

# 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

Produce a Feasibility Analysis for the Integration of the Two Systems

D3.2.1

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

In the age of globalization and rapid technological advancements, the agricultural sector is not exempt from innovation. One of the most promising breakthroughs is an integrated system that combines automatic irrigation technology with automatic fertilization technology. The primary aim of this technology is to enhance efficiency, effectiveness, and consistency in water and nutrient delivery to plants, thereby potentially maximizing crop yields. Such technology also has the potential to increase resilience to the uncertainties brought on by climate change. However, like the deployment of any technology, it is crucial to evaluate its feasibility in a specific context.

This report describes an integrated system which is the design of the macro system and the technologies that enable automatic irrigation and fertiliser application, respectively. This system encompasses 1) data collection of soil moisture and soil chemistry from various field sensors, the interpretation of this data, and subsequent decision-making based on the obtained information, and 2) the automatic dispensing of an appropriate amount of water and fertiliser based on the first point. The overarching goal of this macro system is to ensure that every action taken in the field, including irrigation and fertilization, is based on accurate and pertinent data.

In this feasibility study report, our focus will be on analysing the viability of the automatic irrigation and fertilization technology with the implementation of the macro soil monitoring system. This includes a technical assessment of the technology as well as its compatibility with the selected case study area, Sukabumi Regency in West Java, Indonesia, as the context of specific geographical location. Through this analysis, we hope to provide precise recommendations regarding the potential implementation and adaptation of this technology across various agricultural settings and scales.

With an in-depth understanding of plant needs, soil characteristics, and climatic conditions, we anticipate that this integrated soil sensor and automatic irrigation-fertilization technology can offer an innovative and sustainable solution for farmers and other stakeholders in the agricultural sector.

The report is prepared with the structure: Introduction which is this section, followed by the section that will briefly inform the general condition of Sukabumi region as the target geographic area including agriculture, water and fertiliser. The 3<sup>rd</sup> section will introduce the previous report's result on the Macrosystem of the soil moisture and chemical monitoring system, which will be integrated to automatic irrigation and fertilisation system in this report. The assessment of the irrigation and fertilisation feasibility to produce integrated system will be presented in the 4<sup>th</sup> section and the proposed integrated system will be presented in 5<sup>th</sup> section.



## 2 Selected Geographic Area: the Sukabumi Regency

The Regency of Sukabumi was selected during discussion with working group and based on commodity variabilities, location accessibility, topography, and Gender Empowerment Index. Further discussion with stakeholders from the Regency of Sukabumi, the Sukaraja District was selected with several consideration, such as easy location access, available water sources, and high price commodity that produced at that district. Sukaraja District has several Irrigation areas, such as Cimuncang, Selawangi, and Batu Karut Irrigation Area.

### 2.1 Focus Area: Sukaraja District

The Sukaraja District area is located at an altitude of between 500 m and 700 m in above sea level. The area of Sukaraja District was recorded at 36.64 km<sup>2</sup>, with 9 sub districts. Most areas in Sukaraja District is located in the highlands area and slopes/ridges (Fig. 1). Annual rainfall was about 3044 mm at 2022, where about half of it falls during December – March. While Sun Radiation was highest at Agustus – September (Kecamatan Sukaraja dalam Angka, 2023).

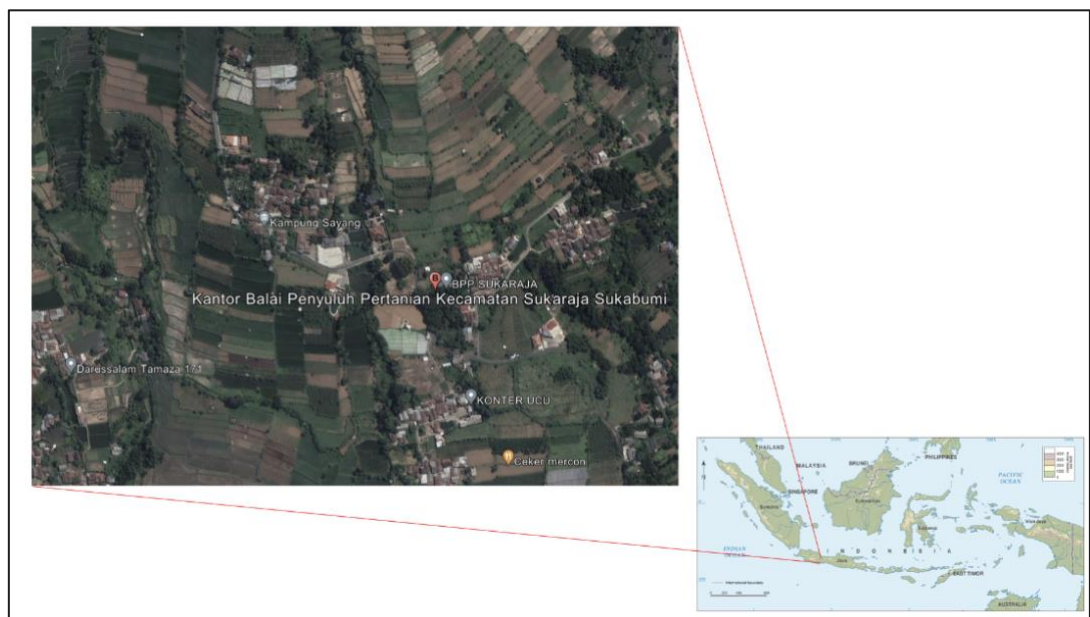


Figure 2.1 The Sukaraja District, Regency of Sukabumi, West Java, Indonesia.

### 2.2 Water and Agriculture

Agricultural land in Sukabumi Regency is fragmented, with small blocks of land that are not always close together. The impermeable layer is deep, except in paddy fields. Fields are connected by embankments or farm roads, and intercropped with a variety of crops with different planting periods. Crops are adapted to market conditions and seasons.

Water supply is dominated by surface water, distributed through channels or piping systems according to a pre-scheduled allocation. However, water quantity is less than

necessary on some blocks, especially those far from water sources. This can result in delayed planting, reduced harvests, or even no harvest..

Irrigation in Sukabumi Regency is dominated by surface irrigation technology for rice fields. There are 157 irrigation areas under the government's authority, covering 28,650 hectares. The irrigation system is simple, depending on land area and commodity prices. Farmers take water from irrigation networks and deliver it to the field by gravity, manual watering, or using field reservoirs. Some farmers have attempted to use sprinklers, but did not continue because the harvest was no different from manual irrigation.

Netafim Indonesia and Sekolah Vokasi IPB held a seminar to introduce the latest technology of smart greenhouse and precision irrigation systems. The seminar featured speakers from the company and the school who explained the benefits, challenges, and components of these systems. The seminar also showcased a project of greenhouses construction in the Teaching Farming area of Sekolah Vokasi IPB, one of which uses sensors to monitor and control the irrigation and fertigation processes. (SV-IPB Bersama Netafim Indonesia Kenalkan Teknologi Terkini Green House Dan Irigasi Presisi Yang Tersistemasi - Sekolah Vokasi IPB, n.d.). The seminar and the project in Sukabumi show that modern irrigation systems are being developed and applied in the region, with the potential to improve water use efficiency, crop yield, and environmental sustainability. However, there are still challenges to overcome, such as high cost, lack of skills, and social acceptance. More research, education, and collaboration are needed to foster innovation and adoption

## 2.3 Gender Equity

Based on The Gender Empowerment Index (GEI), where there are three indicators, namely (1) women in the workforce; (2) female decision-making power; and (3) women in parliament, Sukabumi District is the location at 72.91. It becomes a location where women have adequate economic and political power related to men. It also have meaning that women that involved in agriculture practices should be determined of the technological implementation in avoiding the gender issues, namely marginalization and subordination.

Women participate in agriculture in commodities of chrysanthemum, chili, and paddy. They are involved in many activities such as the nursery, maintaining, harvesting, and irrigating. It can be caused by the existence of a stereotype that leads women to be more involved in *light* activity than men. Women can be laborers in these activities that work from morning to noon with a revenue of Rp. 50.000. It is lower than men who paid more activities as a labour.

In the land, a manual is used to irrigate the chili plant twice daily. Women spray manually with four people in 1 ha. Even in the chili, farmers implemented a sprinkler, but manually, it needs to be moved by labor who irrigates.

Men have more control than women to decide a commodity. It is because men have more information about the price of commodities.

Gender relation is constructed in the social and cultural sphere of the community since there is a *Widow land, for women* (Tanah Janda), a local name for claiming land cultivated. There is no concept of widow land for men. It has a deep meaning that this land needs more intervention to be used for agriculture.

## 2.4 Irrigation Technology Needed Regarding to Agricultural Setting

Sukaraja is a district in Sukabumi Regency, West Java Province, Indonesia. Sukaraja has many rice fields that use technical irrigation, which is irrigation that utilizes technology and infrastructure to regulate water flow. Technical irrigation includes surface irrigation, which has been fulfilled in terms of infrastructure, but consumes a lot of water.

Some rice field locations experience drought in the dry season, and can be used for crops other than rice that require less water, such as corn, soybean, or peanut. These crops can be assisted with sprinkler or drip irrigation, which are more efficient and precise in water application. Subsurface drip irrigation can also be used, which involves placing the drippers below the soil surface to deliver water directly to the root zone.

Land that suffers from water scarcity, upland and home garden areas can improve their resilience to water shortage by introducing water-saving irrigation such as drip or sprinkler. This is especially relevant for Sukaraja, which grows many flowers, vegetables, and chili peppers. These crops can benefit from the improved water and nutrient management, as well as the reduced weed and pest problems, that drip or sprinkler irrigation can provide.



### 3 Macrosystem of Soil Moisture and Monitoring System

The first part of the proposed macro-system which is the utilization of modern technology, software, and cloud platforms to provide real-time soil moisture and chemical analysis essential for agricultural water management, as reported in Output D2.4.1. This macro-system enhances soil management effectiveness by offering farmers key data and tools for decision-making. It gathers and processes data on soil temperature, moisture, and nutrients levels, ensuring optimal crop health. With a cloud-based feature, farmers can access and interpret data remotely, aiding in accurate decision making on irrigation, fertilization, and soil practices, thus boosting crop yields and resource use. This system also includes a web interface for irrigation scheduling. Essentially, by employing a Supervisory Control and Data Acquisition (SCADA) foundation, the system offers farmers real-time soil insights, supporting informed and efficient farming decisions.

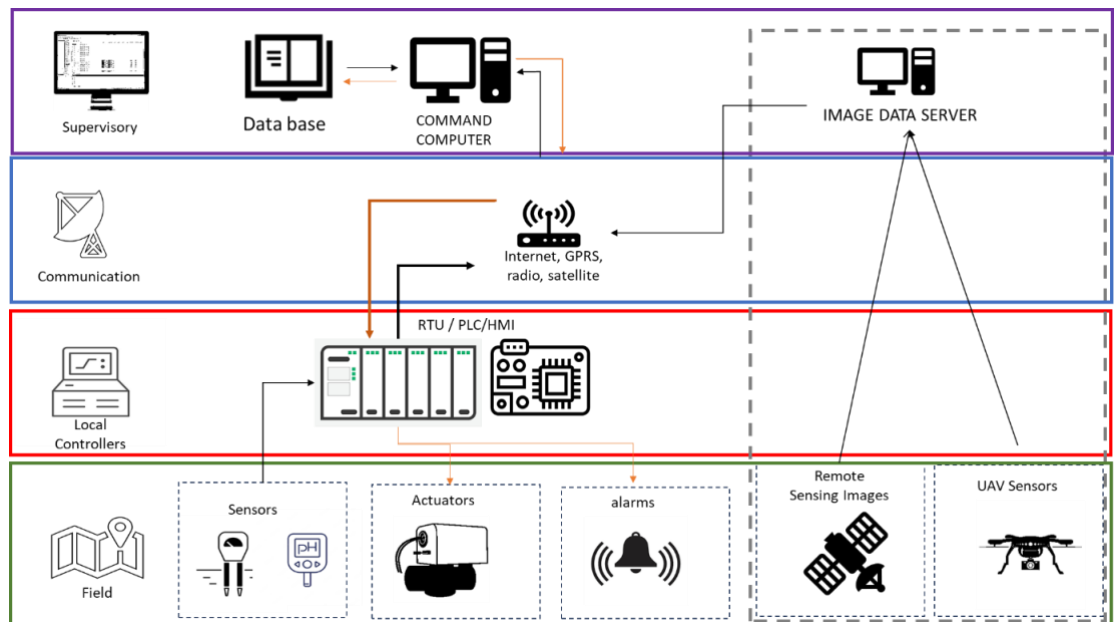


Figure 3.1 Hardware for macro system framework for soil moisture and chemical monitoring and control (Source : Output D2.4.1 report)

The proposed system is an advanced, online soil moisture and chemical monitoring framework using on-site sensors and remote sensing techniques. The framework, as outlined in Figure 3.1, includes:

- Infrastructure:
  - a SCADA-based architecture is used, combining land-based sensors, actuators, and alert systems. The data is gathered, processed, and stored on local or cloud servers. At field level : field implanted sensor are placed to measure soil moisture and chemical properties and the data is acquired by Remote Terminal Unit (RTU) which can be a Programmable Logic Controller (PLC) and has Human-Machine Interface (HMI). The RTU has responsibility to process data, send to command computer by internet connection, and also give instruction to the actuator, a device that converts electrical energy into mechanical motion, such as pumps, valves or regulatory gate. RTU also give notification or alarm for a particular condition.

- Hardware for data collection:
  - Sensors: Based on capacitive sensors implanted in soil using to relay real-time information about soil moisture, temperature, and electrical conductivity, providing insights into soil nutrients.
  - Unmanned Aerial Vehicle (UAV): Equipped with spectral sensors, these periodically monitor soil and crops from above, identifying potential problems before crops are affected.
  - Remote Sensing: Offering larger area coverage with spectral and Synthetic Aperture Radar (SAR) data, two- or three-dimensional images of the landscape can be created to supplement the data from UAV and on-site field implanted sensors.
- Spectral Sub-System:
  - Spectral sub-system is an optional for our design to accommodate larger area monitoring, when the data is required for decision making. It utilizes remote sensing and UAV for daily spectral and SAR data collection, which will be interpreted into soil moisture and chemical information. The data will be stored on a dedicated spectral data computer server, which connect to the command computer .
- Field Power Supply:
  - Primarily relying on renewable sources, the system uses rechargeable batteries charged by solar panels.
- Communication:
  - Ensures real-time and robust soil moisture, soil chemical and fertigation control data transfer through wired and wireless connection. The wireless connection can be Wireless Fidelity (WiFi), "long range" wireless communication LoRa and cellular internet connection. Data streams from sensors to Command Computer through RTU (soil moisture and chemical data) and from Command Computer to RTU and from RTU to actuators (fertigation control command data).
- Software:
  - Custom softwares which run and operate: command computer to meange the whole system, the RTU and spectral data server. That will facilitate data collection, conversion, analysis, and storage, and to control the fertigation. Software will also prepared for user dashboards to enable easy interpretation of soil data.
- Security:
  - Emphasizes physical security (fencing, locks), electrical surges and system security to the networks from cyber attacks which includes Network segmentation, Firewalls and Access control.
- Human Resources:
  - Operators: Manage data storage, UAVs, and remote sensing.
  - Technicians: Oversee installation, security, and maintenance of hardware and software.

- Programmers: Focus on software elements from RTU/PLC/HMI to dashboards.
- Implement a gender-responsive approach: Promote women and men to have the opportunity to access and gain benefits from the irrigation practices as a new technology innovation. The gender equality approach can build a women empowerment by identify the gender constrains as a social differentiation driver in community.

The system enables efficient soil and crop management, promoting sustainability and gender equality. By using the human resources designs, women can access fertigation technology as a men.



## 4 Technology Feasibility Assessment

A feasibility study was conducted to assess the integration of the macro system design with technologies facilitating automatic irrigation and fertilization. The selected geographic area of the Sukabumi Regency in West Java, Indonesia, will serve as a practical example for this analysis. This chapter will detail the methodology employed, present the findings, and provide conclusions and recommendations based on the data analysed.

### 4.1 Methods

A technology feasibility assessment was carried out to develop an integrated system. Evaluation of the technologies to be used was conducted to assess how suitable the technologies are with the needs and characteristics of the macro system by using the following criteria:

- a Electromechanically controllable technology – the fertigation system will be integrated, the information from sensors will be used to decide the operation e.g. to irrigate only or to fertigate, which uses electromechanical control or switching to turn on fertigation system (pumps and valve), which is ignited by control signal from Remote Terminal Unit (RTU).
  - b Durability – evaluate the effective lifespan of the system, which can range from 1 to 5 years.
  - c Integration Flexibility – evaluate how easily the sensor can be integrated with other systems, i.e., whether the sensor can or cannot integrate with other brands.
  - d Maintenance – evaluate the degree of maintenance required by the sensor, from no maintenance required to constant monitoring.
  - e Geographical Suitability – evaluate how well the technology fits with geographical conditions, from being applicable on a large scale to small scale.
  - f Mobilization – assess how easily the system can be moved, from being small and easy to carry, to being large and heavy.
  - g Infrastructure Requirements – evaluate the additional infrastructure required, such as electricity, buildings, and Information and Communication Technology (ICT.)
  - h Security: evaluate the system's security system, whether it's integrated or requires additional infrastructure.
  - i Human Resources Requirement - evaluate the level of expertise required to use the sensor, from regular workers to specialist graduates in gender equality.
- Gender-responsive analysis: assure the gender equality and equity in the business process so women and men have opportunity to access and gain

benefit from new technology implementation in farm and household level to avoid gender issues, like subordination and marginalization, based on five criteria: (1) selection and promotion, (2) training, (3) health and safety environment, (4) income, and (5) work division (Table 4.1).

Table 4.1 Gender-responsive criteria of technology implementation

Aspect	Description
Selection and promotion	Both gender have the opportunity to participate as a employee in technological institutions. Women as men involve in discussing 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. Since selection is open, staff composition procedures are designed for men and women and are accommodated to facilitate 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.
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 open to women have their children to the farm/land dan free from the risk of electricity errors and accident.
Income	Fair income for women and men staff. It is expected that not based on the stereotype that women only do the easy things so the women have barriers to have more responsibilities. It also avoid 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 in order to avoid double burden for women.

- j **Familiarity:** evaluate how familiar the technology is to users in Indonesia.

The criteria are evaluated qualitatively or by scoring 1-5, where 1 means very unsuitable and 5 means very suitable. The scoring is done by a team of experts consisting of experts in technology, system, and management. The expert team gives assessments based on data, facts, and objective and comprehensive analysis.

After scoring is done, the scores obtained by each technology are summed and the highest value is sought. The highest value indicates the level of suitability of the technology with the macro system. The technologies with the highest value will be selected to be integrated with the macro system.

## 4.2 Feasibility on the Integration of the Soil Moisture and Chemical Monitoring System with the Irrigation and Fertilization (Fertigation) System

### 4.2.1 Technology Feasibility

The following automatic irrigation and fertilization technologies were reviewed for their characteristics in report D3.1.1. A detailed description and comparison is presented in Table 4.2.

- 1 Jingxun
- 2 Netafim Fertikit 3G
- 3 DGT by Senmatic
- 4 Rivulis
- 5 JAIN

Each of these technologies offers a unique set of features, with different suitability and infrastructure requirements. All of the technologies involves fertiliser mixing and injection to irrigation. Each of them offers the solution for irrigation and fertilisation for application in agricultural practices. The specific strengths and weaknesses of each technology need to be evaluated before opting for a particular technology.

Table 4.2 Description for each technology (Part A)

Technology / Product	Technology/Product Description	Irrigation System	Fertigation System	Software / Data Base	Elektromekanical controller	Durability	Integration Flexibility	Maintenance
T-1: Jingxun	This technology integrates automatic time-based drip irrigation system with EC and pH-based fertigation system	Drip	EC&pH based	No	Yes	With protection on control unit, it can function properly for more than 3 years.	It is possible since it has extension port.	Easy access and maintenance. The installation unit requires maintenance
T-2: Netafim	This technology integrates automatic time-based Drip or Sprinkler Irrigation system with fertigation system There is also commercial control software made by Netafim	Drip or Sprinkler	Doses	Yes	Yes	More than 5 years for control/processing unit, and more than 3 year for irrigation system	Since it is protected by trade mark, it is not simple to add sensor system or different irrigation system.	Enables over-the-air maintenance and automatic firmware updates
T-3 : Senmatic	This technology integrates automatic time-based Drip Irrigation system with pH/EC-based fertigation system . It is Modular system	Drip	EC&pH based	No	Yes	It is modular system, so it can be replaced fast. Therefore it can function forever with proper maintenance and at green house.	As long as follow the standard, it is high possibility to add sensor system, or other system.	Easy access and maintenance. The installation unit requires maintenance
T-4 : Rivulis	This fertigation technology is based on proportional nutrition doses with irrigation flowrate	Not Include	Proportional Doses	No	Yes	It is simple, and function for long time as long as using proper nutrition solution.	To integrate with automatic irrigation system is high possibility, but for fertigation system is not.	Easy access and maintenance. The installation unit requires maintenance
T-5 : JAIN	Drip irrigation system and constant rate nutrient doses application	Drip	Doses	No	Yes	When install at green house, it can function properly for long time.	It is possible to change the irrigation or fertigation system into other maker.	It is easy maintenance since this system is a totally customized.

Table 4.3 Description for each technology (Part B)

Technology / Product	Maintenance	Geographical Suitability	Mobilization	Infrastructure Requirements	Security	Human Resources Requirement	Familiarity	Distributor in Indonesia
T-1: Jingxun	Easy access and maintenance. The installation unit requires maintenance	farmland irrigation, orchard irrigation, greenhouse irrigation and other scenarios. Green house agriculture is better.	English language operating system. This technology is easy to carry to and install on agricultural land and does not require a large space. Suitable for drip irrigation, sprinkler irrigation and other irrigation models	It requires electricity or batteries to operate, Requires support from EC, pH and soil moisture sensors as well as a micro irrigation network	Security password of control system can be set as desired. Control software can be written according to user requirements.	friendly man-machine interface	Convenient for user authority management and system safe operation	No
T-2: Netafim	Enables over-the-air maintenance and automatic firmware updates	Suitable for use in open field farming including small farms to large scale agricultural projects, horticultural plant nurseries and fruit plantations. Green house agriculture is better.	This technology is easy to carry to and install on agricultural land and does not require a large space. Suitable for drip irrigation, sprinkler irrigation and other irrigation models	It requires electricity or batteries to operate, This technology requires Wi-Fi, Bluetooth, Cellular, Ethernet, LoRa RF, RS-232, RS-485 for communication with the cloud and controlled units.	Security password of control system can be set as desired. Control software can be written according to user requirements.	friendly man-machine interface	Convenient for user management and system safe operation, easy to use and high reliability	Yes
T-3 : Senmatic	Easy access and maintenance. The installation unit requires maintenance	Suitable for use in open field farming including small farms to large scale agricultural projects, horticultural plant nurseries and fruit plantations	This technology is easy to carry to and install on agricultural land and does not require a large space. Suitable for drip irrigation, sprinkler irrigation and other irrigation models	It requires electricity or batteries to operate, Requires support from EC, pH and soil moisture sensors as well as a micro irrigation network	Security password of control system can be set as desired. Control software can be written according to user requirements. rapid EC and pH measurement with alarms	friendly man-machine interface	Easy to operate with well arranged menus shown on a large 10.1" touch screen. Many languages are available and switching between them is very simple.	No
T-4 : Rivulis	Easy access and maintenance. The installation unit requires maintenance	farmland irrigation, orchard irrigation, greenhouse irrigation and other scenarios	This technology is easy to carry to and install on agricultural land and does not require a large space. Suitable for drip irrigation, sprinkler irrigation and other irrigation models.	It requires electricity or batteries to operate, Requires support from EC, pH and soil moisture sensors as well as a micro irrigation network	Security password of control system can be set as desired. Control software can be written according to user requirements.	friendly man-machine interface	Easy to Use (Easy to use, multi language interface), integrated Control with Easy System Management	No

Technology / Product	Maintenance	Geographical Suitability	Mobilization	Infrastructure Requirements	Security	Human Resources Requirement	Familiarity	Distributor in Indonesia
T-5 : JAIN	It is easy maintenance since this system is a totally customized.	Suitable for a wide range land conditions.	It is possible to move, as semi portable system. How ever, fixed system is better.	House protection for contolling unit is necessary	Since it can be set to cheap and simple system, it is no necessary to set up special security system.	Lobour can be set at minimum level.	It is also can be set to simple enough	No

Table 4.4 comprehensively analyses the feasibility of each fertilization and irrigation technology, with a scoring range of 0-5 to rank for each criterion. For example, a score of 5 for "Integration Flexibility" represents a technology that has high flexibility in being integrated into a soil monitoring system and is thus highly preferred. Another example is a low score of 0 for "Distributor in Indonesia", which is not preferable as there are no local representatives existing to distribute this technology. Some of the technologies already include water delivery technology, i.e., emitters and pipe networks in their product. This can be beneficial if a technology product does not allow the combination of non-standardised products. However, since standardized water delivery technologies have been available in the market from various vendors, this should not be a crucial issue. Example of standards in the market include, but are not limited to, dimension, materials, pressure and discharge.

The technology chosen must be one that can be operated electromechanically because the irrigation operation command will be sent by a computer or RTU in the form of an electrical signal that will activate the actuator that uses electric current or voltage as the input energy and produces motion as the output. Actuators can be magnetic switches or valves and pumps that can be electrically triggered.

Based on the score (Table 4.5), Netafim technology has the highest score. Netafim products have also been widely used in Indonesia. Representatives or companies that supply the equipment are also well-established in Indonesia, with experience in supplying equipment to or working on various irrigation projects in the country. This experience would place such a technology or technology architecture as a high priority.

Table 4.4 Feasibility analysis for the enlisted technology (Part A)

Technology / Product	Technology/Product Description	Irrigation System	Fertigation System	Software / Data Base	Elektromekanical controller	Durability	Integration Flexibility
T-1: Jingxun	This technology integrates automatic time-based drip irrigation system with EC and pH-based fertigation system	Drip or sprinkler	EC & pH based	No	Yes	5	5
T-2: Netafim	This technology integrates automatic time-based Drip or Sprinkler Irrigation system with fertigation system There is also commercial control software made by Netafim	Drip or Sprinkler	Doses	Yes	Yes	5	4
T-3: Senmatic	This technology integrates automatic time-based Drip Irrigation system with pH/EC-based fertigation system . It is Modular system	Drip	EC&pH based	No	Yes	5	5
T-4 : Rivulis	This fertigation technology is based on proportional nutrition doses with irrigation flowrate	Drip	Proportional Doses	No	Yes	3	5
T-5 : JAIN	Drip irrigation system and constant rate nutrient doses application	Drip	Doses	No	Yes	4	5

Table 4.5 Feasibility analysis for the enlisted technology (Part B)

Technology / Product	Maintenance	Geographical Suitability	Mobilization	Infrastructure Requirements	Security	Human Resources Requirement	Familiarity	Distributor in Indonesia	Total
T-1: Jingxun	4	4	4	5	5	5	5	3	45
T-2: Netafim	5	5	4	4	5	5	5	5	47
T-3 : Senmatic	5	5	5	5	5	5	5	0	45
T-4 : Rivulis	5	4	5	3	4	4	5	0	38
T-5 : JAIN	4	4	5	4	4	4	4	0	38

#### 4.2.2 Suitability for integration

After evaluating each technology, the next step is to analyze its suitability for integration with the macro system that has been created. The macro system requires a tool that can realize decisions in the form of irrigation water provision and fertilizer application according to the needs. Therefore, the integrated system must have a fertigation function. In general, all irrigation technologies integrated with a fertilization system have the following components:

- Irrigation pump system
- Fertilizer injection system (venturi injector, fertilizer booster pump, fertilizer tank)
- Filter system
- Pipeline network (manifold, lateral)
- Valve for each irrigation unit.

In this case all of the technologies are suitable.

The irrigation unit in question is an area of land that will be irrigated by setting with one valve. One irrigation unit is considered to have flat land, and the irrigation network when operating has good uniformity in terms of pressure and discharge at each irrigation point.

Because the proposed macro system involves ICT-based monitoring technology, the fertigation technology to be combined must have the flexibility to be integrated with third-party products. In this case, in addition to having ICT functions, the products are also compatible with the IC macro system proposed. In this case, technologies by Jixun, JAIN and Netafim show their suitability.

Finally, the macro system will give commands to perform irrigation or and/or fertigation using electronic signals that will activate the actuator. The selected technology must be able to operate electromechanically to perform irrigation or fertigation. Because all technologies use electricity, they can be controlled electromechanically. With the above considerations and evaluation criteria that have been done, netafim technology becomes the highest priority because it can be integrated with the proposed macro system and already has users/suppliers in Indonesia.

With the above considerations and evaluation criteria that have been done, netafim technology becomes the highest priority because it can be integrated with the proposed macro system and already has users/suppliers in Indonesia



## 5 Proposed System Design

In the previous section, the soil moisture and chemical system from report D2.4.1 was introduced and the technology feasibility analysis for fertigation technology was conducted. The following section describes the proposed system that integrates the macro system of soil moisture and chemical monitoring with automatic irrigation and fertilization...

### 5.1 Architecture of the Primary System

The system architecture of automatic irrigation and fertilization that integrates with the macro system previously designed and reported in Section 2 consists of components that enable sensing of soil moisture and chemicals, controlling data acquisition 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.

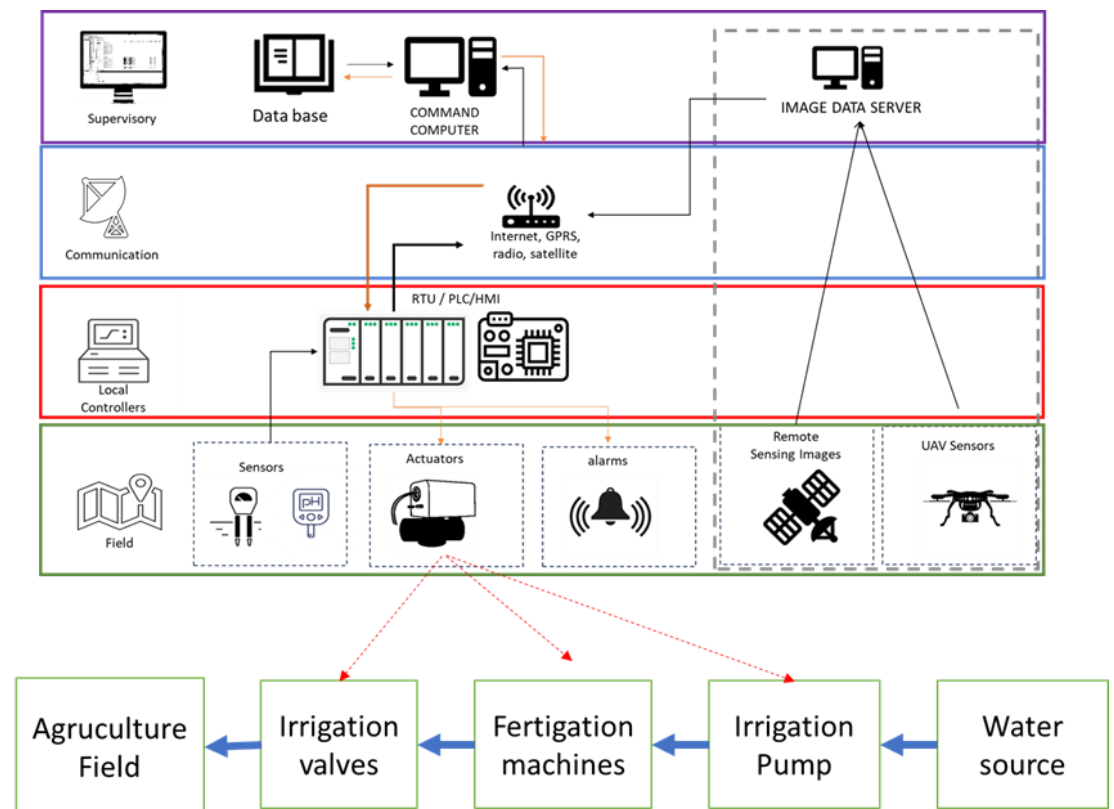


Figure 5.1 Integration of the soil monitoring system and automatic fertigation system

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 Figure 5.1.

### 5.1.1 Field Sensors

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

- **Soil Moisture Sensors:** Using either capacitive, resistive, or tensiometric methods, these sensors monitor water content at various soil depths to determine irrigation needs.
- **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.
- **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.

### 5.1.2 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.

### 5.1.3 Actuators 1 : Irrigation

Actuators are devices that perform actions based on the commands they receive from the RTU or command computer.

- **Pumps:** Ensure the flow of water from the source to the irrigation network.
- **Valves:** Control the amount and direction of water flow within the irrigation system, turning on/off based on soil moisture levels and other parameters.

### 5.1.4 Irrigation Network Pipe

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.

- **Mainlines and Sub-mainlines:** High-capacity pipes that transport water from the source or storage to manifold locations.
- **Laterals:** Smaller pipes/drip tubes that deliver water directly to plants, often equipped with emitters or drippers for slow release.
- **Filters:** Removes debris and sediments to prevent clogging, especially crucial for drip irrigation systems.

#### 5.1.5 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.

- **Venturi Injectors:** Utilize pressure differences to draw and mix fertilizer into the irrigation flow.
- **Dosing Pumps:** Electronically controlled pumps that introduce precise amounts of liquid fertilizers into the water stream.
- **Mixing Tanks:** Location where water and fertilizers are pre-mixed before being released to the field.

#### 5.1.6 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.

#### 5.1.7 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.

#### 5.1.8 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.

The architecture described, as summarised in Figure 5.2, 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.

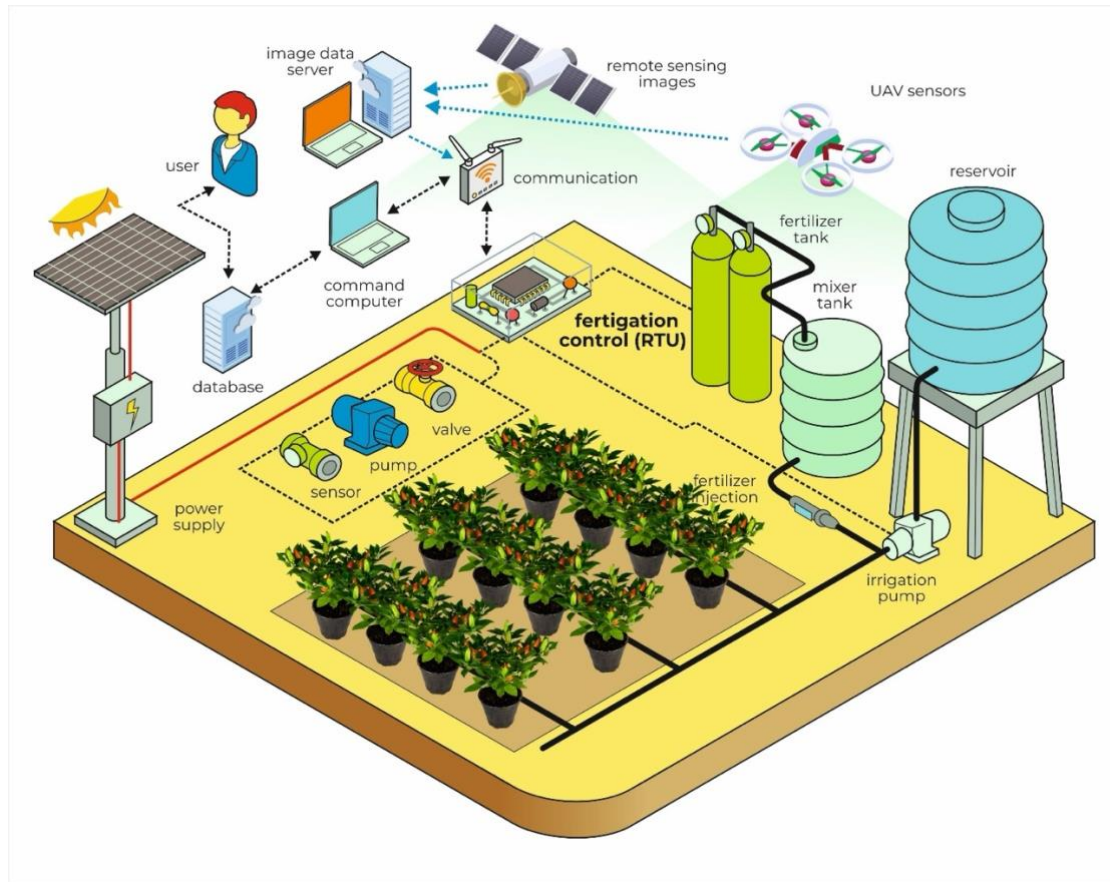


Figure 5.2 Schematics of the proposed integrated system

## 5.2 Energy Supply

This system works with electrical power that can be obtained from various sources according to availability in the field. The easiest method of obtaining electricity is to use solar photovoltaics. 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).

Based on the research that has been conducted in Sukabumi on the potential of solar energy, it was found that most sub-districts have medium or high potential of solar energy (Ali, n.d.). The private sector has already built solar rooftops in Sukabumi (Iman, n.d.), inaugurated by the Governor of West Java (Mediaindonesia, n.d.).

The use of solar power for irrigation is reported to be quite economical (Goel & Sharma, 2021; Karki & Lohani, 2020; Rejekiingrum & 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 to benefit 121 women farmers by increasing their harvest by approximately 25-40% in one year. The project also

tackled the energy crisis in the affected area and increased gender equality and social inclusion.

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(Goel & Sharma, 2021; Karki & Lohani, 2020; Rejekiningrum & Saptomo, 2015)(Ayundyahrini et al., 2023)(Amir, 2021)(Siantoro et al., 2023)

## 5.3 Spectral Data Subsystem: Integration of Remote Sensing and Drone Data

The spectral data subsystem is an advanced technological component that utilizes remote sensing data to inform on soil conditions, such as moisture and nutrition levels. This system merges data from traditional remote sensing sources with drone-acquired data to create a more detailed and specific portrait of agricultural land. In the proposed integrated system, this subsystem is optional and recommended for large-scale areas.

### 5.3.1 Remote Sensing Data

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

- **Advantages:** Covers large areas, ideal for monitoring extensive regions and providing a general overview of an area's conditions. Can be freely acquired for several satellites.
- **Limitations:** Spatial and temporal resolution may not be as high as drones, especially for smaller-scale agricultural plots.

### 5.3.2 Drone Data

Drones or unmanned aircraft can be equipped with spectral sensors. Drones can fly at low altitudes, providing extremely high-resolution data for smaller areas compared to traditional remote sensing.

- **Advantages:** High resolution, with capability to monitor specific areas in greater detail, as well as greater operational flexibility.
- **Limitations:** Coverage area is more limited compared to traditional remote sensing.

### 5.3.3 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.

#### 5.3.4 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.

#### 5.3.5 Subsystem Flexibility

The subsystem is designed with 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.

### 5.4 Gender-Responsive Approach

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 and promotion; (b) Training; (c) Health and safety environment; (d) Income; and (e) Work division.

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