Identification of Technical Practices for Climate-Smart Agriculture (CSA) in Indonesia: A Case Study in the Sukabumi Regency, West Java

Output 3 – Identify Technologies for Automatic Irrigation and Fertiliser and Design an Integrated System for the Suitable Conditions as per the Geographic Location Selected

Finalise the Feasibility Analysis for the Integration of the Two Systems

D3.4.1

United Nations Environment
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Prepared for	United Nations Environment Programme (UNEP)
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1 Introduction

This report is part of a technical assistance (TA) project to identify and design suitable climate-smart agriculture (CSA) technologies and associated systems for engancing climate change adaptation in the agriculture sector in Indonesia.

1.1 Scope of the Report

This report details the design of the fully integrated system including the architecture of the system, system specifications and operating conditions. This integrated system consists of automatic irrigation and fertilisation that integrate with the system for the identification of water content and soil chemistry on agricultural land.

1.2 Report Structure

This report is divided into the following chapters:

- Chapter 1 presents a comprehensive overview of existing irrigation technology in Indonesia, with particular emphasis on conditions in Sukabumi Regency. This review aims to provide in-depth insight into the challenges and opportunities within the irrigation sector that will be addressed through the development of integrated systems.
- Chapter 2 delves deeper into CSA concepts and practices, focusing on how irrigation technologies can integrate with CSA principles to reduce greenhouse gas emissions and create more sustainable and adaptive agriculture.
- Chapter 3 details the proposed integrated system design. This section will build on the results of previous activities, including the work of working groups, technology identification, and macro system development. The design will include plans to optimize water use efficiency, reduce emissions, and increase agricultural productivity, while taking into account the results and outputs of previous activities.

2 The Application of Irrigation Technology in Indonesia

2.1 A Summary of Available Research on Drip Irrigation, Sprinklers and Fertigation

In general, studies on the efficient drip irrigation, sprinkler and fertigation technologies in various agricultural conditions have been conducted, and these technologies can be implemented in Indonesia. Control of irrigation and fertigation for crop cultivation using systems that integrate technologies such as the Internet of Things (IoT) and soil moisture sensors have also been carried out. This approach helps improve water use efficiency, ensure optimal soil moisture, and reduce resource waste.

2.1.1 Drip Irrigation Technology

Examples of the application of drip irrigation in various locations in Indonesia and showing how this system can be adapted to the specific needs of each agricultural land are summarised as follows:

- Gulo *et al.* (2022) researched on a solar-powered automatic drip irrigation system for pakcoy cultivation. The system is controlled with an Arduino microcontroller and HC-SR04 sensor to regulate the volume of water.
- Kusumawardani *et al.* (2019) examined the use of IoT in drip irrigation for citrus plants. This system controls watering automatically based on soil moisture.
- Azam *et al.* (2023) researched on an IoT-based drip irrigation systems using YL-69 soil moisture sensors. The system monitors the condition of the soil and organizes watering on a scheduled basis.
- Franata *et al.* (2014) developed an automatic drip irrigation system based on changes in soil moisture content using Arduino Nano microcontrollers.
- Jamal *et al.* (2021) investigated on an IoT-based drip irrigation systems for vegetable crop cultivation, using microcontrollers and YL-69 Soil Moisture sensors.
- Susilowati *et al.* (2020) studied on drip irrigation technology transfer for cayenne pepper cultivation in dry land in North Lombok.
- Suryatini *et al.* (2018) reviewed the soil temperature and moisture data acquisition system in IoT-based automatic drip irrigation.
- Azzani *et al.* (2022) examined soil temperature and moisture control systems on IoT-based drip irrigation for red lettuce plants.
- Kasiran (2006) studied the technology of drip irrigation "Ro Drip" for the cultivation of vegetable crops in lowland dry lands.
- Alfi *et al.* (2014) examined controlled drip irrigation systems in tobacco plants, using manual control systems and IoT.
- Widiastuti & Wijayanto (2018) implemented the drip irrigation technology in dragon fruit cultivation.

- Munir *et al*. (2015) studied the application of drip irrigation on red chili plants in Enrekang Regency.

These studies demonstrate the various applications and benefits of drip irrigation technology in Indonesia, especially in improving water use efficiency and facilitating agricultural management.

2.1.2 Sprinkler Technology

Some studies on sprinkler irrigation systems in Indonesia are summarised as follows:

- Prastowo *et al*. (2023) studied the smart irrigation applications in P4S Buana Lestari, Nganjuk Regency, East Java. Focus on IoT-based sprinkler irrigation technology for melon cultivation.
- Tusi & Lanya (2016) discussed on the design of portable sprinkler irrigation for pakcoy plants, highlighting initial and operational investment costs.
- Sirait *et al*. (2022) examined the efficiency of sprinkler irrigation technology on Farmer Group land in North Tarakan, Tarakan City.
- Ridwan *et al*. (2014) designed a mini sprinkler type micro irrigation network for tomato plants in the Outdoor Laboratory of the Irrigation Center.
- Saptomo *et al*. (2013) developed an automatic bulk irrigation system based on microcontroller system.
- Kiik *et al*. (2012) studied a sprinkler irrigation system in Oesao Village, Kupang Regency.
- Fajar *et al*. (2019) designed the hand move sprinkler irrigation for dry land and evaluation of its performance.
- Sirait *et al*. (2020) developed a solar-powered automatic irrigation technology in Cahaya Tani Farmer Group, North Tarakan, Tarakan City.

These studies highlight innovation and efficiency in the use of sprinkler irrigation in various conditions and locations in Indonesia, illustrating their application in improving water use efficiency and crop productivity.

2.1.3 Fertigation Technology

The following summarise the various studies on fertigation in Indonesia:

- Jabbar, F.A. & Purnaningsih, N. (2022) discussed on the dissemination of fertigation installations to save water use in Beji Village.
- Suhartono S. *et al*. (2023) examined the drip fertigation and IoT-based microenvironmental control of lettuce plant growth.
- Fajar A.H *et al*. (2018) developed and tested the performance of fertigation control systems with automatic drip irrigation on vegetable crops.
- Wibawa I.M.A.D.T. *et al*. (2021) designed a nutrient mixing system in IoT-based hydroponic fertigation.

- Feriansari V. *et al*. (2021) discussed the design of nutrient and pH control in hydroponic fertigation systems for various types of leaf plants.

These studies highlight the innovation and application of fertigation technology in Indonesia, demonstrating the importance of integrating advanced technologies in improving water use efficiency and nutrients and supporting more sustainable agriculture.

2.2 Irrigation and Agricultural Practices in the Sukaraja District, the Regency of Sukabumi

2.2.1 Water and Agriculture at the Regency of Sukabumi

The agricultural land in the Sukabumi Regency is fragmented into small and scattered plots. While paddy fields have a shallow impermeable layer, other fields do not. These fields, interconnected by embankments or farm roads, support various crops with differing planting seasons, chosen based on market demands and climatic conditions. Water supply, primarily from surface sources, is distributed through channels or piping systems on a pre-set schedule. However, some areas, especially those distant from water sources, face water shortages, leading to planting delays, reduced harvests, or complete crop failures. The measure of land size in Sukabumi is “patok”, that means an area of $400m^2$, which can be a basis of desain for the irrigation system for implementation. A few of agricultural products cultivated iin Sukaraja are shown in Figure 2.1 .

Figure 2.1 Agricultural products of Sukaraja include chilli, flower and rice

2.2.2 Irrigation in Sukabumi Regency

Surface irrigation predominates in Sukabumi Regency, particularly for rice cultivation, encompassing 157 government-managed areas covering 28,650 hectares. The irrigation approach is straightforward, guided by land area and commodity prices. Farmers utilize gravity, manual watering, or field reservoirs to channel water from irrigation networks. Attempts to use sprinklers haven’t been sustained due to no noticeable difference in harvest outcomes compared to manual methods.

2.2.3 Introduction of Modern Irrigation Technologies

Netafim Indonesia and Sekolah Vokasi IPB conducted a seminar introducing smart greenhouse and precision irrigation technologies. The seminar, featuring insights from both the company and the school, highlighted the advantages, challenges, and components of these systems. A project at Sekolah Vokasi IPB's Teaching Farming area, employing sensor-based irrigation and fertigation control, was showcased. This initiative in Sukabumi demonstrates the development and application of modern irrigation systems, promising enhanced water efficiency, crop yield, and environmental sustainability. Yet, challenges like cost, skill deficits, and social acceptance remain, calling for more research, education, and collaborative efforts.

2.2.4 Gender Equity in Sukabumi Agriculture

Sukabumi District, with a Gender Empowerment Index (GEI) score of 72.91, indicates relative economic and political empowerment of women compared to men. Women actively participate in cultivating chrysanthemum, chili, and paddy, engaging in nursery work, maintenance, harvesting, and irrigation. However, they often engage in lighter activities due to societal stereotypes and earn lower wages (Rp. 50,000) than men. While men exert more influence in choosing commodities based on market information, the concept of 'Widow land' (Tanah Janda) reflects a societal structure where land cultivated by women requires more agricultural intervention.

2.2.5 Irrigation Technology Adaptation in Sukaraja's Agricultural Setting

Sukaraja, in Bogor Regency, West Java, features rice fields predominantly using technical irrigation, including surface irrigation with adequate infrastructure but high water consumption. In dry seasons, some areas face drought, making them suitable for less water-intensive crops like corn, soybean, or peanut, which can benefit from efficient sprinkler or drip irrigation. Subsurface drip systems, delivering water directly to roots, are also viable. In water-scarce upland and home garden areas, adopting water-saving irrigation methods like drip or sprinkler systems is crucial. These methods are particularly beneficial for Sukaraja's diverse crops, including flowers, vegetables, and chili peppers, offering improved water and nutrient management and reduced weed and pest issues.

2.3 Fully Integrated System Planning for the Sukaraja District

The fully integrated system being developed for Sukaraja, Sukabumi, is a significant advancement in agricultural technology, incorporating several sophisticated components with an emphasis on Climate-Smart Agriculture (CSA) principles. This system includes soil monitoring sensors, an irrigation and fertigation system, and advanced field control Figure 2.2.

Central to this system are field-implanted soil sensors, designed to provide timely data on soil conditions. These sensors are managed through a field controller RTU that connects directly to a database and user dashboard via a central computer. Although the system primarily relies on direct field sensor technology, it also offers the flexibility to incorporate soil condition data from remote sensing and UAVs (Unmanned Aerial Vehicles), aligning with CSA objectives of utilizing innovative technologies for sustainable agriculture.

The system aligns with the draft guidelines for applied irrigation planning from the PUPR, offering three micro-irrigation options: drip, sprinkler, and furrow. After thorough evaluation, the drip irrigation system was selected, particularly the drip line technique without emitters. This decision, guided by discussions with the working group, reflects CSA’s focus on sustainable practices, as this technique is feasible for implementation by farmers on a self-sufficient basis and promotes efficient water use.

For fertigation, the system incorporates three techniques: gravity injection, venturi, and controlled mixer or pump. Given the CSA's emphasis on sustainability and resource efficiency, the venturi injection technique is favored in Indonesia due to its ease of acquisition and implementation, even though mixer or pump controlled technology offers superior results but requires more energy and skilled human resources for operation and maintenance.

In Sukaraja, Sukabumi, where irrigation and fertigation technologies are relatively new, the chosen technologies—drip line irrigation and fertilizer injection using a venturi system—are the simplest yet reliable options. These technologies are in line with CSA considerations, balancing efficiency, reliability, and affordability, and are conducive to local farmers' adoption of modern, sustainable irrigation and fertigation practices.

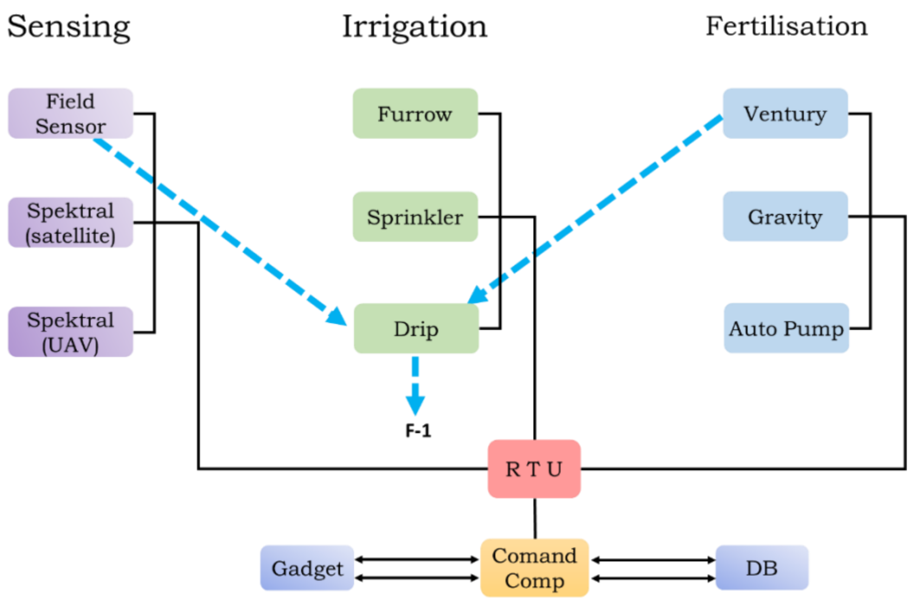


Figure 2.2 Integrated system planning concept for preferred locations

3 Climate Smart Agriculture and Greenhouse Gases Emission

The concept of Climate Smart Agriculture (CSA) is an innovative approach that aims to address the challenges of climate change in the agricultural sector. CSA is built on three main pillars: first, sustainable improvement of agricultural productivity and income; second, adaptation and resilience to climate change; and third, reduction and/or absorption of greenhouse gas emissions. This chapter will briefly explain each of these three pillars contribution to the resilient and sustainable agricultural systems.

3.1 Productivity

The use of soil moisture and chemistry monitoring systems integrated with automatic irrigation and fertigation systems significantly impacts agricultural productivity: Advanced monitoring systems ensure more accurate water usage, significantly improving water productivity. Well-managed irrigation can increase water productivity compared to traditional irrigation methods. This is crucial in Indonesia, where water for irrigation is often a limited resource. With more efficient nutrient and water management, land productivity can increase. The application of smart irrigation technology in agricultural land has shown an increase in crop yields.

More efficient use of water and fertilizers not only saves resources but also reduces operational costs and input costs. The use of traditional irrigation technology often leads to excessive or inefficient water use, resulting in lower productivity and higher costs. Automated monitoring and fertigation systems have been proven to significantly improve the efficiency of resource use.

By increasing efficiency in resource usage, these smart irrigation systems not only support agricultural productivity but also help Indonesian farmers face challenges such as water scarcity and rising production costs. The implementation of this technology is a step forward in Climate Smart Agriculture practices, supporting sustainable efforts to address global and local food issues.

3.2 Resiliency

The integration of soil moisture and chemistry monitoring systems with automated irrigation and fertigation plays a crucial role in enhancing the resilience of agricultural practices. With precise water and nutrient management, crops can grow faster and healthier, allowing for more harvesting cycles within a year. Precision agriculture practices, including automated irrigation, can increase the number of harvests annually, depending on the crop and regional climate conditions.

The system's ability to provide consistent soil moisture levels enables farming even in prolonged dry seasons. Smart irrigation systems can extend the growing season by maintaining optimal soil conditions, even in areas experiencing significant seasonal variations in rainfall. Automated irrigation and fertigation systems offer a robust response to climate variability. Such systems help maintain crop yields even under variable and extreme weather conditions, thereby stabilizing food production.

Continuous monitoring and adjusted irrigation help in maintaining soil structure and preventing soil erosion and degradation. Soil health management is a key component in building agricultural resilience, as healthy soils contribute to better water retention and resistance to erosion, crucial in coping with unpredictable weather patterns. By ensuring the efficient use of water and fertilizers, these systems reduce the risk of over-irrigation and over-fertilization, which can lead to detrimental environmental effects like waterlogging and nutrient leaching. The Food and Agriculture Organization (FAO) recognizes resource optimization as a critical factor in enhancing agricultural resilience, particularly in regions facing water scarcity.

In summary, the application of integrated soil moisture and chemical monitoring systems in CSA irrigation practices in Indonesia not only improves productivity but also builds resilience against the impacts of climate change and variability. These systems enable farmers to adapt more effectively to environmental challenges, ensuring sustainable agricultural production and food security.

3.3 Emission

3.3.1 Conventional System

Greenhouse gas (GHG) emissions in conventional modern irrigation systems can arise from several sources, some of which overlap with those of automatic irrigation systems but may be more pronounced due to less efficient water use and energy management. Here are the primary sources of GHG emissions in conventional modern irrigation systems:

- **Energy Consumption for Pump Operation**: This is a major source of GHG emissions in any irrigation system. In conventional systems, the energy efficiency may be lower compared to more advanced, automated systems. If the energy for pumps is sourced from fossil fuels, it leads to significant CO2 emissions.

- **Fertilizer and Pesticide Use**: Conventional irrigation often involves the use of synthetic fertilizers and pesticides, which are energy-intensive to produce. Moreover, the application of nitrogen-based fertilizers leads to emissions of nitrous oxide (N2O), a potent greenhouse gas. Excess fertilizers can also leach into water bodies, causing eutrophication and subsequent methane emissions.

- **Water Overuse and Inefficient Distribution**: Conventional irrigation systems can be less efficient in water distribution, leading to over-irrigation. This can result in waterlogged soils, creating anaerobic conditions that are conducive to methane production.

- **Soil Erosion and Degradation**: Inefficient irrigation practices can lead to soil erosion and degradation. Degraded soils have a reduced capacity to act as carbon sinks, which indirectly contributes to increased atmospheric CO2 levels.

- **Emissions from Machinery and Equipment**: The use of machinery for the installation, maintenance, and operation of conventional irrigation systems, especially those running on fossil fuels, contributes to GHG emissions. This includes vehicles and equipment used for transporting materials and workers to and from sites.

- **Energy for Water Treatment and Delivery**: If irrigation water needs significant treatment or is transported over long distances, the energy used for these processes can contribute to GHG emissions. This is particularly relevant for large-scale irrigation systems that rely on water from distant sources.

- **Indirect Emissions Related to Water Source**: Similar to automatic systems, if the water source for the irrigation system is a reservoir or is pumped from deep underground, there may be associated GHG emissions.

To reduce these emissions, transitioning to more efficient irrigation methods, adopting renewable energy sources, improving fertilizer management, and enhancing soil health practices are essential strategies. These actions not only reduce the carbon footprint of irrigation but also contribute to overall sustainability in agriculture

3.3.2 Monitored and automated system

The role of integrated soil moisture and chemical monitoring systems in automated irrigation and fertigation can extend to significant impacts on emissions in agriculture:

- Reduced Emissions from Over-Fertilization: Automated fertigation helps in applying the precise amount of fertilizer needed, reducing the risk of over-fertilization. Over-fertilization leads to nitrous oxide emissions, a potent greenhouse gas. According to a study by the International Panel on Climate Change (IPCC), efficient fertigation can reduce nitrous oxide emissions from agricultural soils by up to 50%.

- Mitigation of Methane Emissions: Smart irrigation practices, particularly in rice cultivation, can significantly reduce methane emissions. Alternate wetting and drying in rice fields, can be precisely managed through automated irrigation systems, reduces methane emissions compared to traditional flood irrigation.

- Energy Efficiency and Emissions: Automated systems often use less energy than traditional methods, contributing to lower carbon emissions. The adoption of energy-efficient agricultural practices, such as solar-powered irrigation systems, can reduce the carbon footprint of farming activities.

- Impact of Reduced Water Use: Efficient irrigation reduces the energy required for water extraction and distribution. The FAO states that optimizing irrigation efficiency can significantly cut down energy use in agriculture, thus reducing associated carbon emissions.

- Soil Carbon Sequestration: Proper irrigation and nutrient management can enhance soil organic carbon, a key factor in carbon sequestration. Improved soil health through efficient irrigation and fertigation practices enhances the soil's capacity to store carbon, thereby reducing atmospheric CO2 levels.

In conclusion, the integration of soil moisture and chemical monitoring with automated irrigation and fertigation systems in CSA practices in Indonesia not only enhances productivity and resilience but also significantly contributes to emission reduction. By optimizing resource use and improving soil health, these systems play a crucial role in reducing the carbon footprint of agriculture, aligning with global efforts to mitigate climate change impacts.

3.3.3 Estimation of Emissions

The impact of irrigation practices on greenhouse gas (GHG) emissions is significant, primarily due to their influence on soil microbial activity and substrate supply. A review of existing research, investigated the effects of various irrigation management strategies on the emissions of nitrous oxide (N2O), carbon dioxide (CO2), and methane (CH4) (Sapkota et al., 2020). The review had found that implementing reduced irrigation methods, such as drip and sprinkler systems, was found to be effective in lowering the rate of methane emissions. In contrast, flood irrigation resulted in the highest methane emissions. The rate of carbon dioxide emissions generally increased under conditions of low irrigation. The effect of different irrigation strategies on nitrous oxide emissions was inconsistent, although a majority of the studies reported lower N2O emissions in continuously flooded field treatments. More field-based research is needed to assess the effects of varying rates of irrigation on GHG emissions in agricultural fields

Greenhouse gas (GHG) emissions in automatic irrigation systems can arise from several sources:

- Energy Consumption for Pump Operation: The most significant source of GHG emissions in automatic irrigation systems is the energy used to power pumps. If this energy comes from fossil fuel-based sources, such as coal or natural gas, it leads to direct emissions of carbon dioxide (CO2) and other greenhouse gases.

- Manufacture and Transportation of System Components: The production and transportation of irrigation system components (like pipes, pumps, and controllers) involve energy consumption, often from GHG-emitting sources. The manufacturing process of these materials (especially plastics and metals) also contributes to GHG emissions.

- Installation and Maintenance Activities: The installation of the irrigation system, including the transportation of materials and use of machinery, can contribute to GHG emissions. Additionally, maintenance activities over the system's life can also have an impact, depending on the frequency and nature of these activities.

- Energy Source for Monitoring and Control Equipment: Automatic irrigation systems often include monitoring and control equipment that requires electricity. If the electricity used is generated from fossil fuels, it contributes to GHG emissions.

- Indirect Emissions from Water Source: If the water source for the irrigation system is a reservoir or pumped from deep underground, there may be associated GHG emissions. For instance, large reservoirs can emit methane (CH4), a potent greenhouse gas, through the decomposition of organic matter in anaerobic conditions.

- Fertilizer Application: In systems integrated with fertigation (the application of fertilizers through the irrigation system), the production and use of fertilizers can be a significant source of GHG emissions, particularly nitrous oxide (N2O), which is a potent greenhouse gas.

To mitigate these emissions, the use of renewable energy sources for powering irrigation systems, efficient design and operation to minimize energy use, and sustainable manufacturing and maintenance practices are essential. Adopting renewable energy sources like solar or wind power for pump operation significantly reduces the GHG emissions associated with automatic irrigation systems.

Manufacturing, mobilization and installation are carried out once, not continuously and included in routine cultivation activities. GHG emissions from these activities do not include those calculated as a share of emissions from routine cultivation and irrigation activities.

The entire operation including pumps and electrically driven systems, which are the main source of emissions in irrigation activities. Electricity sources can be taken from the grid (PLN) or electricity generators with oil or gas fuel that will contribute to CO2 gas emissions. However, if electricity can be generated using solar panels, then emissions from electricity use become zero, replaced by the cost of production, mobilization and installation of solar power generation systems.

Example of calculation of the carbon emissions from a 400 m^2 chili farming land in Sukabumi using an automated drip irrigation and fertigation system powered by electricity from PLN

- Data :
  - Land Area: 400 m^2.
  - Crop Type: Chili.
  - Water Usage: Water requirement of 4 liters/m^2/day. For 400 m^2, that is 1600 liters/day or 1.6 m^3/day.
  - Fertilizer Usage: Assume 100 kg of urea (46% nitrogen) per year.
  - Energy Usage: Assume the irrigation system uses 5 kWh/day.
- N2O Emissions from Urea:
  - The IPCC emission factor for urea N2O is 1% of the applied N.
  - Total N applied = 100 kg x 46% = 46 kg N.
  - N2O Emissions = 46 kg N x 1% = 0.46 kg N2O.
  - Converting N2O to CO2-eq: 0.46 kg N2O x 298 (GWP of N2O) = 137.08 kg CO2-eq per year.
- Emissions from Electricity Usage:
  - CO2 emission factor for PLN electricity: Assume 0.7 kg CO2/kWh.
  - CO2 Emissions = 5 kWh/day x 0.7 kg CO2/kWh x 365 days = 1277.5 kg CO2 per year.
- Direct Total Emissions:
  - From Fertilizer: 137.08 kg CO2-eq per year.
  - From Energy: 1277.5 kg CO2 per year.
  - Total Emissions: 137.08 kg + 1277.5 kg = 1414.58 kg CO2-eq per year.
- Note:
  - This calculation does not include emissions from water usage as it is considered neutral in this context.
  - If there are other activities related to chili production that use electricity, the emissions from those activities should be added.
  - The emission factor values and other assumptions should be updated with actual data for more accurate results.

- This calculation provides an overview of how carbon emissions can be calculated for a chili farming land using an automated irrigation and fertigation system based on PLN electricity. For more precise results, it is important to use data that corresponds to local conditions and specific energy sources

4 Proposed Design of The Integrated System

4.1 Architecture of the Primary System

The system architecture of fully integrated technologies consists ot automatic irrigation and fertilization that integrates with the system for sensing of soil moisture and chemicals, controlling data acqusition from sensors, command to actuator, and data storage and analysis. These include field sensors, field controller/RTU, actuators, irrigation network pipe, fertilizer injection system, central computer and user interface/dashboard, all facilitated with internet connection.

The system is following the achitecture of Supervisory Control and Data Acquisition (SCADA) (Figueiredo et al., 2013; Molina et al., 2014; O'Shaughnessy et al., 2016), with the usage of hardwares according to availability and experience in the country.

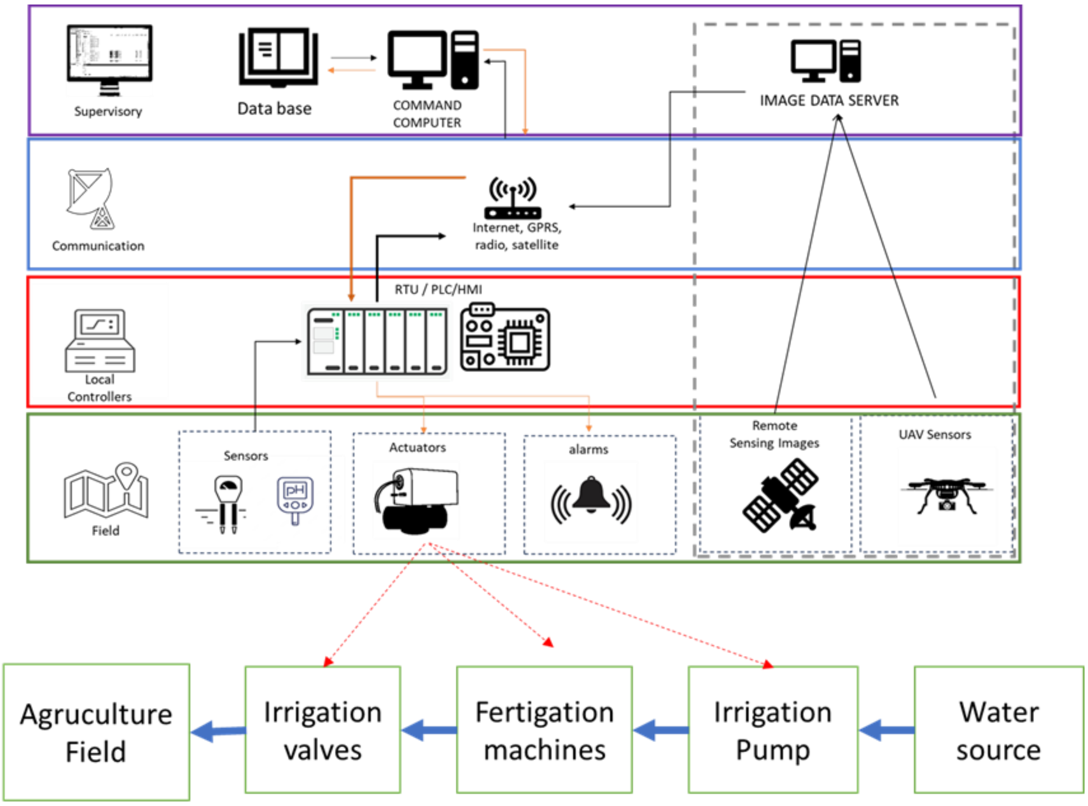


Figure 4.1 Integration of the soil monitoring system and automatic fertigation system.

Irrigation water in the fertigation system flows from the water source with the help of an irrigation pump. Then the irrigation water will pass through the fertigation machine where the fertilizer will be mixed and injected into the irrigation water towards the irrigation valves. Irrigation valves are electromechanical faucets that will deliver water to the specified irrigation plot or unit. This automatic fertigation system will be integrated with the macro system that has been proposed previously through actuators that function to drive the irrigation pump, irrigation valve and fertigation machine This integration is depicted in **Error! Reference source not found.**.

4.1.1 Field Sensors

Field sensors are vital components that detect and measure environmental conditions and soil properties. Common sensors include:

- **Soil Moisture Sensors:** Using RK520-02 sensor to monitor water content at various soil depths to determine irrigation needs (Figure 4.2)

  Specification: RK520-02 sensor

  Moisture; Temperature; EC
  Range: 0-100%(m3/m3);-30°C–+70℃; 0-10mS/cm
  Accuracy; ± 2% (0-50%), ± 3% (51-100%); ± 0.5 ℃; ± 3% FS
  Output Signal: RS485.0-2V
  Response Time: <1s
  Supply: 5VDC, 12-24VDC
  Effective measuring area: With probe center diameter 70mm, cylinder height 70mm
  Housing: ABS
  Dimensions: 45*15*145mm (probe: 3*Ø3*70mm)
  Operating Temperature: -40℃ – +80°C
  Ingress Protection: IP68
  Storage: 10-60 ℃ @20%-90%RH
  Probe material: 316L stainless fertilizer

  Working Conditions:

  Soil Moisture, Temperature and soil EC Sensor. Stainless steel probes are inserted into the ground surface or ground profile for quick testing. Products with temperature compensation to ensure measurement accuracy. The probe can be permanently embedded underground and connected to a data logger for unlimited testing.

Figure 4.2 Soil moisture, EC and Temperature sensors (https://www.microthings.id/product/soil-moisture-temperature-probe-ec-sensor/)

- **Soil Nutrient Sensors:** Employ electrochemical or optical sensors to detect specific nutrient levels, ensuring optimal fertilization and preventing over-fertilization. The use of EC sensors to detect soil nutrients, especially N, can be done as presented in (Vyavahare et al., 2023), This can be done to simplify sensor configuration to optimize material and programming requirements.The sensor can be multi parameter sensors to measure soil moisture temperature and EC as in (Figure 4.2)
- **Weather Stations:** Equipped with an array of instruments like anemometers (wind speed), barometers (atmospheric pressure), pyranometers (solar radiation), and hygrometers (humidity), these stations provide crucial climate data to optimize irrigation schedules.

Specification: RK900-12 Ultrasonic Automatic Weather Instrument

Tabel. Specification RK900-12 Ultrasonic Automatic Weather Instrument

item	**Technical Specification**		
	Range	**Resolution**	**Accuracy**
Wind speed	0-70m/s	0.1m/s	±3%
Wind direction	0-359°	1°	±3°
Atmospheric temperature	-40℃ — +80℃	0.1℃	±0.5℃
Atmospheric humidity	0—100%	1%	±5%
Atmospheric pressure	300 — 1100hPa	0.1hPa	±1
Rainfall	0-200mm/hr.	0.1mm	±5%
Altitude	-500m - 9000m	1m	±5%
Radiation	0-2000W/m^2	0.1 W/m2	±5%
Illumination	0-200000lux	0.1 lux	±5%
UV	0-2000W/m^2	0.1W/m2	±10%
PM2.5,PM10	0-2000ug/m3	1 ug/m3	±5%
Item	**Technical Specification**		
Power Supply	12-24VDC		
Power consumption	<1.7W		
Output Signal	RS232/RS485(Modbus or NMEA-183), SDI-12		
Operating Temperature	-20℃-+50℃		
Ingress Protection	IP65		
Dimension	Φ110*(217-298)mm(Dimensions will vary depending on the parameters)		
Weight(unpacked)	0.39kg		
Main material	ASA		

Working Conditions:

The weather sensor is installed at a standard height of 2 meters from ground level in a location that is not affected by the obstruction of high objects. Connection to the data logger via modbus.

Figure 4.3 Weather sensors (https://www.rikasensor.com/rk900-12-ultrasonic-automatic-weather-instrument.html)

4.1.2 Field Controller/Remote Terminal Unit (RTU)

The field controller, or RTU, is a robust and reliable electronic device that collects data from the field sensors. It processes this data in real time and sends commands to the actuators based on pre-programmed logic or commands from the central computer.

- **Data Aggregation**: Collects readings from all sensors in real-time.
- **Local Decision Logic**: Can run preset logic to make immediate decisions if connectivity to the central computer is lost.
- **Communication Module**: Facilitates data transmission between the RTU and the central computer.

Spesification and Working Conditions: The RTCU LX4 pro, designed to meet full TLS on all major protocols and includes a hardened protected execution environment with dual-boot and automatic fallback and recovery.

- Platform:
  - Based on the RTCU M2M Platform.
  - NX32L (NX32 for Linux) execution architecture.
  - RTCU IDE development tool.
  - Operates under a full and highly optimized Linux variant.
  - Open and extendable with the RTCU Platform SDK (under development).
- LX hardware Core:
  - Cortex-A7 32-bit ARM processor operating at up to 1 GHz.
  - Cortex-M4 32-bit co-processor for advanced power-management.
  - Hardware floating-point and DSP instructions.
  - 128 MByte RAM.
  - 256 MByte NAND Flash (system boot, persistent memory, and file-systems).
  - Real-time clock with a dedicated backup battery.
- Security:
  - Embedded firewall with router functionality.
  - Port forward and NAT services.
  - TLS/SSL support with full certificate management.
  - TLS/SSL support for all major TCP protocols, such as SMTP, MQTT, and sockets.
  - Hardware assisted encryption/authentication.

- Wireless Communication:
  - LTE Cat. 4 Worldwide Cellular Engine.
  - Internal SIM-card reader with support for eSIM.
  - Optional: Wireless M-Bus. EN 13757-4/7 OMS EU/CE.
- Wired Communication:
  - 100 Mbps Ethernet LAN interface.
  - Wired M-Bus (EN 13757-2/3) interface with up to 20 slave devices.
  - Wire bus for accessories such as ID-button reader, temperature sensors, etc.
  - 1 x RS232 channel handshake support.
  - 2 x RS485 channels.
- I/O Interfaces:
  - 8 x digital inputs.
  - Up to 4 digital inputs configurable as IEC62053-31 Class A compliant.
  - 4 x analog inputs with 0..10 volt / 0..20 mA with 12 bit resolution.
  - 2 x analog outputs with 0..10 volt / 0..20 mA.
  - 8 x high-power solid-state digital outputs.
  - Expandable I/O with standard Modbus modules.
- User Interaction:
  - Graphical 144x32 pixels display with backlight.
  - Keypad with 8 keys for sophisticated user interaction and control.
  - 3 x bi-colour, 1 x single colour LED.
  - High-speed Mini-USB service-port connector.
- Sensors:
  - Temperature sensor.
- Audio:
  - Fully digitized audio system.
  - Transfer, store, and play audio.
  - Digitized cellular audio.
  - DTMF support for Interactive Voice Response applications.
- Storage:
  - Internal flash drive with up to 64 MByte capacity.

  - Persistent memory and circular datalogger.
  - Standard SD-CARD reader.
- Power and Battery:
  - Operating voltage from 8 to 36 VDC.
  - On-board 2 Ah Li-Ion battery with intelligent charging.
- Encapsulation:
  - Housed in a industry standard M36 DIN complaint encapsulation.
  - Two-part pluggable connectors for easy installation and maintenance.
- Regulatory Approvals:
  - Radio Equipment Directive, RED 2014/53/EU.
  - EMC Directive, 2014/30/EU.
  - RoHS Directive, 2011/65/EU.

Figure 4.4 Remote Terminal Unit RTCU LX4 Logic IO (https://www.logicio.com/rtcu_products.htm)

4.1.3 Irrigation Network : Drip Line

This network comprises a series of interconnected pipes, hoses, and drippers/sprinklers/other emitters type. It is responsible for efficiently distributing water (and liquid fertilizer) to the plants, based on the area's layout and plant requirements. Figure 4.6 shows the irrigation network. Drip line irrigation is the easiest to install and uninstall, and the investment is also the lowest compared to drip irrigation with emitters.

Figure 4.5 Drip Line irrigation (https://www.waterforce.co.nz/vdb/image/788)

- **Mainlines and Sub-mainlines**: High-capacity pipes that transport water from the source or storage to manifold locations. Each delivers water to different filed/plot (irrigation unit) and is controlled by irrigation solenoid valves.

- **Pressure regulator**: A pressure regulator ensures that the water pressure is not too high, which could damage the emitters.

- **Laterals**: Smaller pipes/drip tubes that deliver water directly to plants, often equipped with emitters or drippers for slow release. Driplines irrigation is used for this design

  Specifications:
  1. Diameter: Ranging from 1/2 inch to 1 inch depends on the size of the area to be irrigated and the flow rate of the water source.
  2. Flow rate: The flow 2 liters per hour (LPH) based on the water requirements of the plants and the spacing of the emitters.
  3. Emitter spacing: 30 cm.
  4. Pressure**:** The pressure of the water source should be between 10 and 20 psi
  5. Materials**:** Polyethylene or Polypropylene

  Advantages
  1. Water efficiency: Driplines can save up to 70% of water compared to traditional sprinkler systems.
  2. Weed control: Driplines deliver water directly to the plant roots, which can help to suppress weed growth.
  3. Erosion control: Driplines deliver water slowly and evenly, which can help to prevent soil erosion.
  4. Labor savings: Driplines are a low-maintenance irrigation system that requires little labor to operate.

- **Filters**: Removes debris and sediments to prevent clogging, especially crucial for drip irrigation systems. This is depicted in Figure 4.10.

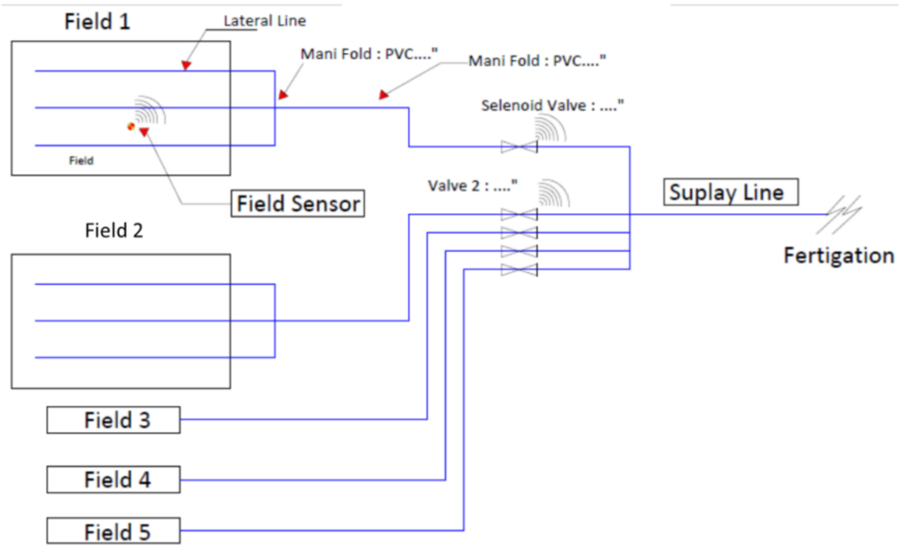


Figure 4.6 Irrigation Network with multiple fields as irrigation units

4.1.4 Actuators 1 : Irrigation

Actuators 1 are devices that perform actions based on the commands they receive from the RTU or command computer, which consists of irrigation pumps which is shown in Figure 4.10. and irrigation solenoid valves which direct water to each of irrigation unit as in Figure 4.6.

- **Power Control** : Power control is a tool used to deliver power to an actuator with commands from the RTU. The command from the RTU is in the form of a low-voltage direct electric (DC) signal and a small current, which is enough to activate the power control so that it can flow power to the actuator device. In this case, a magnetic relay with voltage and electric current is used according to the pump and solenoid valve used.

  Specification: RELAY LY2 12V OMRON

Mounting method	With plug-in socket
Usage	General purpose
Poles	2
Rated carry current	10 A
Coil voltage	12 V
Operation voltage	DC
Contact material	Ag alloy
Contact description	DPDT
Features	Transparent case
Terminal	Plug-in, Solder

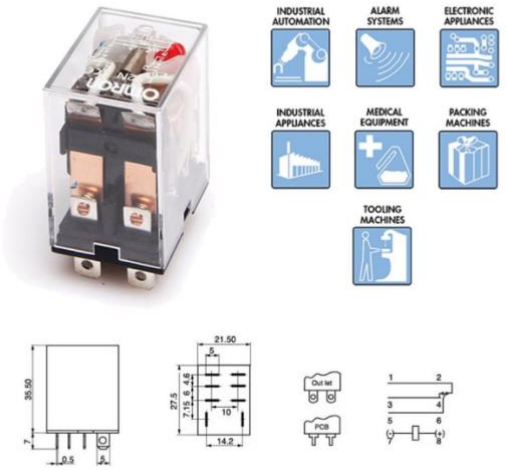


Figure 4.7 Power control (magnetic relay)

- **Pumps**: Ensure the flow of water from the source to the irrigation network.

  Specification: Electric Pump:
  1. Flow Rate (Debit): Given the size of the land and water requirements for chili plants, the pump should provide a flow rate of about 2,000 - 2,500 liters per day. This would be sufficient to meet the average water needs of chili, which range between 5-6 liters per square meter per day, considering the climate variations in Sukaraja, Sukabumi.

2. Head (Lifting Capacity): The head requirement will depend on the land's topography and the distance between the water source and the irrigation area. For flat land, a head of about 10-20 meters should be sufficient.
3. Pump Power: Based on the required flow rate and head, a pump with a power rating of about 0.5 to 1 HP (0.37 - 0.75 kW) should meet these needs.

UV	0-2000W/m^2	0.1W/m2	±10%
PM2.5,PM10	0-2000ug/m3	1 ug/m3	±5%
Item	**Technical Specification**		
Power Supply	12-24VDC		
Power consumption	<1.7W		
Output Signal	RS232/RS485(Modbus or NMEA-183), SDI-12		
Operating Temperature	-20℃-+50℃		
Ingress Protection	IP65		
Dimension	Φ110*(217-298)mm(Dimensions will vary depending on the parameters)		
Weight(unpacked)	0.39kg		
Main material	ASA		

Figure 4.8 Water pumps

- **Irrigation Valves**: Solenoid valves that control the amount and direction of water flow within the irrigation system to the respective irrigation unit (plot), turning on/off based on soil moisture levels and other parameters.Number off irrigation valves depend on the number of irrigation units.Figure 4.9 shows typical 1" 12VDC Brass Solenoid Valve.

  Specification:

  1. Diameter: For a 400m² area, a solenoid valve with a diameter of about 1 inch (25 mm) would be adequate for regulating the flow of water and nutrient solutions.
  2. Voltage: Typically, solenoid valves operate at standard voltages, like 12VDC, 24V DC or 220V AC. The choice depends on the availability of the electrical source and the control system used.

3. Current: The current required by the valve usually ranges between 0.5 to 2 A, depending on the valve's specifications.
4. Operating Pressure: The suitable operating pressure for the irrigation and fertigation system in a 400m² area should be in the range of 1 to 3 bar, in line with the requirements of the drip line and fertigation system.

Figure 4.9 Solenoid valves

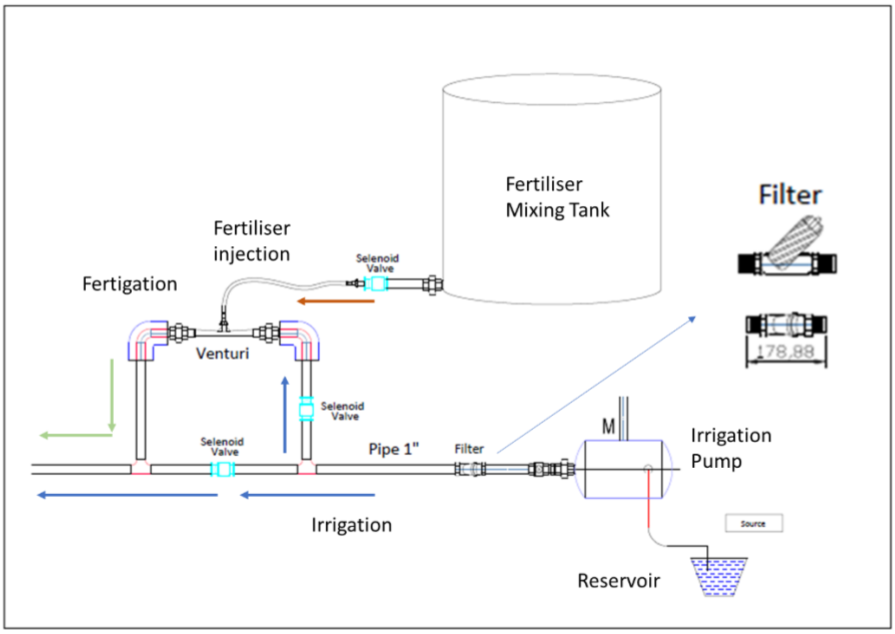


Figure 4.10 Actuators : Irrigation, fertigation, pump, valves

4.1.5 Actuators 2 : Fertilizer Injection System

The fertilizer injection system is a mechanism that mixes liquid fertilizer with irrigation water at a specified rate. It ensures that plants receive nutrients directly at their root zone, promoting better absorption and minimizing wastage. In case for Sukaraja, Sukabumi fertigation mixer system is replaced by low cost and low energy, but more manageable by local farmers in Indonesia. The actuators responsible for fertiliser injection is as deppicted in Figure 4.10.

- **Venturi Fertiliser Injectors**: Utilize pressure differences to draw and mix fertilizer into the irrigation flow.
- **Mixing Tanks**: Location where water and fertilizers are pre-mixed before being released to the field.
- **Fertigation and venturi control valve:**. Solenoid valves which control the direction of water to ventury and control the opening of fertiliser pipe from tank.
- **Power control** : similar to actuator 1, power control device is required

4.1.6 Central Computer

The central computer is a powerful processing unit that gathers data from multiple RTUs in different fields. It provides:

- **Data Analysis**: Evaluates data trends and determines irrigation and fertilization needs.
- **Command Issuance**: Sends commands to RTUs based on analysis and user input.
- **Data Storage**: Maintains a database of historical data for better decision-making.

4.1.7 Internet Connectivity

Internet connectivity ensures seamless communication between the RTU and the central computer. Depending on the field's location, either a wired (Ethernet) or wireless (Wi-Fi, cellular, satellite) connection can be used.

4.1.8 User Interface

The user interface, usually software or a web portal, allows users to:

- Monitor: View real-time data from the fields.
- Control: Manually override or adjust the automatic commands of the system.
- Analyse: Access historical data, generate reports, and make informed decisions about irrigation and fertilization.

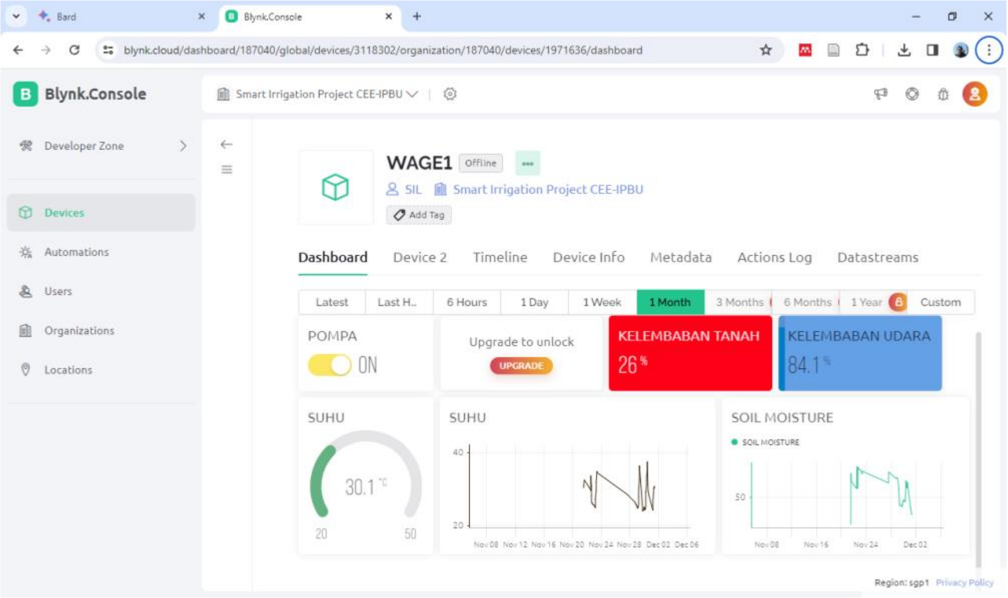


Figure 4.11 User Interface Illustration

The architecture described, as summarised in **Error! Reference source not found.**, describes an integrated approach to automating irrigation and fertilization, ensuring that crops receive the right amount of water and nutrients based on real-time field conditions.

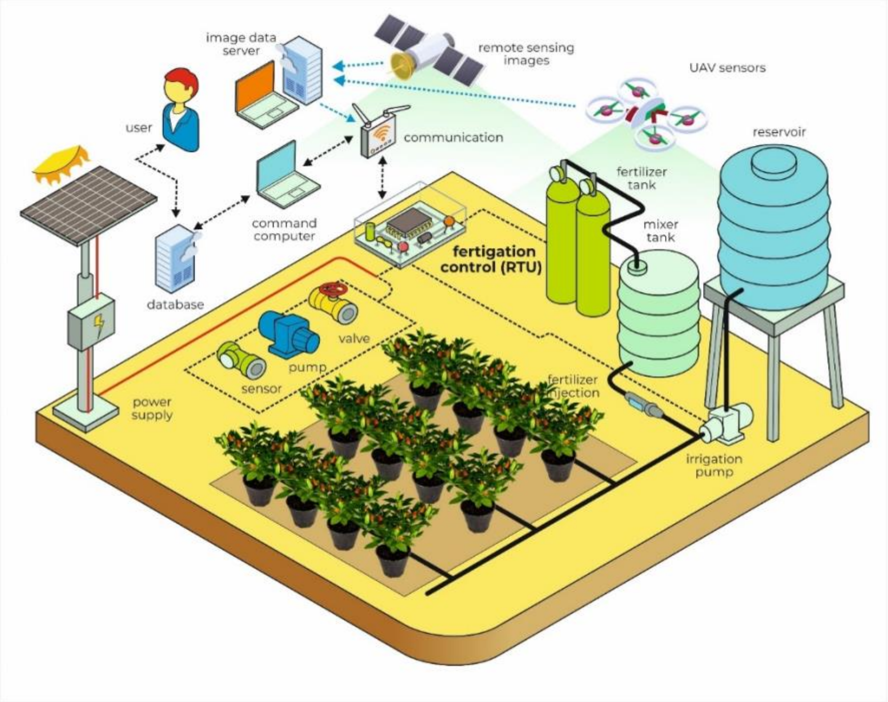


Figure 4.12 Schematics of the proposed integrated system

4.2 Energy Supply

The system works with electrical power that can be obtained from various sources according to availability in the field: electricity on-grid (PLN), solar panels and fosil fuel electric generators. The most flexible method of obtaining electricity from renewable energy is to use solar photovoltaics panel. Studies conducted on the use of solar energy in Sukabumi have shown that rooftops have high potential in capturing solar energy in the region (Arsyad et al., 2022; Dharmawan et al., 2022).The use of solar power for irrigation is reported to be quite economical (Goel & Sharma, 2021; Karki & Lohani, 2020; Rejekiningrum & Saptomo, 2015). The application of solar irrigation can provide benefits for farmers through increasing productivity and quality of agricultural products (Ayundyahrini et al., 2023), including in Indonesia (Amir, 2021). Solar irrigation technology can also be managed by women (Siantoro et al., 2023) in an effort to increase women's resilience to climate change through a project to increase girls' and women's resilience through climate change adaptation used solar-powered dripping irrigation.

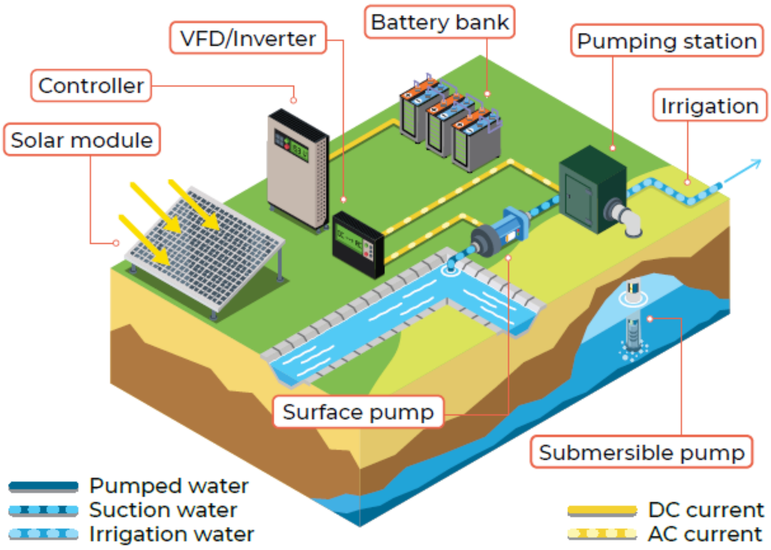


Figure 4.13 Schematics of stand alone solar power system for irrigation (Salman et al., 2022)

The configuration of solar power system as in Figure 4.13, consists of several key components and their specifications which of commonly used in a solar power system for irrigation:

- Water Pump
  - Type, Power and efficiency depends on irrigation pumps specification. Assumming 400m2 of land and using surface water, a pump with a power of about 0.5 to 1 HP (0.37 - 0.75 kW).
- Solar Panels
  - Capacity: Typically measured in kilowatts-peak (kWp), For a 0.5 kW pump, and assuming 5 hours of effective sunlight per day, the capacity of the solar panel : 0.625 kWp
  - Type : Monocrystalline or polycrystalline
  - Efficiency: Ranges from 15% to 22%.
- Inverter
  - Function: Converts direct current (DC) from solar panels to alternating current (AC) to operate the water pump.

  - Capacity: match the output from the solar panels and the input requirement of the water pump.

- Battery:
  - Type: Lead-acid, lithium-ion, or other types, DC12V or 24 V
  - Capacity: Determined by the energy storage needs and the duration of irrigation.
  - Lifecycle Sustainability: the battery life and how many times it can be recharged.
- Charge Controller:
  - Function: Regulates the flow of energy between the solar panels, battery, and pump.
  - Features: Protection from overcharging, deep discharging, and other extreme conditions.
- Frame and Mounting:
  - Material: Usually made of galvanized steel or aluminum.
  - Design: Must be robust and able to withstand extreme weather conditions, also adjustable to achieve optimal sunlight incidence angle.
- Cables and Connectors:
  - Type: UV :resistant and suitable for outdoor conditions.
  - Size: Appropriate for the system's capacity and cable run length.

4.3 Optional Spectral Data Subsystem

The spectral data subsystem utilizes sensed image from spectral camera, remote sensing data or UAVs data to inform on soil conditions, such as moisture and nutrition levels. In the proposed integrated system, this subsystem is optional depending on the area and coverage of surface trees that block the sensor to record imges from beneath.

The subsystem should have high flexibility. Drones can be operated either on-demand or periodically, depending on the user's needs. This allows for more intensive soil monitoring during critical periods or as required.

4.3.1 Field implanted spectral camera

Field implanted camera that capture spectral image of the irrigated field. Analysis of water requirement uses NDVI to detect vegetation stress of water and nurients deficit.

4.3.2 Remote Sensing Data

Remote sensing data is obtained from aircraft or satellites orbiting Earth. Extensive areas can be scanned at various resolutions. Alternatively active radar image can be used

4.3.3 Drone Data/Unmanned Aerial Vehicles (UAVs)

Drones or UAVs that are equipped with spectral sensorsto provide high-resolution data for smaller areas compared to traditional remote sensing.

4.3.4 Spectral Data Server

A digital platform designed to store, manage, and analyse spectral data obtained from both remote sensing and drone sources.

- Functions:
  - Data Processing: Converts raw spectral data into interpretable information, such as soil moisture and nutrient conditions.
  - Data Integration: Combines data from various sources to create a more holistic view of soil conditions.
  - Data Analysis: Employs advanced algorithms to assess soil conditions based on the acquired data.

4.3.5 Communication to the Central Computer

- Processing: Once the spectral data is interpreted by the spectral data server, information on soil moisture and nutrition is relayed to the central computer.
- Purpose: The central computer utilizes this information to make informed decisions, such as when and how much water or fertilizer should be applied to the soil.

4.4 Operating Systems

Figure 4.14 shows the schematics of the integrated system, including irrigation system and monitoring system. Generally the flow of the system is : 1. Soil monitoring measure soil condition 2. RTC - Field controller read the data from the sensors and decide whether irrigate, fertigate or stop; send data to central computer server; received setting information from central computer server. 3. Centar computer received data and keep the dat ain the database; serve user that access to the computer and data base using desktop/gadget installed with user interface dashboard application.

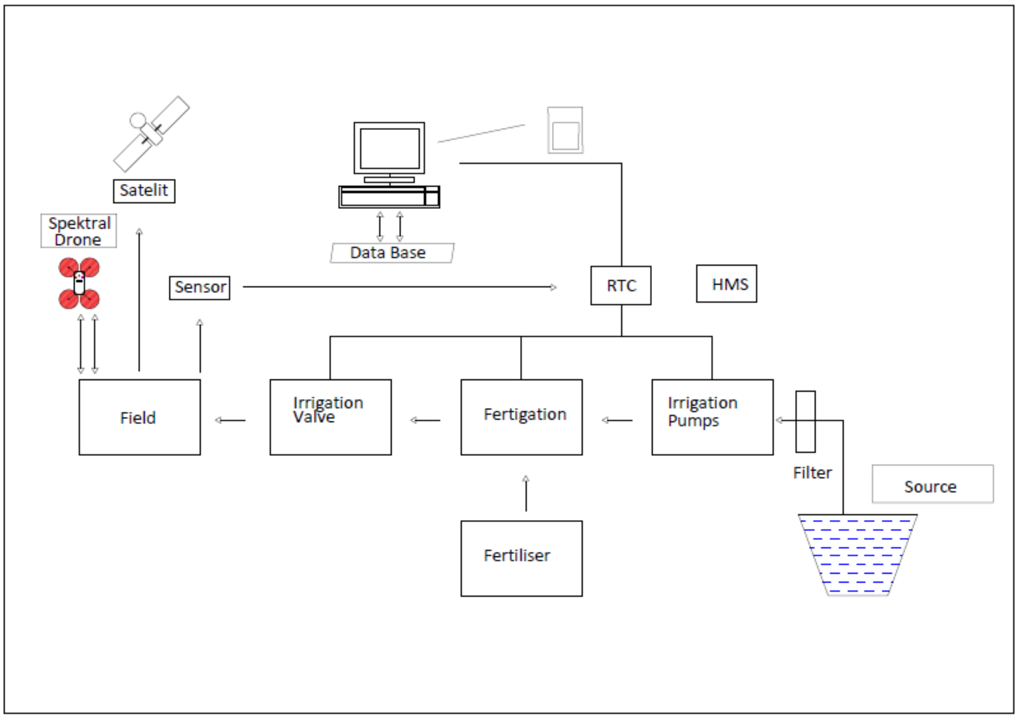


Figure 4.14 Schematics of The Integrated System

- Workflow of the system
  - **The soil monitoring system** will activate sensors to detect soil moisture and nutrient conditions.
  - Information on soil moisture conditions from the field sensor will be received by the RTC **Field Controller** then processed, stored and sent to the central computer / server
  - **The Field Controller** compares the soil moisture value with the target set point of soil moisture, if it is still within the set range, nothing will be done.
  - If the soil moisture falls below the lower limit of the permissible range, the **Field Controller** will give an order to turn on irrigation for the unit as much as the volume needed to meet the available water, namely:

    $V = (Fc – SM) * Z*A$ (1)

    V = water volume (l)

    SM = measured soil moisture (%)

    Fc = Field capacity soil moisture (%)

    Z = soil depth (cm)

    A = Field area (m2)
  - This volume is given based on the irrigation water discharge multiplied by time (T), so in this situation the Field Controller will instruct the irrigation pump to turn on and the irrigation solenoid valve opens according to the irrigation unit to be irrigated during the time

- When the irrigation time has been met, the **Field Controller** will read back the sensors from other irrigation units and repeat the automatic irrigation process until all units are met their water needs.

- **The field controller** will update the upper and lower limits of soil loss and override pump and valve activity based on data sent by **Central Computer**

- Fertigation is done automatically by scheduling, when the **central computer** fertilizer schedule instructs **the field controller** to apply fertilizer along with the irrigation flow. The amount of fertilizer applied is calculated based on the concentration of fertilizer x volume of water.

- **Central Computer** serves users through a **user interface dashboard application** installed on the computer or user/operator gadget.

- **The User Interface** can be used to view and download data, change settings and manage irrigation and fertigation manually.

4.5 Maintenance

These maintenance procedures ensure the longevity and efficient operation of the irrigation system. It's crucial to adhere to these guidelines and consult the system's manufacturer manuals for specific maintenance recommendations and safety precautions.

4.5.1 Irrigation

4.5.1.1 Pipes and driplines

- **Routine Inspection:** Conduct thorough inspections for leaks, physical damage, and blockages in pipes and driplines. Look for signs of wear, corrosion, or damage that could affect the system's efficiency.

- **Cleaning:** Implement a regular cleaning schedule to remove dirt, algae, and mineral deposits that can clog driplines and reduce water flow. Use appropriate cleaning agents and flush the system periodically.

- **Replacement:** Identify and replace parts that are damaged, corroded, or worn out to prevent system failure and ensure optimal performance.

4.5.1.2 Pump and valves

- Inspection: Regularly inspect pumps and valves for operational efficiency. Check for leaks, unusual noises, and performance issues that might indicate problems.

- Lubrication: Lubricate moving parts as per manufacturer guidelines to ensure smooth operation and prolong the lifespan of the equipment.

- Replacement: Replace any parts that show signs of damage or excessive wear. This includes seals, gaskets, and mechanical components that are crucial for the efficient functioning of pumps and valves.

4.5.1.3 Filter

- Cleaning: Regularly clean filters to maintain water flow and prevent blockages. This includes backwashing sand filters or replacing cartridge elements as necessary.
- Replacement: Monitor filter condition and replace any components that are damaged or have reached the end of their service life to ensure effective filtration and system efficiency.

4.5.2 Fertigation

4.5.2.1 Injector

- Inspection : Check injectors for accurate delivery of fertilizers. Ensure there are no leaks and that the injector is delivering the correct dosage.
- Maintenance: Clean and maintain injectors according to the manufacturer's instructions. Replace worn or damaged parts to ensure precise fertigation.

4.5.2.2 Fertiliser Mixing Tanks

- Cleaning: Clean fertigation tanks to prevent sediment build-up and contamination. Ensure tanks are free of residues that can clog the system.
- Inspection : Regularly inspect tanks for cracks, leaks, or corrosion. Ensure the structural integrity of the tanks to prevent spills and contamination.

4.5.3 Sensors

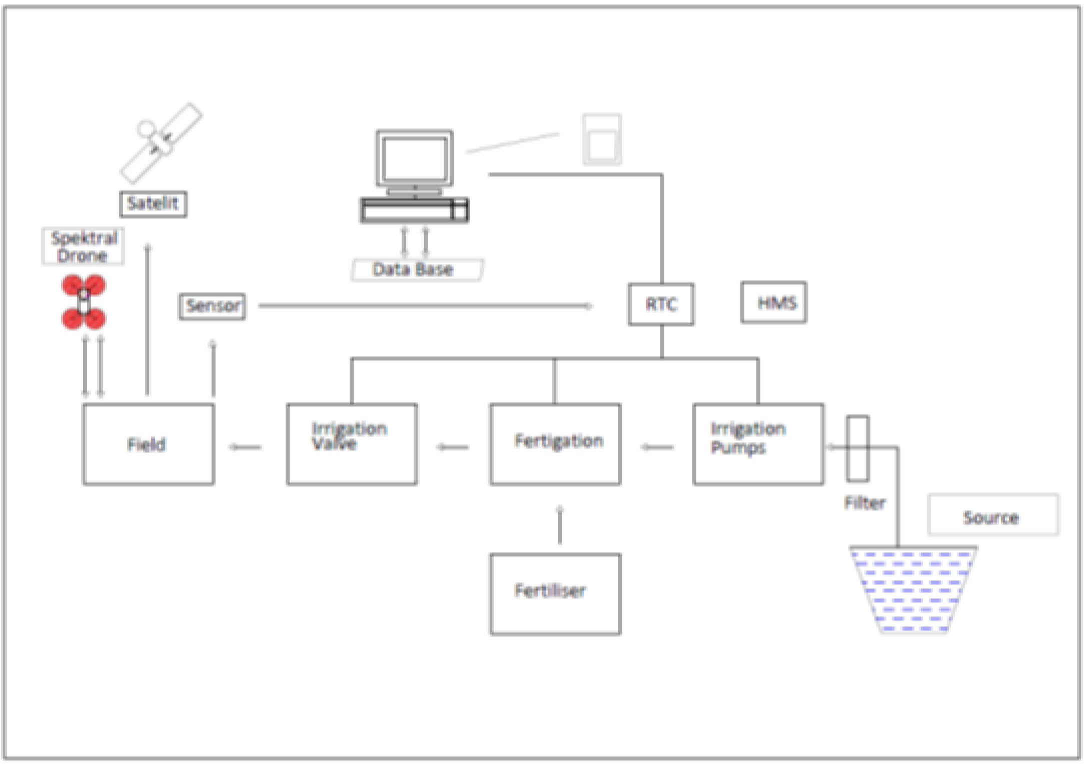
- Routine Calibration: Perform regular calibration of sensors to ensure accurate readings. Follow the manufacturer’s guidelines for calibration frequency and procedures.
- Routine Cleaning: Regularly clean sensors to remove dust, soil, and other contaminants that could affect their performance.
- Replacement: Replace sensors that show signs of malfunction, inaccuracy, or have reached the end of their useful life to ensure reliable data for irrigation management.

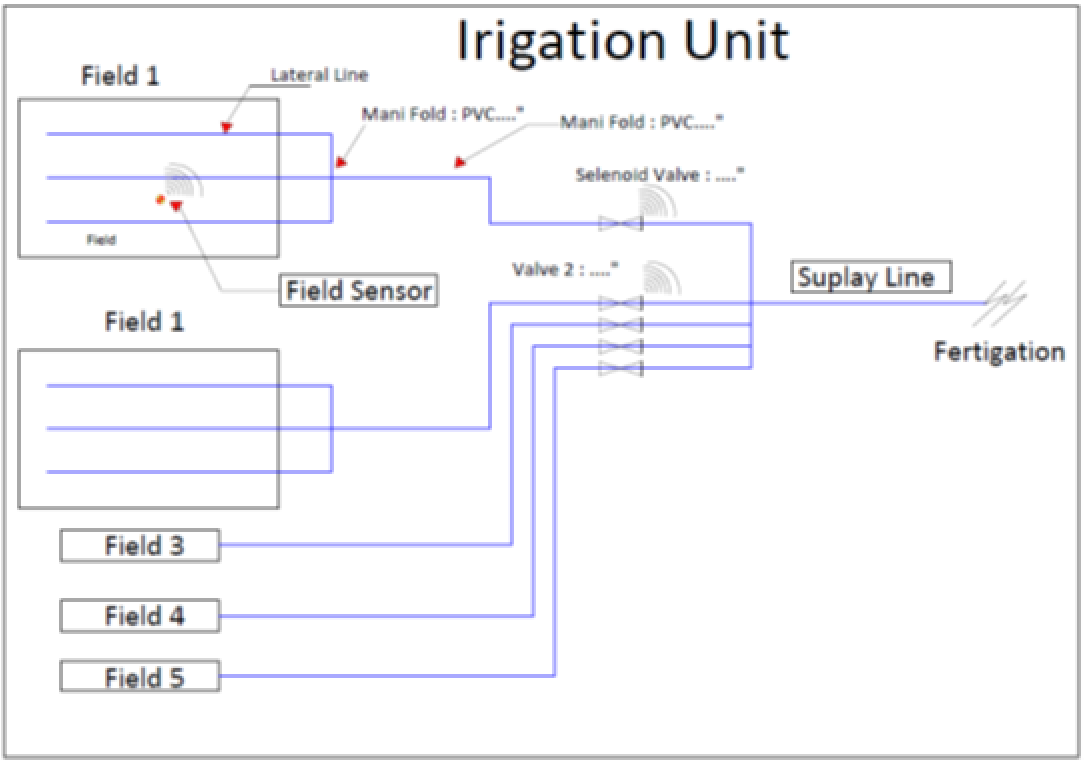
4.5.4 Field Controler

- Inspection and Maintenance: Regularly inspect the field controller for signs of wear, damage, or environmental impact. Keep the software updated to the latest version for optimal performance and security.
- Troubleshooting: Address any operational issues promptly. Refer to the manufacturer's guide for troubleshooting common problems.

4.5.5 Power Supply (Solar Power System)

- **Solar Panel Maintenance:** Regularly clean solar panels and remove any obstructions that block sunlight. Inspect for damage or wear that could affect performance.
- **Battery Maintenance**: Regularly check the batteries for charge levels, corrosion, and connections. Ensure batteries are properly charged and maintained for reliable power supply.

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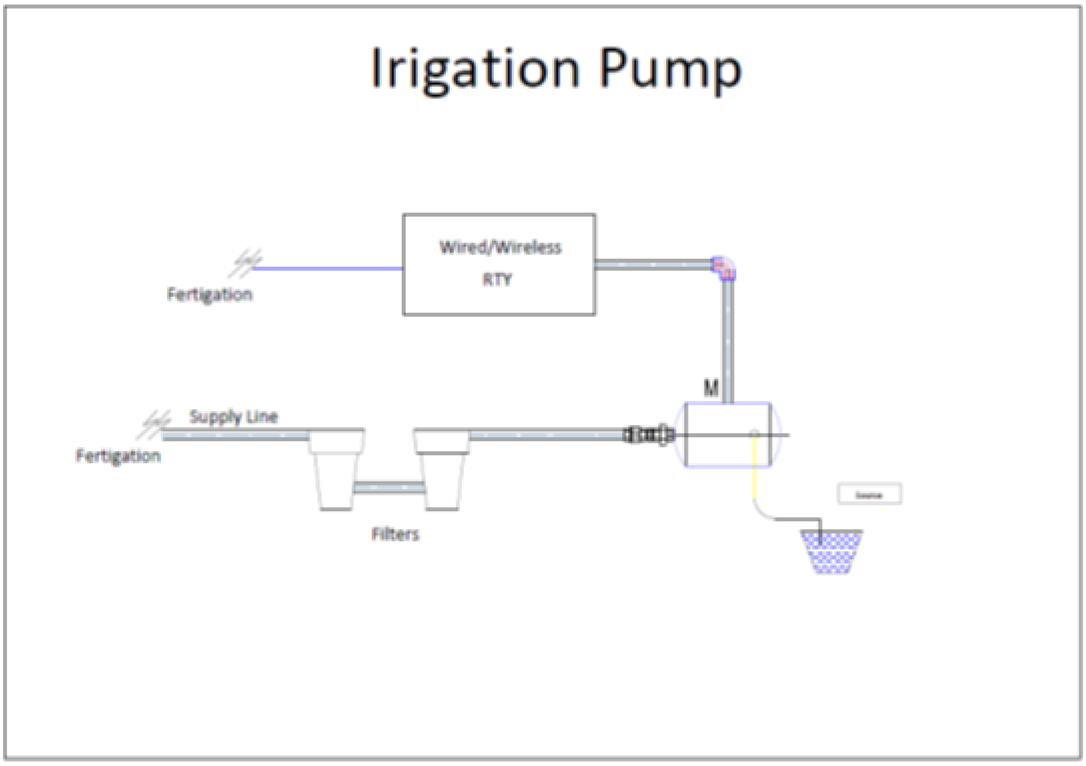
Field 5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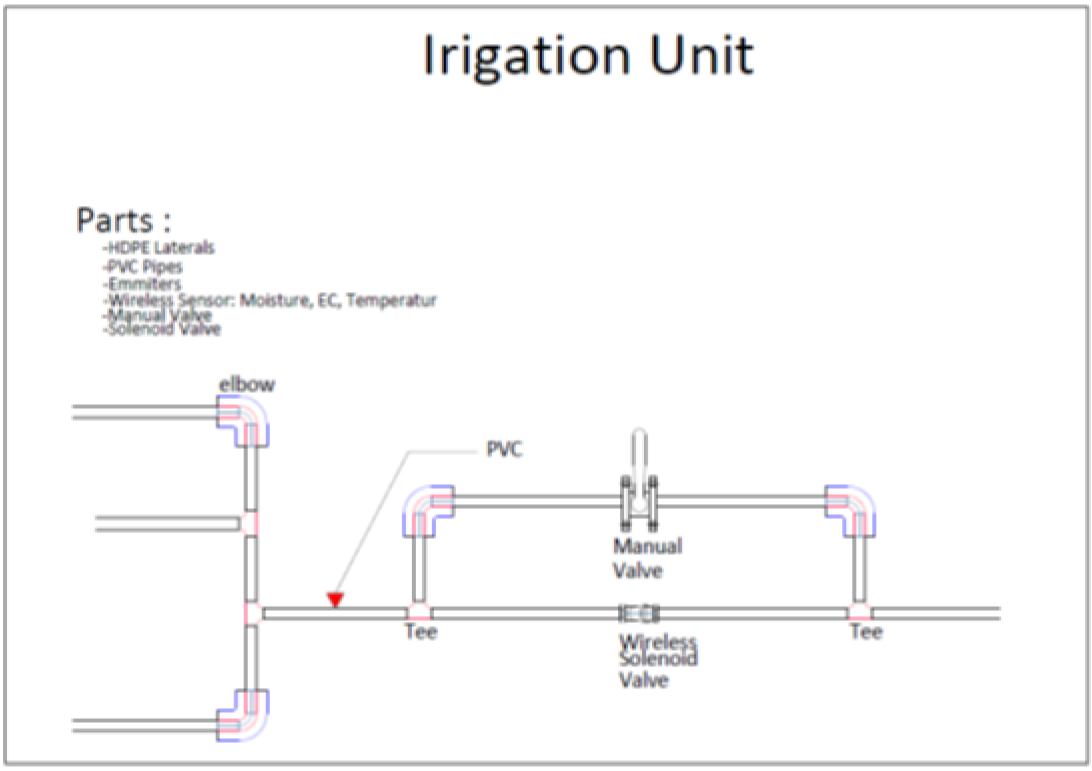

4.6 Gender-responsive approach

This approach assures the gender equality and equity in the technology implementation so women and men can have an equality relation as gain from new technology implementation in farm, household, and community level to avoid gender issues, like subordination and marginalization, with the requirements in many aspects, such as: (a) Selection (b) Training; (c) Health and safety environment; (d) Income; and (e) Work division.

evaluate the level of expertise required to use the sensor, from regular workers to specialist graduates in gender equality. -

Selection
Eventhough the number of operator only can provide a limited of number of people, both gender should have the opportunity to participate in fertigation technological implementation. Women as men can involve since planning about the technology design, staff, the commodity to be grown, or the whole business process for each growing season through the economic institution in the community, namely farmers group meeting or other relevant group.
If there is few women to be involved, it needs an affirmative action that women can reach the number of 30% from total employee who involved in this innovative adaption program to climate change. having women representatives. It is an effort to avoid marginalization so farmers of both genders have equal opportunity as human resources to use the sensor technology in calculating water and nutrient need. It is to facilitate a social construction before the technology implemented that women's position involved in fertilizing and irrigating activities while men work outside of the village. It is also accomdate that social demographic that women in many varieties of age group can have this opportunity, both young and old.

Training

Training guided by Standard Operating Procedures (SOPs), emphasizes equal opportunity for involvement of women and men employee in every position. Training participants should composed of women and men. After training, women can be self-confident and capable of operating the technology as a man. They can also have a promotion as a team leader if possible.

Health and safety environment

The workload is secure so women can do their responsibility in healthy in environment settings. It opens to women free from the risk of electricity errors, accident, and harrasment.

Income

Fair income for women and men as an technology operator. It is expected that not based on the stereotype that women only do the easy stuff, so the women have barriers to have more responsibilies. It also avoids the subordination that the women payment is lower than men.

Work division

Socialization about gender roles in the household level that men and women can support and empower each other with sharing activity the domestic, social, and economic areas; and decision-making of family resources, like income, providing food, and leisure-time to avoid double-burden.

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