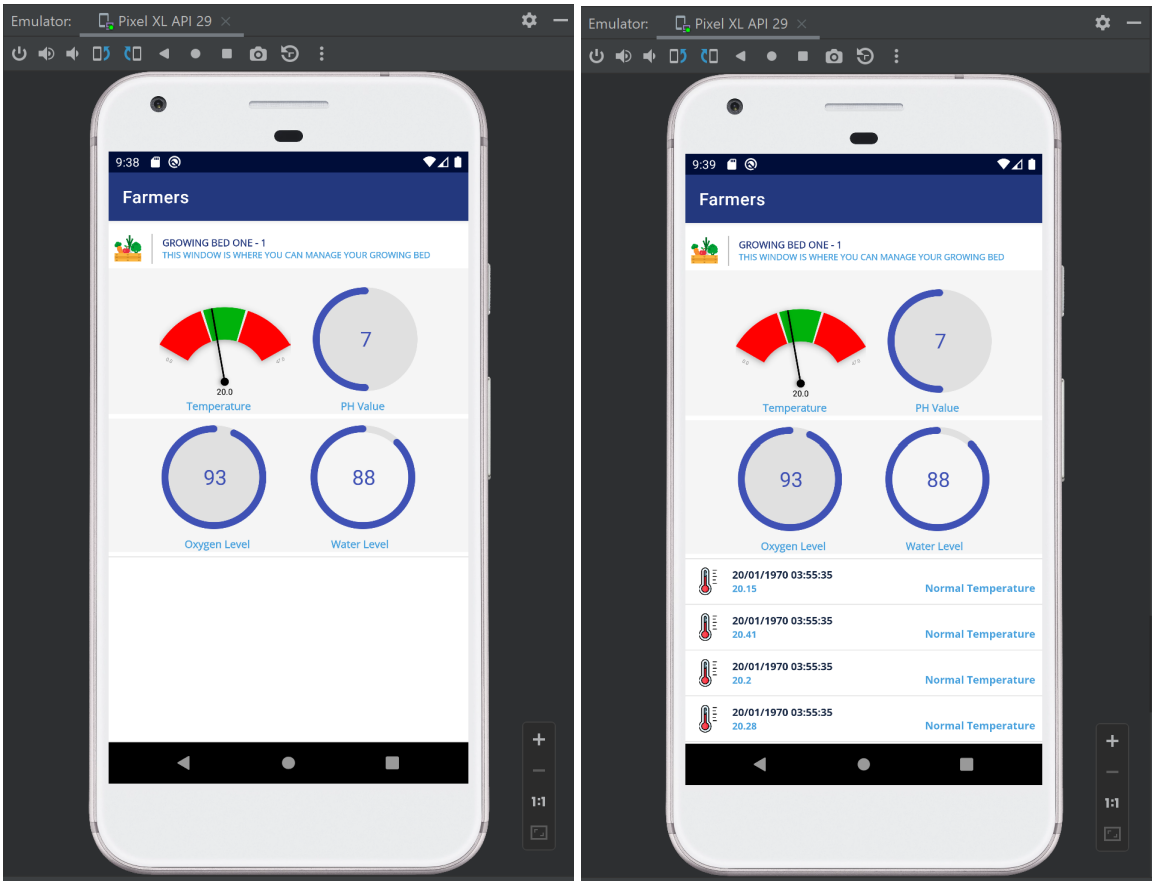


Fig 22: Screen for managing the growing beds and fish tanks

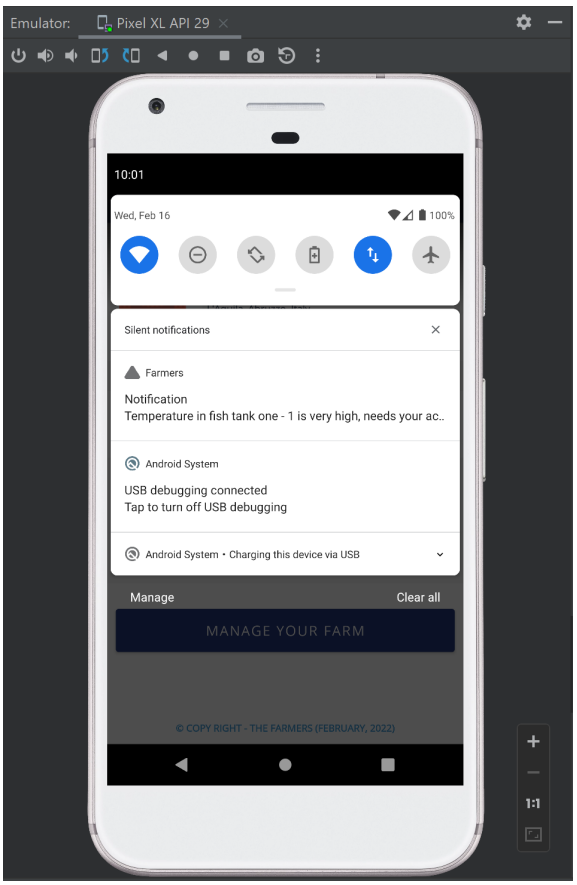


Fig 23: Notification