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

## Output 5 – Train Governmental Bodies in the CSA Practices and the Fully Integrated System

### Consolidated Training Material

D5.1.1

United Nations Environment Programme (UNEP)

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# Training Modules
# Advancing Knowledge of Climate-Smart Agriculture (CSA) and Its Implementation in Indonesia:

## Integration of Soil Monitoring, Irrigation and Fertigation Technology for Advanced Agriculture and Its Financial Analysis

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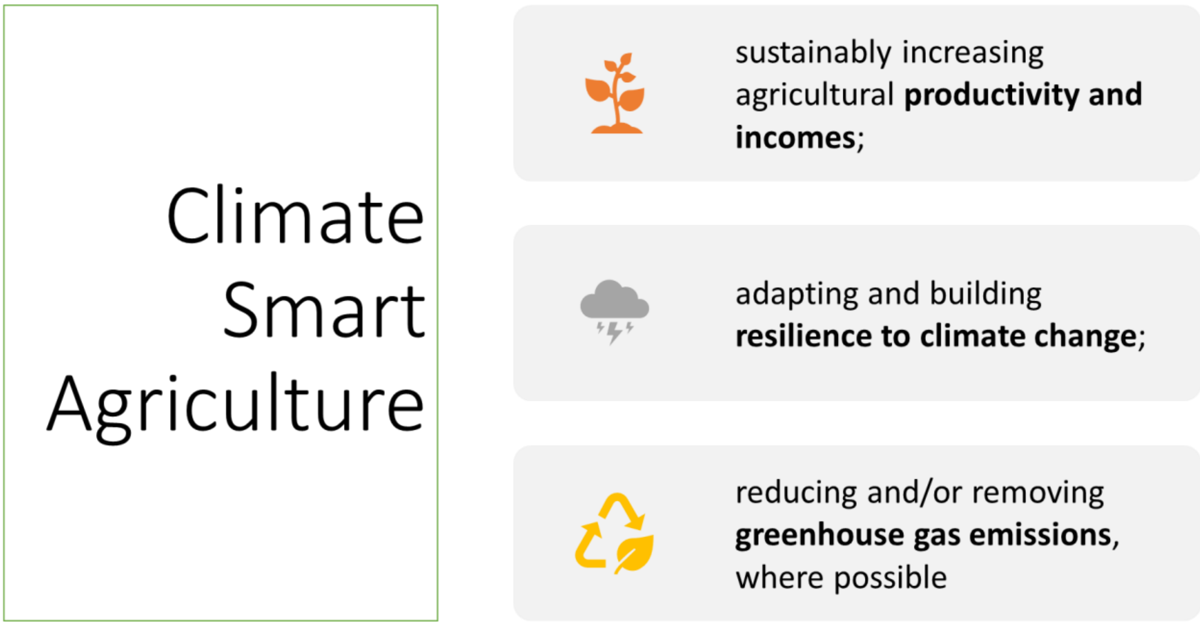
# 1 Modul 1: Introduction to CSA and Its Implementation in Indonesia




**Modul 1 Learning Objectives:**

1.1. Participants understand and can explain the concept of Climate-Smart Agriculture (CSA).
1.2. Participants can explain the implementation of CSA in Indonesia.
1.3. Participants will be able to explain the importance of a gender-responsive Climate-Smart Agriculture (CSA) and describe strategies to support CSA as a gender-responsive program.

## 1.1 Sub Module 1.1. Introduction to Climate-Smart Agriculture

**Learning Objectives:** Participants understand and can explain the concept of Climate-Smart Agriculture (CSA)

### 1.1.1 Introduction

Climate-smart agriculture (CSA) Climate-smart agriculture (CSA) (or climate resilient agriculture) is an integrated approach to managing landscapes to help adapt agricultural methods, livestock and crops to the effects of climate change and, where possible, counteract it by reducing greenhouse gas emissions from agriculture, at the same time taking into account the growing world population to ensure food security. It is an approach that jointly addresses food security and climate change by achieving its three goals:

1 Sustainably increasing agricultural productivity and incomes (productivity)
2 Adapting and building resilience to climate change (resilience)
3 Reducing greenhouse gas emissions from agricultural production and processing (emission).

By focusing on food security, climate change adaptation, and ecosystem management, the concept of CSA addresses the three dimensions of sustainable development and aims to maintain a balance between them while enhancing agricultural productivity.

### 1.1.2 Practices of CSA

Example of aspects of CSA practices[1]

a. Soil management:
   - Conservation agriculture, biomass recycling and soil health,
   - Integrated farming –nutrient management.

b. Crop management:
   - Use of diverse and appropriate varieties,
   - Crop and livelihood diversification,
   - Organic farming for sustainable agriculture,
   - Participatory seed production and seed saving,
   - Seed System

c. System of Rice Intensification:
   - Moist and not flooded soil,
   - Soil enhancement with organic matter content,
   - Young seedlings transplant spaced widely in a square grid pattern,
   - Less irrigation water.

d. Crop and livelihood diversification:

[1] CLIMATE SMART AGRICULTURE Curriculum/Module for Training of trainers in Myanmar, FAO, 2019

- Crop diversification to reduce risk in adversely affected areas,
- Integrated farming system (fish-rice, duck – rice, cow, goat, pig raising),
- Mixed, Inter, Relay cropping & Cropping System.

e. Water management:

- Water harvesting and saving techniques,
- Improved Micro irrigation for vegetables,
- Alternate Wetting and Drying (AWD) techniques for rice cultivation.

f. Agroforestry

- Agroforestry,
- Sloping Agricultural Land Technology (SALT),
- Community forestry.

### 1.1.3 Stakeholders of CSA

CSA stakeholders include farmers, researchers, policymakers, civil society organizations, private sector companies, and consumers.

**Farmers:**

- Crucial stakeholders in CSA,
- Responsible for implementing the practices that make their farms more sustainable and resilient to climate change,
- Directly impacted by the effects of climate change, including droughts, floods, and changes in temperature and precipitation patterns.

**Researchers and scientists:**

- Developing and testing new technologies and practices that can help reduce greenhouse gas emissions, improve productivity, and enhance resilience to climate change,
- Monitoring and evaluating the impacts of CSA interventions to ensure effectiveness and efficiency.

**Policymakers and government officials**:

- Important stakeholders in CSA,
- Provide the necessary national regulatory framework,
- Provide financial support to scale up CSA interventions,
- Play a role in shaping international policies and agreements that promote sustainable agriculture and reduce greenhouse gas emissions.

**Civil society organizations and private sector companies:**

- Key stakeholders in CSA,
- Can provide funding, technical expertise, and other forms of support to farmers and other actors in the food system,
- Driving demand for sustainable and climate-friendly agricultural products,
- Promoting greater transparency and accountability across the food system.

**Consumers:**

- Important stakeholders in CSA,
- Driving demand for sustainable and climate-friendly agricultural products.

Stakeholders are widely open to building the CSA in Indonesia, providing food security, adaptation to climate change, and reducing emissions pillars, with outcomes such as food security or good nutrition.

### 1.1.4 Activity: QUIZ

| | |
|---|---|
| **What is the primary goal of Climate-Smart Agriculture (CSA)?**<br>**A) Increasing use of chemical fertilizers**<br>**B) Sustainably increasing agricultural productivity and incomes**<br>**C) Focusing solely on greenhouse gas reduction**<br>**D) Ignoring climate change impacts** | |
| **Which of the following is NOT a goal of CSA?**<br>**A) Adapting to climate change**<br>**B) Reducing agricultural productivity**<br>**C) Building resilience to climate change**<br>**D) Reducing greenhouse gas emissions** | |
| **What practice is associated with soil management in CSA?**<br>**A) Use of heavy machinery**<br>**B) Conservation agriculture**<br>**C) Solely chemical pest control**<br>**D) Avoiding organic matter use** | |
| **Which crop management strategy is emphasized in CSA?**<br>**A) Monoculture farming**<br>**B) Use of diverse and appropriate varieties**<br>**C) High chemical input farming**<br>**D) Reducing seed diversity** | |
| **The System of Rice Intensification (SRI) includes which of the following practices?**<br>**A) Keeping soil flooded**<br>**B) Use of older seedlings**<br>**C) Moist and not flooded soil**<br>**D) High-frequency irrigation** | |
| **Which of the following is a water management technique in CSA?**<br>**A) Increased water usage for irrigation**<br>**B) Alternate Wetting and Drying (AWD) for rice**<br>**C) Avoiding water harvesting techniques**<br>**D) Sole reliance on rainwater** | |
| **Agroforestry in CSA involves:**<br>**A) Sole crop farming**<br>**B) Decreasing tree cover on agricultural lands**<br>**C) Integrating trees within agricultural systems**<br>**D) Removing existing natural forests** | |
| **Who are the primary stakeholders in CSA?** | |

| | |
|---|---|
| A) Only farmers<br>B) Only policymakers<br>C) Farmers, researchers, policymakers, civil society, private sector, and consumers<br>D) Only private sector companies | |
| What role do researchers and scientists play in CSA?<br>A) Ignoring the effects of climate change<br>B) Developing technologies to increase greenhouse gas emissions<br>C) Testing new practices for resilience and productivity<br>D) Focusing solely on agricultural profits | |
| How do consumers influence CSA?<br>A) By demanding non-sustainable agricultural products<br>B) Having no influence on agricultural practices<br>C) Driving demand for sustainable and climate-friendly products<br>D) Only purchasing imported food products | |

Answers: B, B, B, B, C, B, C, C, C, C.

## 1.2 Sub Module 1.2. CSA Implementation in Indonesia

**Learning Objectives:** Participants can explain the implementation of CSA in Indonesia

### 1.2.1 Introduction

Climate-Smart Agriculture (CSA) represents a transformative approach to ensure sustainable agricultural practices and food security in the face of climate change. This module is designed to elucidate the implementation of CSA in Indonesia, emphasizing the roles of pivotal institutions like the Ministry of Environment and Forestry (KLHK), the United Nations Environment Programme (UNEP), the Climate Technology Centre and Network (CTCN), and the National Research and Innovation Agency (BRIN).

Climate-Smart Agriculture (CSA) is pivotal for Indonesia's agricultural sustainability, addressing the urgent need for food security amid climate change. This module delves into CSA's implementation in Indonesia, focusing on the critical roles of the Ministry of Environment and Forestry (KLHK), the United Nations Environment Programme (UNEP), the Climate Technology Centre and Network (CTCN), and the National Research and Innovation Agency (BRIN).

Indonesia faces significant climate change impacts, threatening its agricultural productivity and biodiversity. CSA emerges as a strategic response, promoting practices that enhance resilience, productivity, and emission reduction. KLHK integrates climate-smart principles into agricultural policies, ensuring sector resilience. It collaborates with stakeholders across levels, enhancing the adoption of sustainable practices.

International support from UNEP and CTCN brings technical expertise and global resources, emphasizing the importance of international partnerships in tackling climate challenges. These organizations play a crucial role in mobilizing support and facilitating access to cutting-edge climate-smart technologies and practices.

BRIN's contribution is fundamental in researching and developing innovative technologies tailored to Indonesia's diverse agricultural needs. From advanced irrigation systems to sustainable land management practices, BRIN's work is essential in making CSA practices viable and effective across Indonesia's agricultural landscapes.

Programs like SIMURP highlight practical CSA applications, showing the effectiveness of combining policy support, international collaboration, and local innovation. This module will provide a comprehensive understanding of how various stakeholders, from government bodies to international organizations and research agencies, collaborate to advance CSA in Indonesia.

Participants will explore these collaborative efforts, gaining insights into the multifaceted approach required to implement CSA successfully. This knowledge aims to equip them with the ability to contribute to Indonesia's journey towards sustainable and resilient agricultural practices in the face of climate change.

### 1.2.2 Stakeholders of CSA in Indonesia's Government

Climate-Smart Agriculture (CSA) in Indonesia represents a multi-faceted approach, involving various government institutions each playing a critical role in the implementation, development, and advancement of CSA practices. These stakeholders collaborate to ensure that agricultural practices not only meet the current needs for food security and livelihood but also address the challenges posed by climate change. This introduction outlines the pivotal roles of key government institutions in fostering a climate-resilient agricultural sector in Indonesia.

**Ministry of Environment and Forestry (KLHK)**

As the National Designated Entity (NDE), KLHK spearheads the national agenda on climate change, including the integration of CSA into national policies. This ministry plays a crucial role in setting the regulatory framework, facilitating international cooperation, and ensuring environmental sustainability in agricultural practices.

**Ministry of Women Empowerment and Children Protection (KPPA)**

KPPA ensures that CSA initiatives are gender-sensitive, promoting community involvement with a strong emphasis on empowering women in agriculture. Recognizing the significant role women play in agriculture and rural economies, KPPA's involvement ensures that CSA practices are inclusive and equitable.

**Ministry of Public Works and Housing (KPUPR)**

KPUPR is instrumental in improving and maintaining irrigation infrastructure, a cornerstone for increasing water use efficiency in climate-resilient agricultural practices. Their work is critical in ensuring that water resources are managed sustainably, supporting the adaptation of agricultural systems to climate variability.

**Coordinating Ministry for Economic Affairs (KemenKoE)**

KemenKoE oversees the monitoring, analysis, evaluation, and reporting in the food and agribusiness sector. This ministry coordinates between various departments and stakeholders, ensuring that economic policies align with the goals of CSA, enhancing food security, and sustainable development.

**Ministry of Agriculture (Kementan)**

Kementan is at the forefront of facilitating smallholder access to extension services that assist with CSA technology. It supports farmers in adopting CSA practices by providing necessary infrastructure, services, and program support. Kementan's role is vital in enhancing agricultural productivity, improving resilience to climate impacts, and reducing greenhouse gas emissions from agriculture.

**National Research and Innovation Agency (BRIN)**

BRIN conducts research and development activities focused on identifying and developing practical CSA practices. Their work is crucial for innovation in agriculture, providing evidence-based solutions and technologies that can be adopted by farmers to face the challenges of climate change effectively.

| **Government Institutions** | **Role in CSA** |
|---|---|
| Ministry of Environmentand Forestry(KLHK) | National designated entity (NDE) |

| | |
|---|---|
| Ministry of Women Empowerment and Children Protection (KPPA) | To ensure community involvement (gender-sensitive) |
| Ministry of Public Worksand Housing(KPUPR) | Improving and maintaining irrigation infrastructure toincrease the efficiency of water use in climate-resilientagricultural practices. |
| CoordinatingMinistry for Economic Affairs (KemenKoE) | Monitoring, analysing, evaluating, and reporting in the field of food andagribusiness |
| Ministry of Agriculture (Kementan) | • Facilitate smallholder with excellent extension who can provide assistant related CSA technology<br>• Supporting farmers to adopt CSA practices by providing the necessary infrastructure and services to enhance agricultural productivity, improve resilience, and reduce greenhouse gas emissions.Provide program support/input for smallholders regarding CSA's pillar |
| National Research and Innovation Agency (BRIN) | Conduct research and development activities to identify and develop CSA practices that can be adopted by farmers |

### 1.2.3 Best Practices of CSA in Indonesia

In Indonesia, the adoption of Climate-Smart Agriculture (CSA) best practices is reshaping the agricultural landscape towards greater sustainability and resilience against climate change. Agroforestry, a standout approach, cleverly merges agriculture with forestry to create a symbiotic ecosystem that enhances biodiversity, improves soil structure, and boosts carbon sequestration. This method not only supports environmental health but also elevates farmers' livelihoods by diversifying income sources.

The System of Rice Intensification (SRI) is another exemplary practice, revolutionizing rice production through optimized planting techniques and water management. This method significantly increases yields while conserving water and reducing the need for chemical fertilizers, showcasing how targeted interventions can lead to sustainable agricultural advancements.

Efficient water management practices, including rainwater harvesting and the use of micro-irrigation systems, demonstrate Indonesia's commitment to overcoming water scarcity challenges. These practices ensure the judicious use of water resources, crucial for maintaining agricultural productivity in the face of fluctuating weather patterns.

By incorporating these best practices, Indonesia is not only enhancing its agricultural productivity but also fortifying its food security and contributing to global efforts against climate change. These initiatives underscore the importance of sustainable practices in achieving long-term agricultural resilience. The following are examples of best practices in Indonesia:

1. CSA technology application in Nagekeo Regency, East Nusa Tenggara, through the SIMURP Program by the Indonesian Ministry of Agriculture, resulting in

increased corn productivity over one hectare by using modern agricultural techniques and smart farming practices to adapt to climate change[2].

2. A study on the Bio-Industry model in West Papua integrated cocoa and goat farming, showing a self-sustaining cycle of matter and product diversification that enhances income and land productivity.[3]
3. Smart irrigation introduction at P4S Buana Lestari, Nganjuk Regency, featuring a portable sprinkler system that efficiently manages water for agricultural use, highlighting its specifications and operational efficiency.[4]
4. Development solar-powered automatic irrigation technology in North Tarakan, demonstrating its efficiency in water use and its positive impact on irrigation productivity through moisture-based pump operation.[5] [6]
5. Implementation of CSA strategies on Sumba Island, introducing water use efficiency and management innovations like mulching, drip irrigation, and agroforestry, contributing to drought resilience and sustainable farming[7].
6. The Central Java and Wonogiri Regency Governments developed an agroforestry system in Tempursari Village, blending food crops with forestry, thereby enhancing biodiversity, soil protection, and additional income through diversified farming practices.[8]
7. The research on irrigated rice fields in Central Java compared traditional farming with CSA techniques, showing CSA's potential to reduce greenhouse gas emissions, increase crop productivity, and improve economic returns.[9]
8. Positive perceptions towards smart farming technology among farmers and extension workers in Aceh for rice, corn, and potatoes, citing benefits like cost reduction and productivity increase despite facing challenges in technology adoption.[10]
9. Demonstration of the effectiveness of the urban farming program in Surabaya for poverty reduction, overcoming dry season water shortages, and producing high-quality vegetables through modified agricultural techniques.[11]

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[2] Teknologi CSA jadikan Petani Nagekeo NTT Pintar Adaptasi Perubahan Iklim. https://www.berita2bahasa.com/berita/08/155299-teknologi-csa-jadikan-petani-nagekeo-ntt-pintar-adaptasi-perubahan-iklim

[3] Pendekatan Climate Smart Agriculture (Csa) Dalam Membangun Model Pertanian Adaptif Perubahan Iklim Dan Pola Sinergi Peneliti-Penyuluh Dalam Diseminasi Inovasi Teknologi. Buletin Agro-Infotek, 4(1).

[4] Aplikasi Irigasi Cerdas di P4S Buana Lestari, Kabupaten Nganjuk, Jawa Timur. Jurnal Pusat Inovasi Masyarakat (PIM), 5(1), 22–33. https://doi.org/10.29244/jpim.5.1.22-33

[5] Teknologi Irigasi Otomatis Bertenaga Surya Di Kelompok Tani Cahaya Tani Kecamatan Tarakan Utara Kota Tarakan. J-PEN Borneo : Jurnal Ilmu Pertanian, 2(2). https://doi.org/10.35334/jpen.v2i3.1530

[6] Efisiensi Teknologi Irigasi Sprinkler Di Lahan Kelompok Tani Kecamatan Tarakan Utara, Kota Tarakan. Rona Teknik Pertanian, 15(1), 13–24. https://doi.org/10.17969/rtp.v15i1.23360

[7] Impact of Climate Change on Agriculture and Food Crops: Options for Climate Smart Agriculture and Local Adaptation in East Nusa Tenggara, Indonesia. Dalam IRGSC Working Paper.

[8] Sustainable Landscape Newsletter. Edition 3 December 2016 Light Version. Business watch Indonesia. https://www.sustainable-landscape.org/

[9] Climate smart agriculture to increase productivity and reduce greenhouse gas emission–a preliminary study. IOP Conference Series https://doi.org/10.1088/1755-1315/200/1/012024

[10] Farmers’ perspectives on the adoption of smart farming technology to support food farming in Aceh Province, Indonesia. Open Agriculture, 7(1), 857–870. https://doi.org/10.1515/opag-2022-0145

[11] Program Urban Farming Sebagai Model Penanggulangan Kemiskinan Masyarakat Perkotaan (Kasus, Studi Kelurahan, Tani Sukolilo, Kecamatan Surabaya, Kota Junainah, Wahida Kanto, Sanggar). Wacana, Jurnal Sosial dan Humoniora, 19(3), 148–156

10. Analysis of cropping patterns in Banyumas Regency based on climate indices and rainfall, recommending various rotations to optimize water use and crop yield under changing climatic conditions. Diverse studies demonstrate how Climate Smart Agriculture (CSA) and smart farming technologies effectively address climate challenges, increase productivity, and aid in sustainable farming. These approaches, ranging from strategic irrigation systems to agroforestry, highlight innovation in water management, crop diversification, and the integration of traditional and modern techniques, proving essential for enhancing agricultural resilience and sustainability[12]

### 1.2.4 Activity

1. Participants are asked to identify activities that fulfil one or more objectives of Climate-Smart Agriculture (CSA) and to mention the objectives achieved.
2. Participants are also requested to mention the potential programs or roles of stakeholders from relevant government institutions in those activities.

[12] Cropping Pattern Scenario based on Global Climate Indices and Rainfall in Banyumas District, Central Java, Indonesia. Dalam Agriculture and Agricultural Science Procedia (Vol. 9, hlm. 54–63). Elsevier BV. https://doi.org/10.1016/j.aaspro.2016.02.124

## 1.3 Sub Module 1.3. Gender Mainstreaming in CSA

**Learning Objectives:** Participants will be able to explain the importance of a gender-responsive Climate-Smart Agriculture (CSA) and describe strategies to support CSA as a gender-responsive program.

### 1.3.1 Introduction: Significance of Gender Responsive CSA Projects

As a climate change adaptive capacity building project, CSA recognises that it can have different impacts on men and women. There may be programmes that do not consider the impact of their programmes on men and women, as well as those that understand gender injustice but do not take any measures to stop it.

Men and women may have different perspectives and knowledge about climate change risks, which may affect their livelihood strategies and responses to changes. This is because womenhave different roles, constraints, and access to resources than men, such as in land rights, technology, information, knowledge, and climate and weather information. Reducing inequalities in gender injustice will also reduce hunger.

Thus, gender-responsive CSA needs to be built to strengthen the adaptive capacity of men and women in families and communities to implement CSA technology programmes with equal opportunities to access and benefit from CSA so as to improve gender equality and equity.

### 1.3.2 Strategies for Building a Gender Responsive CSA

Conducting a gender analysis where men and women are mapped based on the division of labour profile in the farm prior to the CSA. The more activities that are jointly undertaken, themore gender equality and equity in farming practices are considered.

Table 1.1 Sample Labour Division Profile of Farmers by Gender in Rice, Chrysanthemum and Chilli Commodities in Sukabumi District in 2023.

| **Activities** | **Male** | **Women** |
|---|---|---|
| Sowing | √ | √ |
| Maintenance | √ | √√ |
| Irrigation | √ | √√ |
| Fertilisation | | √ |
| Harvest | | √ |
| Post-harvest (sorting and grading) | √ | √ |
| Marketing | √√ | √ |

Thereafter, the analysis can be scaled up to identify practical gender needs and strategic genderneeds in CSA practice. Practical needs concern current conditions that need to be met and cannot be delayed while strategic needs relate to the position of women vis-à-vis men throughstructural interventions. In the context of CSA, this can be exemplified like this:

Table 1.2 Gender Practical and Strategic Needs in CSA Implementation.

| | |
|---|---|
| Practical needs | • Selection and promotion in labour in operating the CSA<br>• CSA technology training to be able to operate CSA<br>• Health and safety of the working environment in operating CSA technology<br>• Revenue from the role of operating a CSA |
| Strategic needs | • Participation of women and women's organisations in financial planning and decision-making for CSA<br>• implementation<br>• Equal division of labour between men and women in organisations implementing CSA and households |

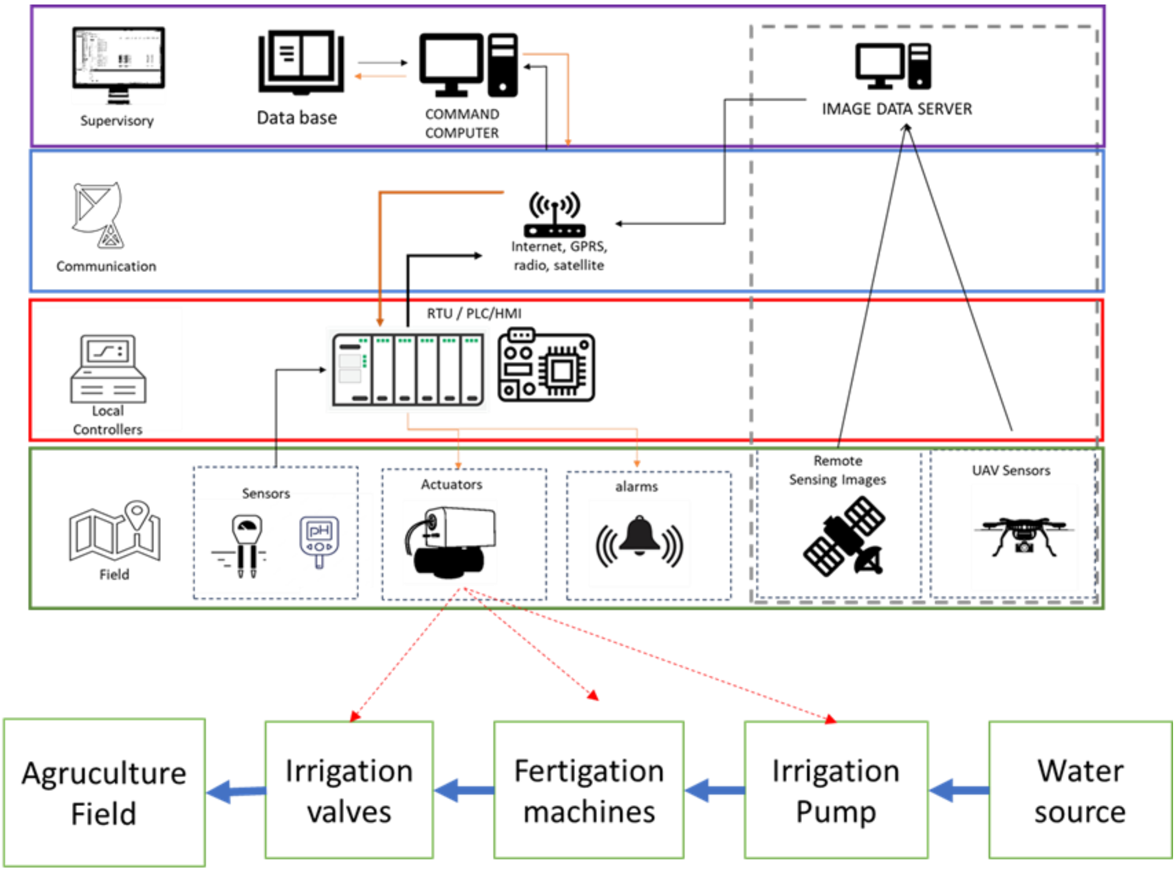
The more practical and strategic needs are met, the more programmes will be considered gender-responsive.

### 1.3.3 Activity

Participants were asked to write down the tasks usually performed by women and men in each organisation.

1. Participants are asked to think about and write down the gender equity trends seen in each organisation. Consider factors that may contribute to gender inequity.
2. Participants write down the practical and gender needs that need to be met for CSA tobe a gender-responsive programme.

# 2 Modul 2: Soil Monitoring, Automatic Irrigation Technology and Fertigation




**Modul 2 Learning objectives:**

2.1. Participants learn about soil water content and soil chemistry identification technology.
2.2. Participants understand automatic irrigation technology and fertilization applications.
2.3. Participants know the products available for CSA implementation.

## 2.1 Sub Module 2.1. Identification of Water Content and Soil Chemistry

**Learning Objectives:** Participants learn about soil water content and soil chemistry identification technology.

### 2.1.1 Introduction

**Soil Water**

Understanding soil water content is crucial for effective agricultural practices, especially in the context of Climate-Smart Agriculture (CSA). It involves several aspects:

1. Soil Moisture

Soil moisture refers to the water held in the spaces between soil particles. This component is vital for plant growth as it is a primary source of water for plants. The amount of soil moisture available to plants can significantly affect their health and productivity. Monitoring soil moisture helps in managing irrigation more efficiently, ensuring plants receive the right amount of water at the right time.

2. Soil Texture

Soil texture is determined by the relative proportion of sand, silt, and clay particles in the soil. This characteristic influences the soil's ability to hold and retain moisture. For instance, sandy soils drain quickly but hold less water, making them dry out faster. Clay soils, on the other hand, retain water well but have slower drainage. Understanding soil texture is essential for determining water holding capacity and irrigation needs.

3. Root Depth

Root depth is the measure of how deep the roots of a plant extend into the soil. This depth affects a plant's ability to access water. Deeper roots can tap into moisture reserves found further below the surface, which is particularly beneficial during dry periods. Knowledge of root depth is important for selecting appropriate crops for an area based on the water availability and soil depth.

4. Available Water Capacity

Available water capacity is the amount of water that the soil can store and that is available for use by plants. It is influenced by both soil texture and structure. This capacity indicates the volume of water that can be absorbed by the soil from rainfall or irrigation and then used by plants. Maximizing the available water capacity of soil through practices like mulching, proper irrigation, and soil health management can significantly improve plant growth and reduce the need for frequent watering.

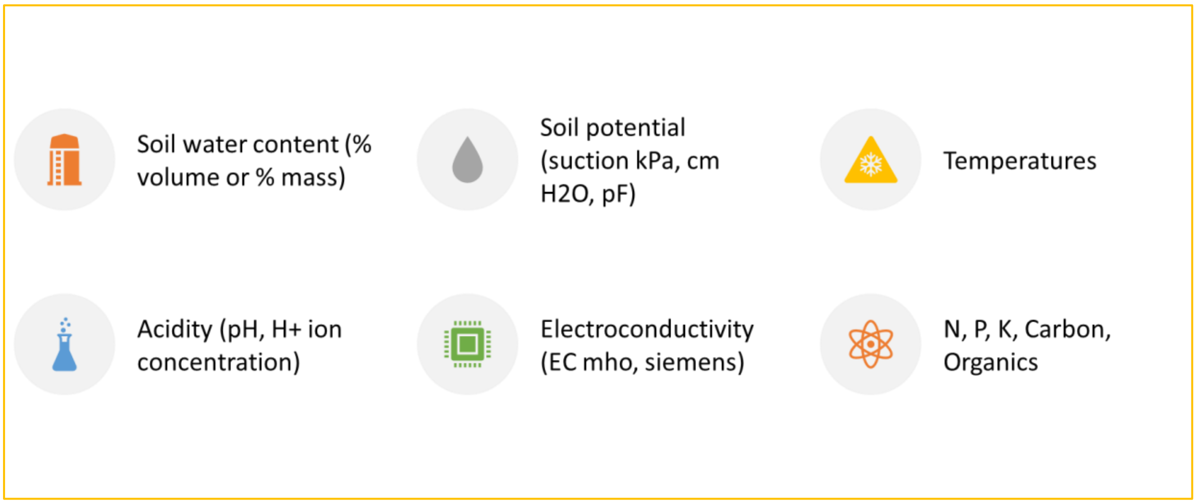



Figure 2.1 Soil Parameters

### Soil Fertility

Soil fertility is a critical aspect of agricultural productivity, encompassing various factors that contribute to the growth and health of plants. Key elements include:

1. Content of N, P, K, and Micronutrients
    - Nitrogen (N): Essential for plant growth, nitrogen is a key component of amino acids, proteins, and chlorophyll. It plays a crucial role in the vegetative growth phase of plants.
    - Phosphorus (P): Vital for energy transfer within the plant, phosphorus contributes to root development, flower and seed production, and overall plant vigor.
    - Potassium (K): Important for water uptake and retention, potassium aids in photosynthesis, protein synthesis, and resistance to diseases.
    - Micronutrients: Elements like iron, manganese, zinc, copper, molybdenum, and boron, although needed in smaller quantities, are essential for plant development, enzyme function, and various physiological processes.
2. Cation Exchange Capacity (CEC)

    The Cation Exchange Capacity refers to the soil's ability to hold and exchange positively charged ions or cations. A higher CEC indicates that soil can retain more nutrients, making them available to plants. This property is influenced by the soil's organic matter content and its mineral composition, particularly the presence of clay particles. Soils with high CEC are better at supplying plants with essential cations such as calcium, magnesium, and potassium.
3. Pore Space

    Pore space in soil refers to the voids or gaps between soil particles, which are filled with air or water. This space is crucial for:

    - Aeration: Allowing roots to access the oxygen needed for respiration.
    - Water Drainage and Retention: Managing the balance between water being held for plant use and excess water draining away.
    - Root Penetration: Facilitating root growth and access to nutrients.

### 2.1.2 Soil Moisture and Chemical Measurement Technology

Soil moisture and chemistry sensing systems are pivotal in climate-smart agriculture (CSA), offering insights critical for soil health, crop growth, and sustainability management. These systems fall into four main categories: on-site implanted sensors, remote sensing satellites, drones (unmanned aerial vehicles), and combined approaches, each with distinct advantages and limitations tailored for specific applications.

On-site implanted sensors provide real-time, localized data on soil moisture and chemistry by being directly placed in the soil. While offering detailed monitoring at specific depths and locations, their application might be hindered by high costs, limited spatial coverage, and potential environmental interferences.

Remote sensing satellites cover extensive areas, even on a global scale, making them invaluable for broad-scale soil monitoring. These satellites can assess soil parameters through various sensing techniques, including microwave, infrared, and optical sensing. However, their accuracy may be impacted by atmospheric conditions, vegetation, and the need for ground-based calibration.

Drones present a versatile solution, capable of rapidly covering large areas with high-resolution imaging to assess soil conditions. They can be equipped with a range of sensors, including multispectral and hyperspectral cameras, to estimate soil moisture and chemistry. Limitations include flight endurance, regulatory constraints, and the requirement for specialized data processing skills.

Combined approaches leverage the strengths of multiple sensing systems to enhance the accuracy and reliability of soil information. By integrating data from on-site sensors, satellites, and drones, these approaches offer a comprehensive view of soil conditions, though they may face challenges in data compatibility and management.

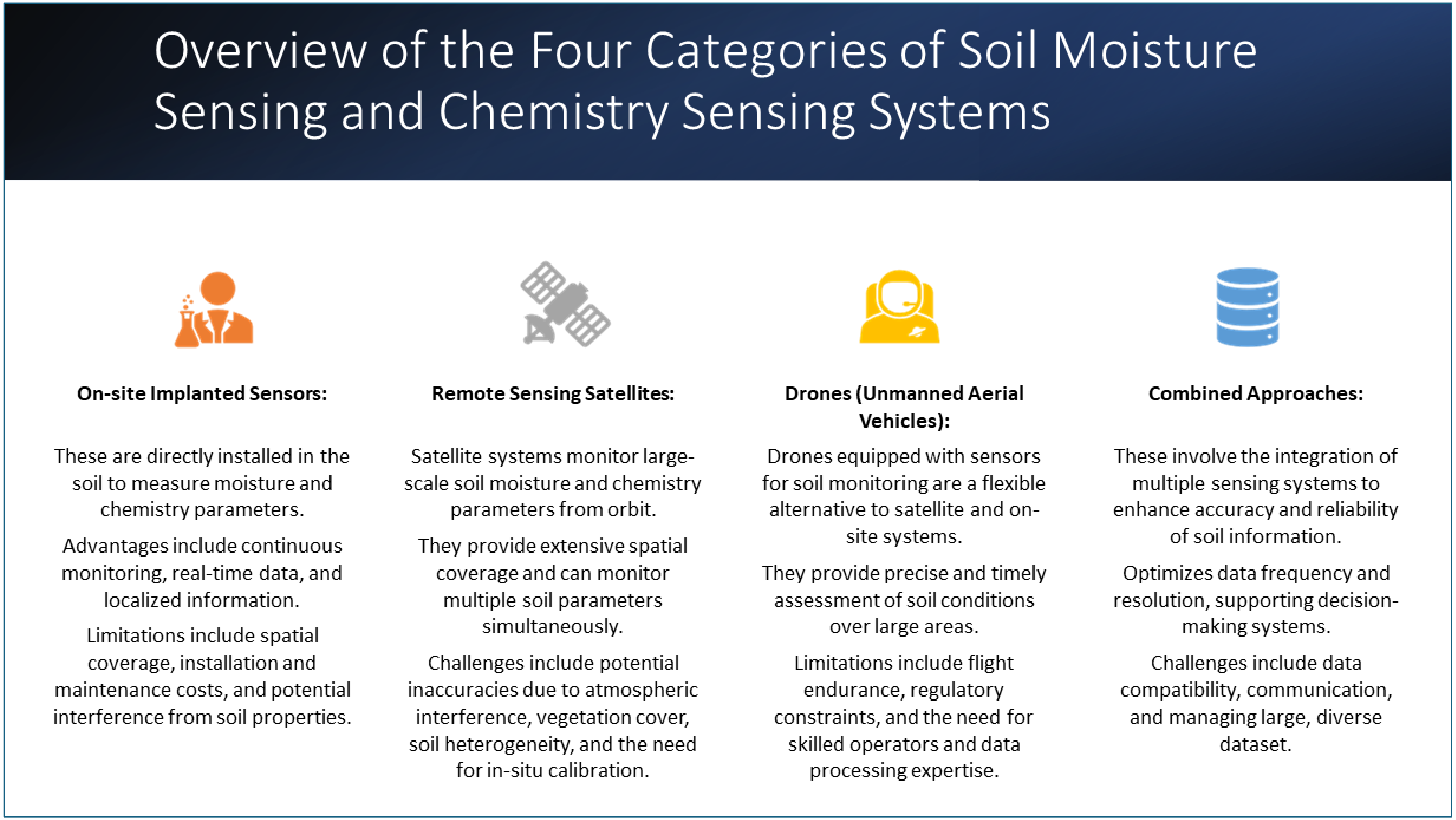



Figure 2.2 Categories of soil moisture and chemical sensors

Table 2.1 Soil parameters and sensors.

| Soil parameter | Sensor Type | Categories |
|---|---|---|
| Soil moisture | Capacitive Sensors | Field Implanted |
| | Resistive Sensors | Field Implanted |
| | Time-Domain Reflectometry (TDR) Sensors | Field Implanted |
| | Frequency Domain Reflectometry (FDR) Sensors | Field Implanted |
| | Neutron Scattering Sensors | Field Implanted |
| | Tensiometer Sensors | Field Implanted |
| | Thermal Infrared Sensors . | Field Implanted/UAV/Remote Sensing |
| | Multispectral Sensors | Field Implanted/UAV/Remote Sensing |
| | Hyperspectral Sensors | Field Implanted/UAV/Remote Sensing |
| | Radar Sensors / Active sensor | Field Implanted/UAV/Remote Sensing |
| Soil Chemistry | Ion-Selective Electrodes (ISEs) | Field Implanted |
| | Optical Sensors | Field Implanted |
| | Electrochemical Sensors | Field Implanted |
| | Spectroscopy-Based Sensors | Field Implanted |
| | Microbial Fuel Cell-Based Sensors | Field Implanted |

**Field-implanted sensors:** Deploying sensors such as soil moisture probes, ion-selective electrodes, and electrochemical sensors will provide valuable information on the local soil conditions, nutrient levels, and soil moisture. This data will enable farmers to optimize irrigation and nutrient management practices for their specific crop types and environmental conditions.

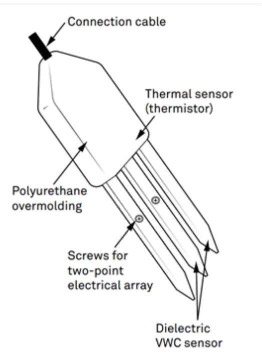
## Product catalog of Site Implanted Sensors

Name of Sensor :
RiTx Jinawi sensor
Measurement parameters:
levels of N, P, K and pH

Name of Sensor :
Campbell CS655
Measurement parameters:soil volumetric-
water content, bulk electrical conductivity, and temperatur

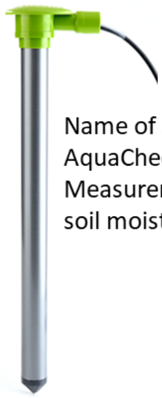
Name of Sensor :
Sensor Jingxunchangtong (JX IoT)
Soil analyzer-5 in 1
Measurement parameters:
soil temperature, soil moisture, soil pH, soil electrical conductivity, soil nitrogen, phosphorus and potassium

## Product catalog of Site Implanted Sensors




Name of Sensor :
METER 5TE
Measurement parameters:
VWC, Temperature, and EC

Name of Sensor : SENTEK SDI-12 SERIES II Probe
Measurement parameters:
soil moisture, salinity, temperature and humidity



Name of Sensor:
AquaCheck Sub-Surface
Measurement parameters:
soil moisture and soil temperature

Name of Sensor : Delta-T PR2
Measurement parameters:
moisture content

Figure 2.3 Field Implanted Sensors.

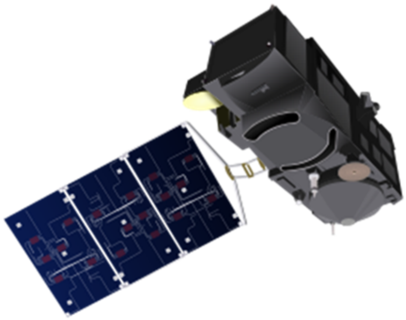
**Drone-based sensors:** Utilizing drones equipped with multispectral or hyperspectral cameras will enable high-resolution monitoring of crop health, pest and disease detection, and nutrient deficiencies. In addition, thermal imaging sensors can provide information on plant stress, irrigation efficiency, and canopy temperature, which can be helpful in determining optimal irrigation scheduling.


Figure 2.4 UAV based Sensors.

**Satellite remote sensing:** Integrating data from satellite remote sensing platforms, such as Sentinel-2 or Landsat, can provide large-scale information on vegetation health and land use changes. This data can help farmers monitor the effectiveness of their agricultural management practices and identify areas that require further attention.

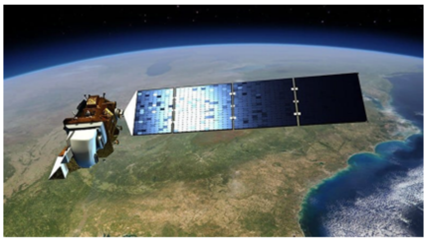
## Product catalog of Remote Sensing Technology

Name of Remote Sensing Technology:
Sentinel -1 Satellite
Measurement parameters:
soil moisture content, surface roughness, vegetation biomass, crop type and health, soil salinity and chemical properties



Name of Remote Sensing Technology: Sentinel – 3 Satellite
Measurement parameters:
soil moisture content, surface temperature, vegetation indices, land cover and land use, soil salinity and chemical properties

## Product catalog of Remote Sensing Technology



Name of Remote Sensing Technology:
USGS Landsat 8
Measurement parameters:
observations of land surface (e.g soil moisture content)

Name of Remote Sensing Technology: Landsat – 9 Satellite
Measurement parameters:
soil moisture, soil salinity, soil pH, and chemical of soil

Figure 2.5 Remote sensing satellites.

**Combining the data from** field-implanted sensors, drone-based sensors, and satellite remote sensing will enable a comprehensive understanding of the agricultural landscape. Advanced data analytics, machine learning algorithms, and GIS tools can be utilized to process and analyze this data, providing valuable insights to support decision-making and optimize agricultural practices.

### 2.1.3 Implementation

The implementation of sensors in Climate-Smart Agriculture (CSA) practices is important for enhancing agricultural sustainability and resilience in the face of climate change. Sensors for soil moisture, chemistry, and other environmental parameters provide vital data that enable farmers to make informed decisions about irrigation, fertilization, and crop management. This real-time information helps optimize water use, reduce waste, and increase crop yields while minimizing environmental impacts. By precisely monitoring soil conditions, sensors allow for the implementation of targeted interventions that improve soil health and crop productivity. Furthermore, sensor technology supports the adaptation of agricultural practices to changing climate conditions, ensuring food security and reducing the agriculture sector's carbon footprint. The strategic use of sensor technology in CSA not only promotes efficient resource management but also contributes to the overall goal of achieving sustainable and resilient agricultural systems. The following figure illustrates the full monitoring system incorporates sensors' 3 categories.

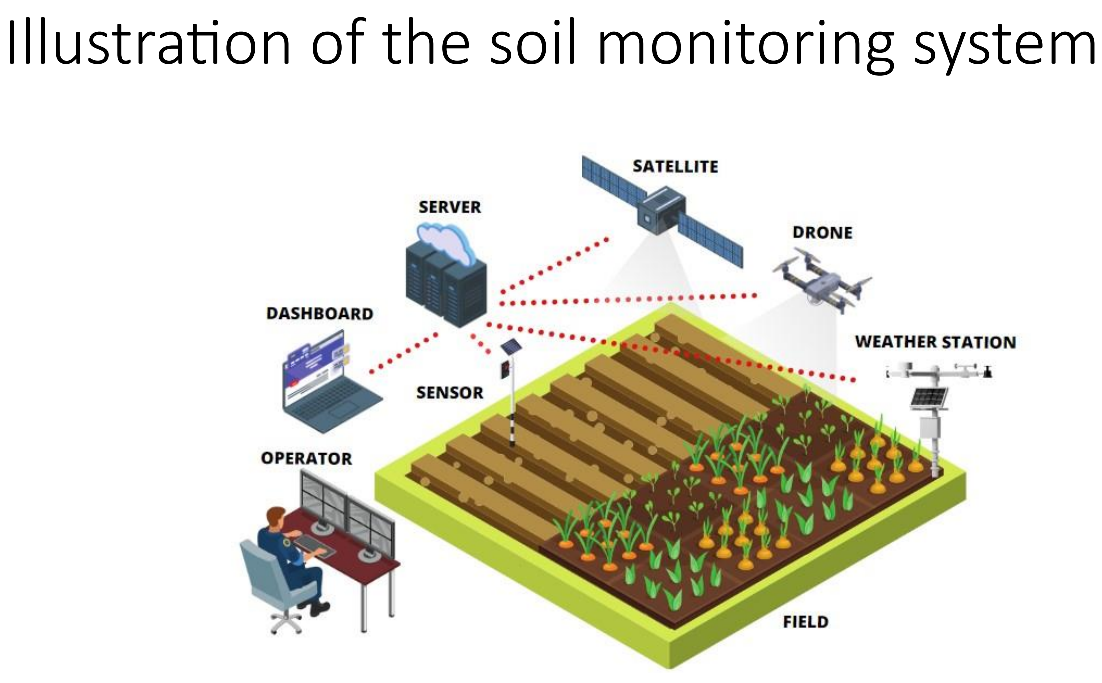



Figure 2.6 Soil monitoring.

The incorporation of field-implanted sensors into Climate-Smart Agriculture (CSA) represents a significant step toward achieving sustainable and resilient farming in the face of climate change. These sensors, buried within the soil, provide real-time insights into soil health indicators such as moisture levels and nutrient content. This information allows for precise adjustments in irrigation and fertilization practices, resulting in improved resource efficiency. CSA's objectives, including enhanced agricultural productivity, climate resilience, and environmental preservation, align well with this precision approach.

By ensuring optimal water and nutrient application, these sensors mitigate the risks associated with overuse while promoting higher crop yields. Simultaneously, they contribute to the conservation of natural resources. The emphasis on sensor technology reflects a shift toward data-driven agricultural practices, which are essential for addressing climate change challenges and optimizing farm management. Field-implanted sensors play a crucial role in shaping the future of agriculture, guiding the sector toward global food security and environmental sustainability. Their adoption makes farming more productive, resilient, and eco-friendly.

The following figure presents a simplified soil moisture and chemical monitoring system, comprising a soil moisture, temperature, and EC (Electrical Conductivity) sensor, data logger, internet connection, and cloud server. Soil temperature and EC are indicators of the soil's chemical properties, relating to soil fertility. EC can indicate nutrient availability in the soil, overall soil fertility, water or soil salinity, and the need for soil amendments (such as leaching or acidity adjustment).

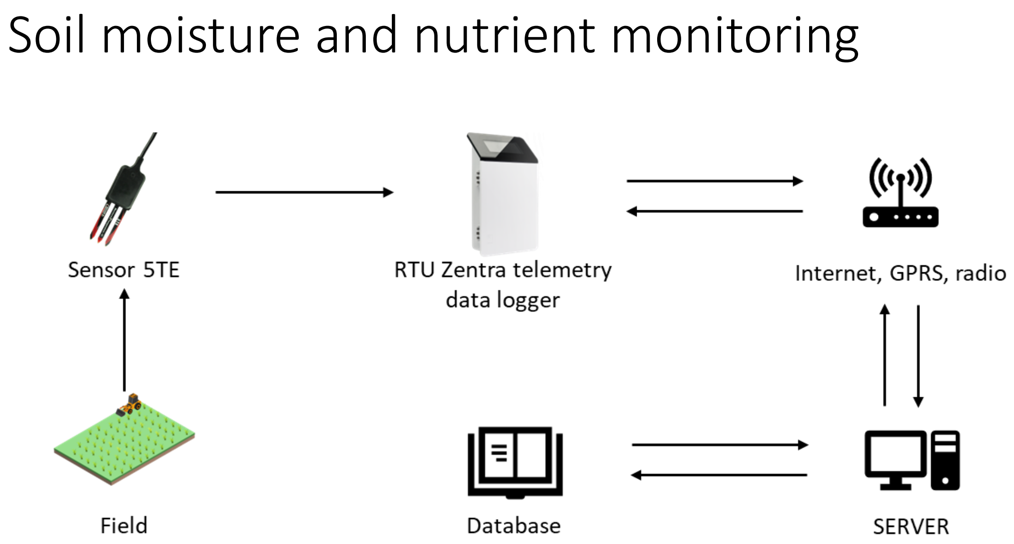



Figure 2.7 Soil moisture and nutrient monitoring with implanted sensor.

### 2.1.4 Activity: Quiz

| | |
|---|---|
| **What does soil moisture primarily refer to?**<br>**A) Water held in the spaces between soil particles**<br>**B) Water on the surface of soil particles**<br>**C) Water in the atmosphere**<br>**D) Water in plant leaves** | |
| **How does soil texture influence soil's ability to hold moisture?**<br>**A) Determines the soil's color**<br>**B) Influences the soil's ability to hold and retain moisture**<br>**C) Has no effect on moisture retention**<br>**D) Only affects the soil's temperature** | |
| **What is the significance of root depth in plant growth?**<br>**A) Determines the plant's height**<br>**B) Affects a plant’s ability to access water**<br>**C) Has no impact on plant health** | |

| | |
|---|---|
| D) Only affects the plant's ability to absorb sunlight | |
| Available water capacity in soil indicates:<br>A) The volume of water that can be absorbed and used by plants<br>B) The total volume of water in the soil<br>C) The amount of water lost due to evaporation<br>D) The capacity of soil to filter water | |
| Cation Exchange Capacity (CEC) is important because it:<br>A) Indicates the soil's color<br>B) Shows the soil's ability to retain and exchange nutrients<br>C) Measures the soil's temperature<br>D) Determines the soil's age | |
| The primary purpose of using on-site implanted sensors in agriculture is to:<br>A) Increase the soil's temperature<br>B) Monitor soil moisture and chemistry in real-time<br>C) Decorate the field<br>D) Reduce the soil's nutrient content | |
| What limitation is associated with remote sensing satellites for soil monitoring?<br>A) High accuracy in cloudy weather<br>B) Atmospheric interference affecting accuracy<br>C) Unlimited spatial coverage<br>D) Immediate data processing | |
| Drones in agriculture are used to:<br>A) Predict weather changes<br>B) Cover large areas with high-resolution imaging for soil assessment<br>C) Transport crops<br>D) Increase soil moisture directly | |
| High levels of EC in the soil may indicate:<br>A) Low soil fertility and need for immediate irrigation<br>B) An optimal environment for all types of crops<br>C) Excessive salinity that can hinder plant nutrient uptake<br>D) That no soil amendments are necessary | |
| Why is monitoring soil moisture crucial in Climate-Smart Agriculture (CSA)?<br>A) It ensures optimal plant growth by preventing over or under-watering<br>B) It is only necessary for decorative purposes<br>C) Soil moisture levels do not influence plant health<br>D) It increases soil salinity | |

Answers: A, B, B, A, B, B, B, B, C, A.

## 2.2 Sub Module 2.2. Automatic Irrigation and Fertilization Applications

**Learning Objectives:** Participants understand automatic irrigation technology and fertilization applications.

### 2.2.1 Introduction

Understanding the irrigation water requirements is essential for the sustainable management of water resources in agriculture. This encompasses several key factors such as the evapotranspiration rate (ETo) during the growing period, the crop coefficient (Kc), effective rainfall, available water, and the scheduling of irrigation. These elements are crucial for determining the precise amount of water needed to support crop growth without wastage or over-irrigation.

- Cropping pattern planning: It is important to plan the cultivated crop during a year. Generally, it was based on harvest price, water availability, and other technical or non-technical aspects of local wisdom.
- Evapotranspiration (ETo): This refers to the amount of water evaporated from the soil and transpired by plants over a specific planting period. It is a critical factor in calculating the water needs of a crop.
- Crop Coefficient (Kc): The Kc value adjusts ETo to reflect the water use of a particular crop at different stages of its growth cycle.
- Crop Water Requirement: ETo multiply by Kc.
- Effective Rainfall: Not all rainfall contributes to meeting the crop's water needs. Effective rainfall is that portion of total rainfall which is actually used by the crop.
- Available Water: This is the quantity of water in the soil that is readily accessible for plant uptake.
- Irrigation Scheduling: Effective irrigation scheduling considers traditional practices, local wisdom, labor availability, and water sources. It aims to apply water in quantities and at times that align with the crop's specific needs, thereby enhancing water use efficiency and ensuring the sustainability of water resources.

Incorporating these components into irrigation management practices allows for the optimization of water usage, ensuring that crops receive the necessary water at the right time while conserving water resources. This approach not only supports agricultural productivity but also aligns with the principles of sustainable water management in the face of changing climate conditions and varying water availability.

Integrating Fertigation into this equation allows for the precise application of nutrients through the irrigation system, ensuring that plants receive the right amount of nutrients at the right time. This method enhances nutrient uptake efficiency, reduces nutrient leaching, and contributes to better water management by combining irrigation with nutrient delivery.

Nutrient Management: Involves the strategic application of fertilizer to match the nutritional requirements of the crop, considering the soil's nutrient status and the crop's growth stage. Effective nutrient management is essential for maximizing crop yield and quality while minimizing environmental impacts.

## 2.2.2 Planning of Irrigation and Fertilizing Systems

**Irrigation**

Irrigation methods are divided into 4 categories:

1. Surface irrigation: This is the application of water to the soil surface by gravity flow. It includes methods such as basin, border, furrow, and wild flooding.
2. Sprinkler irrigation: This is the application of water to the soil surface by spraying it through nozzles or sprinklers. It includes methods such as center pivot, linear move, solid set, hand move, and traveling gun.
3. Drip irrigation: This is the application of water to the soil surface or root zone by dripping it through emitters or drippers. It includes methods such as surface drip, subsurface drip, and micro-sprinklers.
4. Subirrigation: This is the application of water to the soil below the surface by raising the water table or flooding the root zone. It includes methods such as seepage, capillary, ebb and fow (continuous flow hydroponic) and subsurface drip irrigation.

Irrigation Planning:

1. To maximize irrigation efficiency, the maximum irrigation interval is determined by the available water divided by the crop evapotranspiration (ETc). It's essential to choose an irrigation interval that facilitates easy management.

**Example**

**Reference Evapotranspiration (ETo):** 5 mm/day (This is a typical value but can vary based on climate, time of year, and location).

**Crop Coefficient (Kc) for Chili:** 0.7 (The Kc value varies with the growth stage of the crop; 0.7 is an average value for the vegetative stage).

**Formula**:

$ETc=ETo \times Kc$$ETc=ETo \times Kc$

**Calculation:**

Calculate the Daily Water Requirement (ETc):

$Etc = 5\ mm/day \times 0.7 = 3.5\ mm/day$

$Etc = 5 mm/day \times 0.7 = 3.5 mm/day$

**Convert Daily Water Requirement to Volume:**

The depth of water (3.5 mm) needs to be converted into a volume. The area of the crop is 400m².

$Volume = Area \times Depth = 400\ m^2 \times 3.5\ mm = 400\ m^2 \times 0.0035 = 1.4 m^3/day$

2. Selecting the type of irrigation—furrow, drip, or sprinkler—is crucial and should be based on the specific needs of the crop and soil conditions.

a. Furrow Irrigation:

| Advantages | Disadvantages |
|---|---|
| • Lower initial investment of equipment and lower pumping costs per acre-inch of water pumped.<br>• Can save water and money by recirculating irrigation runoff water and reducing chemical leaching.<br>• Can ensure higher crop yields by providing adequate moisture and aeration to the root zone. | • Requires more labor and skill to maintain water flow and avoid surface runoff or excessive infiltration.<br>• Not suitable for sandy soils or soils with high salinity, as they can cause uneven water distribution and salt accumulation.<br>• Can cause soil erosion and compaction by the repeated movement of water and farm equipment in the furrows. |

Furrow irrigation is a type of surface irrigation where water is applied to the field through small channels or furrows between rows of crops. These furrows are typically made by plowing or scraping soil into ridges. Water flows along the furrows, wetting the soil and infiltrating to the roots of the plants. Furrow irrigation is commonly used in row crops such as maize, cotton, and vegetables.

Furrow irrigation systems can vary in design, with factors such as furrow spacing, length, and slope affecting water distribution and efficiency. Management practices, such as controlling flow rates and timing of irrigation, are crucial for optimizing water use and minimizing runoff and soil erosion.

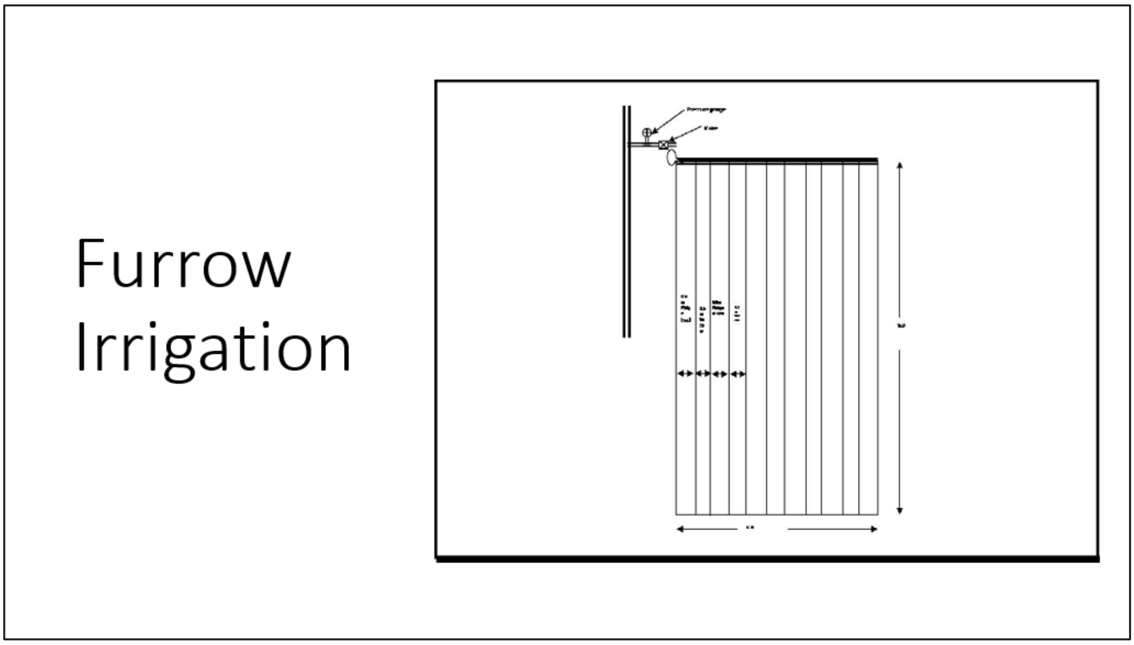



Figure 2.8 Furrow Irrigation

b. Sprinkler Irrigation:

| Advantages | Disadvantages |
|---|---|
| • Water Efficiency: Direct water delivery to plants reduces runoff and evaporation.<br>• Uniform Water Distribution: Enhances crop yields and quality.<br>• Reduced Soil Erosion: Eliminates the need for soil tillage, reducing erosion.<br>• Versatility: Applicable to various crops, soil types, and uneven surfaces.<br>• Automation: Systems can be automated, saving time and labor costs. | • Cost: Installation can be more expensive than other methods.<br>• Wind Susceptibility: Systems vulnerable to wind, affecting water distribution.<br>• Disease Susceptibility: Increased risk of plant diseases due to prolonged leaf wetness.<br>• Salinity: Can elevate soil salinity, reducing crop yields. |

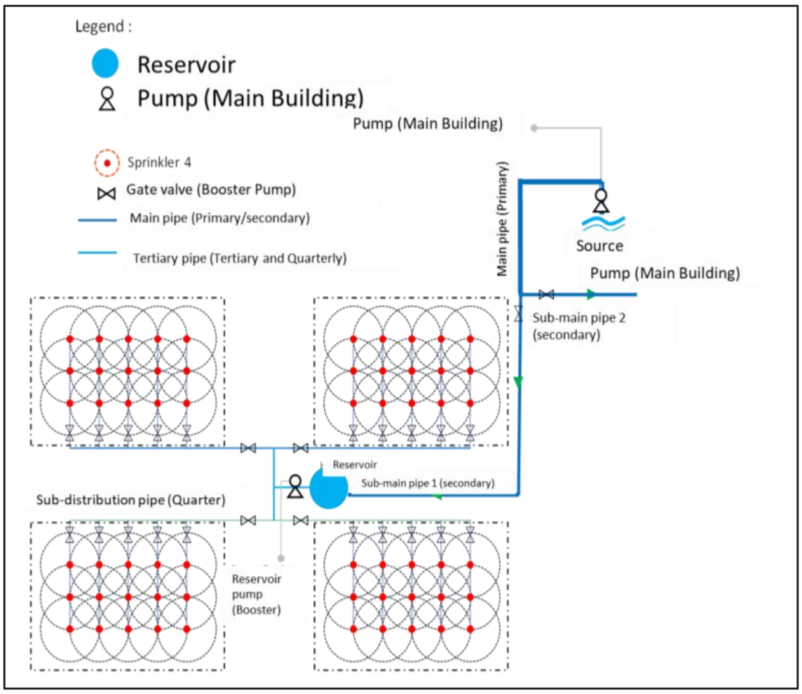



Figure 2.9 Sprinkler Irrigation

Sprinkler irrigation networks consist of a series of pipes, fittings, and sprinkler heads that distribute water over a field in a manner similar to natural rainfall. These networks typically include several service zones, each covering a specific area of the field. In each service zone, a main pipe or lateral pipe is connected to a water source, such as a pump or a pressurized irrigation system. Along the main or lateral pipe, there are valves or control devices that regulate the flow of water into individual sprinkler heads.

The sprinkler heads are strategically placed throughout the field to ensure uniform water distribution. They release water in a controlled manner, either through a rotating mechanism or a fixed nozzle, covering a predetermined area with a specific rate of application.

c. Drip Irrigation:

| Advantages | Disadvantages |
|---|---|
| • Water Efficiency: Conserves water resources.<br>• Fertilizer Efficiency: Reduces nutrient runoff and pollution.<br>• Reduced Soil Erosion: Less likely to cause erosion compared to traditional methods | • Installation Cost: Can be more expensive than traditional methods.<br>• Maintenance: Requires more maintenance.<br>• Susceptibility to Clogging: More prone to clogging |

Drip irrigation networks are composed of various components, including mainlines (MP), submains (SMP), laterals (LP), emitters, filters, and pressure regulators. The mainline transports water from the water source to the field, while submains distribute water to different sections of the field. Laterals run parallel to rows of plants, delivering water to individual plots. Emitters, strategically placed along the laterals, release water drop by drop directly to the soil near the plant roots. Filters and pressure regulators ensure that the water delivered to the emitters is clean and at the appropriate pressure for efficient operation. This precise irrigation method allows farmers to customize water application based on the specific needs of different crops and soil conditions, promoting water conservation and healthy plant growth.

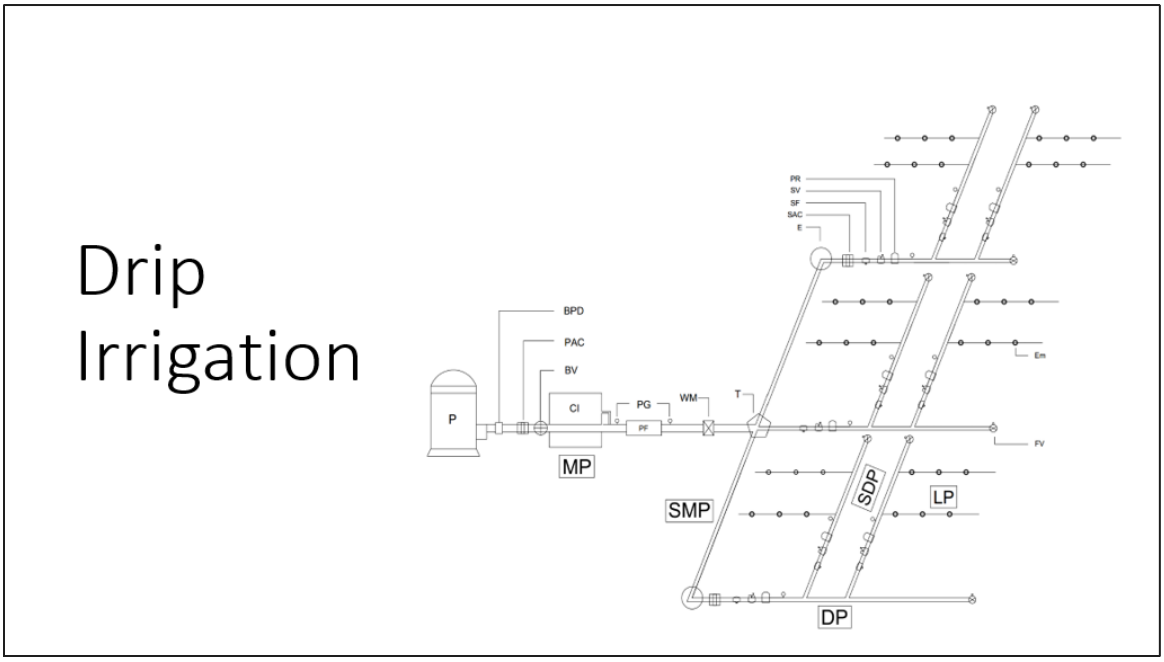



Figure 2.10 Drip Irrigation.

3. Assessing the infiltration rate is necessary to ensure that water penetrates the soil effectively.

Measurement of infiltration with Ring Infiltrometer Method:

Procedure:

1. Insert a cylindrical metal ring into the soil.
2. Fill the ring with water and maintain a constant water level inside it.
3. Measure the time it takes for the water to infiltrate the soil.
4. Calculate the infiltration rate by dividing the water depth by the infiltration time.

Application:

This method is suitable for gardeners, farmers, and researchers who need to measure the infiltration rate at specific locations

4. Determining the operation duration leads to calculating the flow rate required. If the flow rate is less than the source's flow rate, adjustments or additional water sources may be needed to meet irrigation demands.

Example of irrigation schedule and volume required for chili plants across a 400m² area with a drip irrigation system is essential, particularly when adapting to the specific needs of Climate-Smart Agriculture (CSA). Here's an adjusted schedule based on a crop evapotranspiration (ETc) of 3.5 mm/day:

**Step 1: Determining Plant Water Needs**

The water requirement for chili plants is calculated using the ETc and adjusting for drip irrigation system efficiency. Assuming the ETc for chili plants is 3.5 mm/day.

**Step 2: Irrigation System Efficiency**

For this scenario, we'll consider the drip irrigation system's efficiency to be 90%.

**Step 3: Calculating Water Volume Requirement**

Given a 400m² area and an ETc of 3.5 mm/day, the daily water volume needed without efficiency correction is:

Volume = Area×Etc

Volume = 400 $m^2$×3.5 mm

Volume = 400 $m^2$×0.0035 m

Volume =1.4 $m^3$/day

Adjusting for the efficiency of 90%:

Adjusted Volume = 1.4 $m^3$ / 0.9 ≈ 1.56 $m^3$/day

**Step 4: Scheduling Irrigation**

Opting for two irrigation sessions daily can help avoid water wastage and ensure optimal root absorption. Therefore, each session would need:

Session Volume =1.56 m3/day / 2 ≈ 0.78 $m^3$/session

**Step 5: Continuous Monitoring**

It's vital to monitor soil moisture and adjust irrigation as necessary based on real-time data, weather conditions, and the chili plants' growth stage.

**Proposed Schedule:**

- **Morning Session:** 07:00 AM, watering with a volume of 0.78 $m^3$
- **Evening Session:** 05:00 PM, watering with a volume of 0.78 $m^3$

**Fertilization**

Fertilizer application through drip irrigation systems, termed fertigation, facilitates precise and efficacious nutrient delivery directly to plant roots, thereby enhancing nutrient uptake efficiency and minimizing wastage. In this process, liquid fertilizer is mixed with irrigation water and uniformly disseminated across the field via the drip system. This strategy enables a controlled nutrient application, tailored to the plants' developmental requirements, effectively mitigating the risks associated with nutrient leaching and runoff. Adhering to a fertigation schedule that is synchronized with growth stages-namely, vegetative growth, flowering, and fruiting-ensures the provision of nutrients in optimal quantities at critical times.

This practice is particularly advantageous for crops where precise nutrient management is necessary for maximizing yield and quality. Moreover, the implementation of a drip fertigation system not only conserves water but also aligns with sustainable agricultural practices by enhancing fertiliser use efficiency and dropping the ecological footprint. Thus, it represents the principles of Climate-Smart Agriculture (CSA), supporting farmers in their efforts to improve crop productivity while parallelly advancing environmental sustainability.

Fertilization Planning:

1. Soil sampling for laboratory analysis is a critical step in determining the precise fertilizer dosage, measured in tons per hectare per season.
2. Nitrogen (N) fertilizers are crucial during the vegetative growth phase,
3. Phosphorus (P) is vital during the generative phase to support flower and seed development.
4. Potassium (K) is required throughout the growing period, essential for the translocation of photosynthesis products within the plant, strengthening cell walls, and enhancing grain per panicle and the percentage of filled grains.

Fertilizer injection into an irrigation network, a key component of fertigation systems, involves the integration of liquid or water-soluble fertilizers into the irrigation water, ensuring efficient nutrient delivery directly to the plant roots. This process utilizes specialized equipment to accurately meter and inject fertilizer into the irrigation system at predetermined rates.

The process begins with the preparation of the fertilizer solution, which involves dissolving water-soluble fertilizers or diluting liquid fertilizers to the required concentration in a mixing tank. From here, the solution is introduced into the irrigation water using one of several methods:

1. Venturi Injectors: Utilize the flow of water through a constricted section of the irrigation pipe to create a vacuum that draws the fertilizer solution from the mixing tank into the irrigation water.
2. Positive Displacement Pumps: Directly inject the fertilizer solution into the irrigation line at precise rates, controlled by the pump's settings. These pumps can handle a wide range of viscosities and allow for accurate dosing.
3. Injection Pumps (Diaphragm or Peristaltic): These pumps offer precise control over the injection rate, making them ideal for delivering specific nutrient doses required by the crops.

The chosen method depends on the irrigation system's design, the type of fertilizer used, and the specific requirements of the crops.

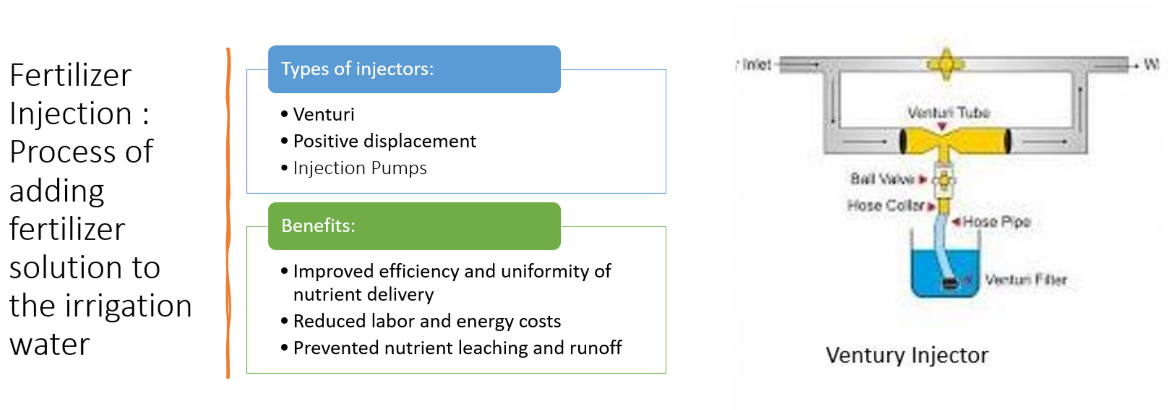



Figure 2.11 Fertilizer injection to irrigation.

Example for a 400m² chili farm in Sukabumi, Indonesia, applying nutrition through liquid fertilizer via drip fertigation, utilizing an injector and mixer tank, streamlines the fertilization process, ensuring precise and efficient delivery of essential nutrients directly to the plant roots. Here's a refined approach for implementing this system:

**Step 1: Soil and Plant Nutrition Analysis**

Conduct a thorough soil and plant tissue analysis to accurately determine the nutrient requirements of chili plants. This step identifies specific needs for nitrogen (N), phosphorus (P), potassium (K), and micronutrients.

**Step 2: Calculating Liquid Fertilizer Dosages**

Based on the analysis, calculate the liquid fertilizer dosages required for optimal chili growth. Assuming the farm needs a balanced NPK ratio, we calculate the dosage as follows for the entire growth period:

**Nitrogen (N):** Adjust to a concentration of 150 ppm in the fertigation solution.

**Phosphorus (P2O5):** Adjust to 75 ppm.

**Potassium (K2O):** Adjust to 75 ppm.

These concentrations should be adjusted according to the specific stage of plant growth and nutrient uptake rates.

**Step 3: Fertigation System Setup**

Install a fertigation system equipped with an injector and a mixer tank. The injector introduces the liquid fertilizer into the irrigation water, while the mixer tank ensures the fertilizer is thoroughly mixed and dissolved before application.

**Step 4: Fertilization Schedule**

**Initial Stage:** Apply a higher proportion of P to support root development, with a reduced N and K ratio.

**Vegetative Growth:** Increase N and K supply to promote leafy growth and overall plant health.

**Flowering and Fruiting:** Maintain or slightly reduce N levels while keeping P and K levels consistent to support flowering and fruit development.

Fertilizer application should be divided into weekly or bi-weekly intervals, depending on the growth stage and observed plant needs.

**Step 5: Fertigation Management**

Utilize the drip system's injector to precisely meter the prepared liquid fertilizer solution into the irrigation water.

Regularly check the mixer tank to ensure the fertilizer solution is consistent and homogenous before application.

Adjust the fertigation frequency and nutrient concentrations based on ongoing observations of plant health, soil conditions, and weather patterns.

This liquid fertilizer application strategy via drip fertigation allows for the efficient use of water and nutrients, minimizing waste and environmental impact. The injector and mixer tank setup ensures that chili plants in Sukabumi receive balanced nutrition throughout their growth cycle, promoting healthy development and maximizing yield potential. Regular monitoring and adjustment of the fertigation schedule and nutrient concentrations are crucial for optimal results.

**Automation**

- System and Tools Used: Modern irrigation and fertilization systems utilize automated technologies, such as programmable irrigation controllers, soil moisture sensors, and automated fertigation units, to apply water and nutrients precisely when and where needed.
- Advantages and Efficiency: Automation offers significant benefits, including improved resource use efficiency, reduced labor costs, and enhanced crop performance. By precisely timing and dosing irrigation and fertilization, automated systems minimize waste and environmental impact while maximizing crop yield and quality. These systems allow for real-time adjustments based on soil moisture and nutrient data, ensuring optimal growth conditions throughout the growing season.

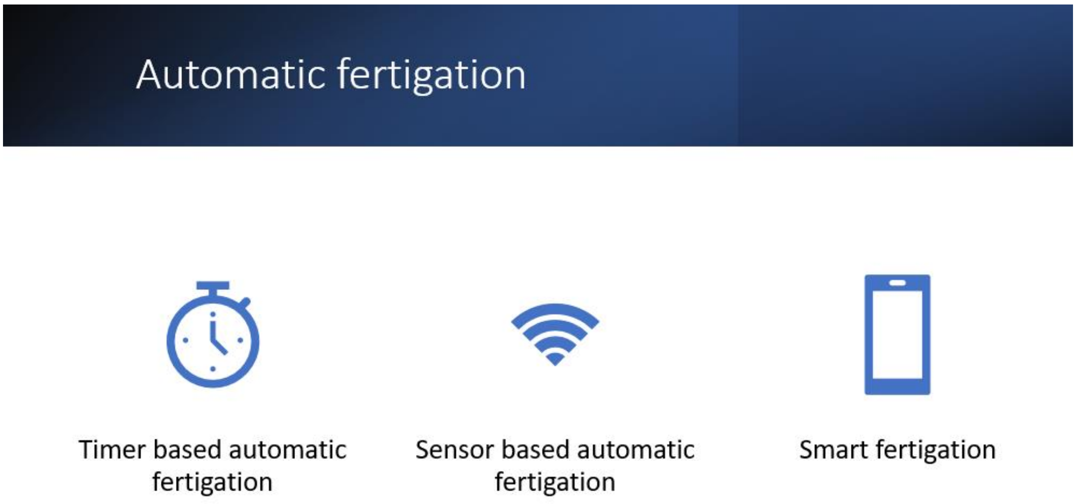



Figure 2.12 Automation categories.

- Timer based automatic fertigation:  uses a timer to control the frequency and duration of fertigation. The timer can be set manually or programmed according to a schedule based on crop needs, weather conditions, or soil moisture levels. Timer based automatic fertigation can reduce labor costs and human errors, but it may not be able to adjust to changing environmental factors or crop requirements.
- Sensor based automatic fertigation: uses sensors to monitor the soil moisture, nutrient status, pH, electrical conductivity, or other parameters of the crop root zone. The sensors send signals to a controller that activates the fertigation system when the measured values fall below or exceed a certain threshold. Sensor based automatic fertigation can provide more precise and timely fertigation, but it may require more maintenance and calibration of the sensors and the controller.
- Smart fertigation: uses the Internet of Things (IOT) to connect the fertigation system with various devices, such as sensors, weather stations, drones, smartphones, or computers. The IOT enables data collection, analysis, and

communication among the devices, which can be used to optimize the fertigation process. IOT based Smart fertigation can offer more flexibility and functionality, such as remote control, real-time feedback, predictive modeling, or artificial intelligence.

### 2.2.3 Implementation

The system architecture of fully integrated technologies consists of automatic irrigation and fertilization that integrates with the system for 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. The system follows the architecture of Supervisory Control and Data Acquisition (SCADA).

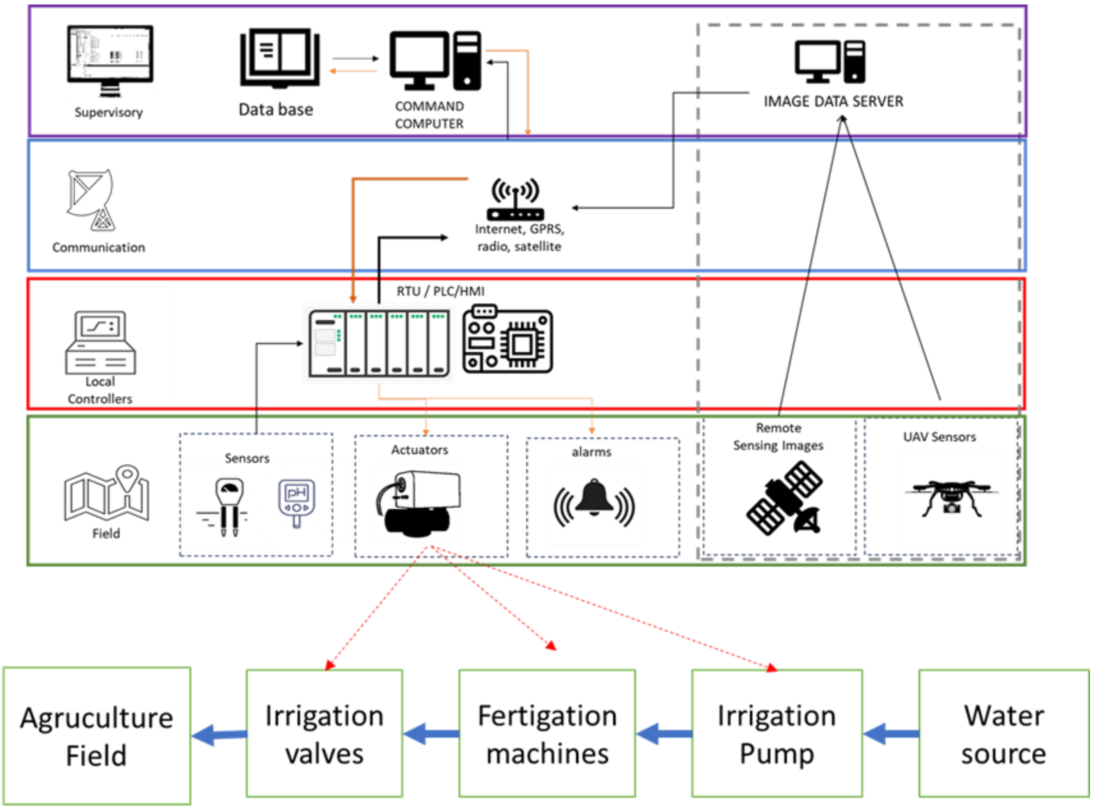



Figure 2.13 Integration of the soil monitoring system and automatic fertigation system.

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.

**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.

- 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 2.14 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.

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

### 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.
- **Specification 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.

Figure 2.16 Remote Terminal Unit RTCU LX4 Logic IO (https://www.logicio.com/rtcu_products.htm).

### 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. Drip line irrigation is the easiest to install and uninstall, and the investment is also the lowest compared to drip irrigation with emitters.

Figure 2.17 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:**
  - 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.
  - Flow rate: The flow 2 liters per hour (LPH) based on the water requirements of the plants and the spacing of the emitters.
  - Emitter spacing: 30 cm.
  - Pressure**:** The pressure of the water source should be between 10 and 20 psi
  - Materials**:** Polyethylene or Polypropylene
- **Advantages**
  - Water efficiency: Driplines can save up to 70% of water compared to traditional sprinkler systems.
  - Weed control: Driplines deliver water directly to the plant roots, which can help to suppress weed growth.
  - Erosion control: Driplines deliver water slowly and evenly, which can help to prevent soil erosion.
  - 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.

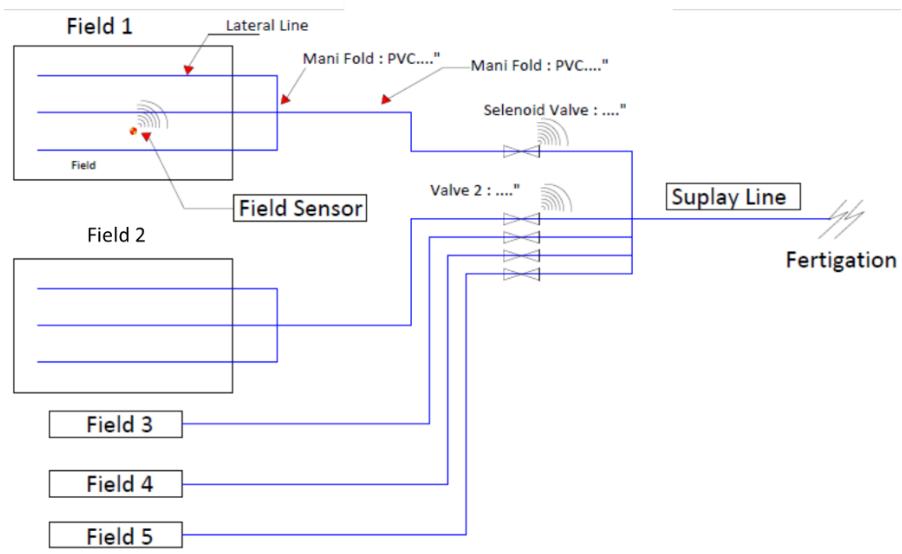



Figure 2.18 Irrigation Network with multiple fields as irrigation units.

**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 2.20. and irrigation solenoid valves which direct water to each of irrigation unit as in Figure 2.21.

- **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.

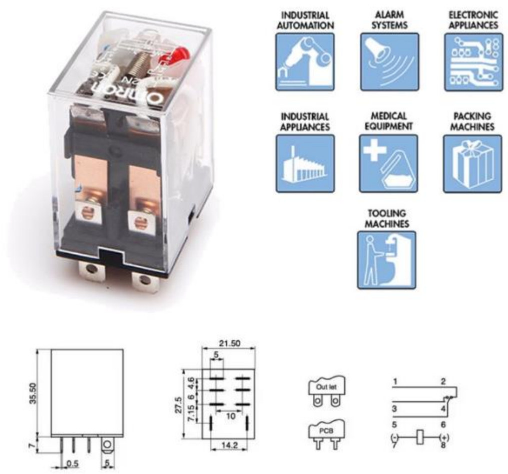



Figure 2.19 Power control (magnetic relay).

- **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.

Figure 2.20 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 2.21 Solenoid valves.

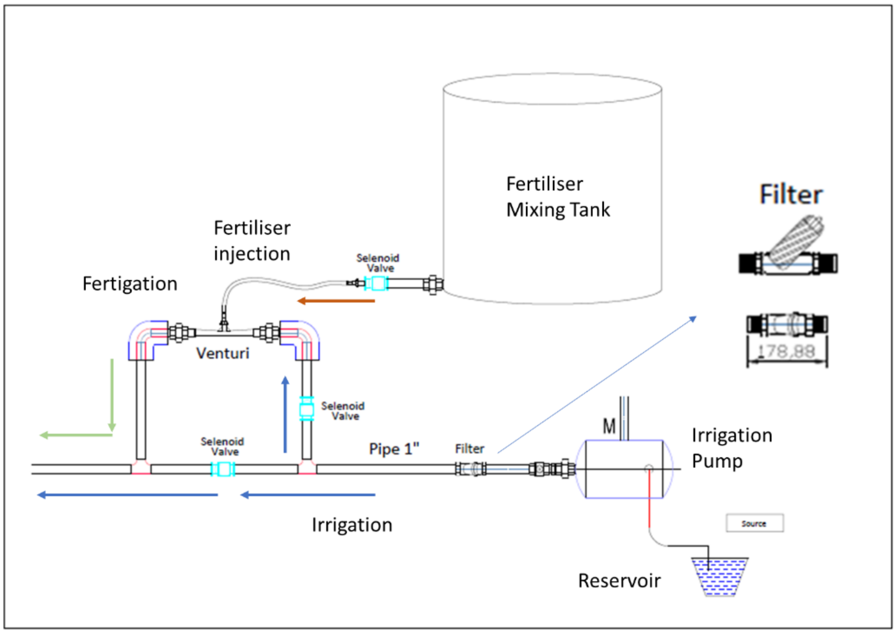



Figure 2.22  Actuators : Irrigation, fertigation, pump, valves.

### 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 depicted in Figure 2.22.

- **Ventury Fertilizer 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.

### 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.

## 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.

## 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.

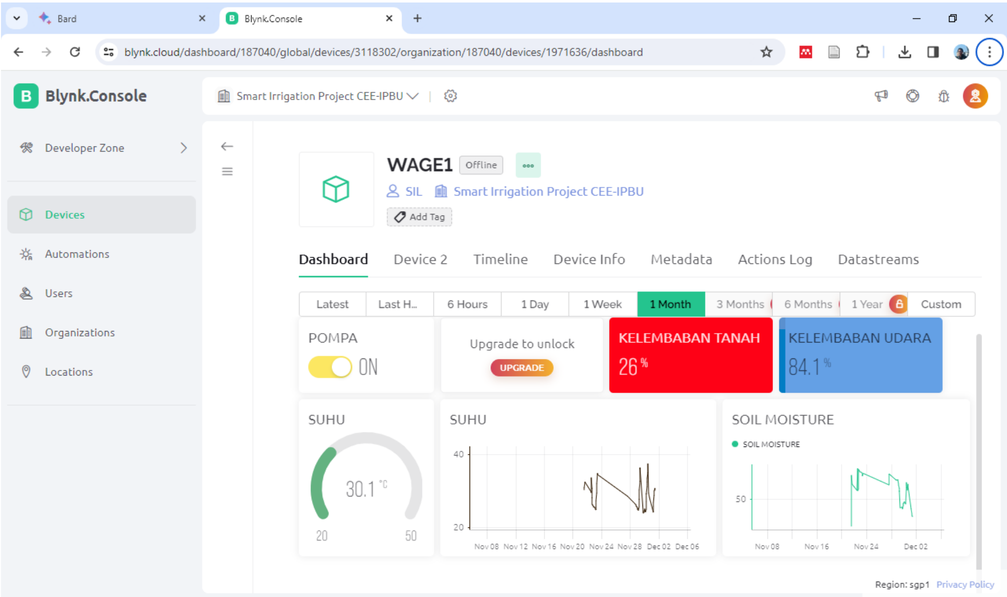



Figure 2.23 User Interface Illustration.

## 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.

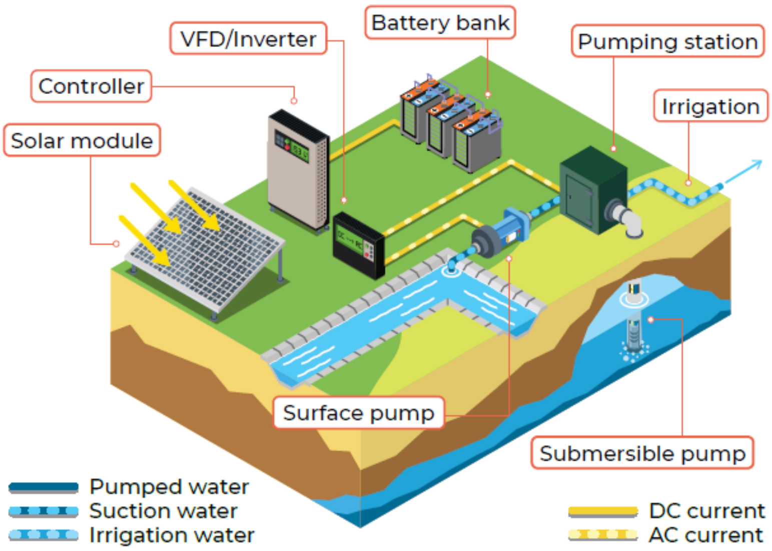



Figure 2.24 Schematics of stand alone solar power system for irrigation (Salman et al., 2022).

The configuration of solar power system consists of several key components and their specifications which of commonly used in a solar power system for irrigation: **Water Pump, Solar Panels**, **Inverter, Battery, Charge Controller, Frame and Mounting, Cables, and Connectors.**

### 2.2.4 Activity

1. Plan the cultivation of one of the plants on a land with a certain area.
2. Determine the water needs of plants
3. Determine plant fertilizer needs
4. Plan suitable irrigation water requirement
5. Plan irrigation and fertigation systems, with guidance from technology product providers
6. Plan an irrigation schedule and fertilize through an irrigation system.
7. Visualize the actual irrigation water for several effective rainfall pattern during planting periods:

Scenario 1:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DAP (Daya After Planting) | 6 | 9 | 19 | 24 | 25 | 35 | 37 | 44 | 50 |
| Effetif Rainfall (mm) | 0 | 19 | 0 | 10 | 12 | 16 | 16 | 12 | 18 |

Scenario 2:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DAP (Daya After Planting) | 2 | 7 | 12 | 22 | 26 | 27 | 31 | 35 | 42 |
| Effetif Rainfall (mm) | 20 | 2 | 16 | 0 | 0 | 0 | 0 | 11 | 2 |

Scenario 3:

| DAP (Daya After Planting) | 5 | 18 | 29 | 33 | 41 | 42 | 53 | 56 | 62 |
|---|---|---|---|---|---|---|---|---|---|
| Effetif Rainfall (mm) | 0 | 13 | 0 | 0 | 5 | 0 | 6 | 0 | 3 |

8. Point out several conditions according case no.7 that may put into consideration on modification of the automatic irrigation and fertigation system.

## 2.3 Sub Module 2.3. Presentations by Technology Suppliers

**Learning Objectives:** Participants know the products available for CSA implementation.

### 2.3.1 Introduction

This session focuses on a comprehensive presentation by a single technology supplier who specializes in state-of-the-art automated irrigation systems that are seamlessly integrated with fertigation and soil moisture and chemical monitoring solutions. The goal is to introduce participants to an innovative approach that combines water management, nutrient delivery, and soil health monitoring to optimize agricultural productivity and sustainability.

Objectives of this session are:

1 To introduce a cutting-edge automated irrigation system that incorporates fertigation and soil monitoring technologies.

2 To facilitate an understanding of how this integrated system can significantly enhance the efficiency and effectiveness of agricultural practices.

3 To explore the system's potential applications and benefits for participants' specific agricultural environments.

### 2.3.2 Activity

**Introduction to the Technology Supplier and Their Technology Supplies**

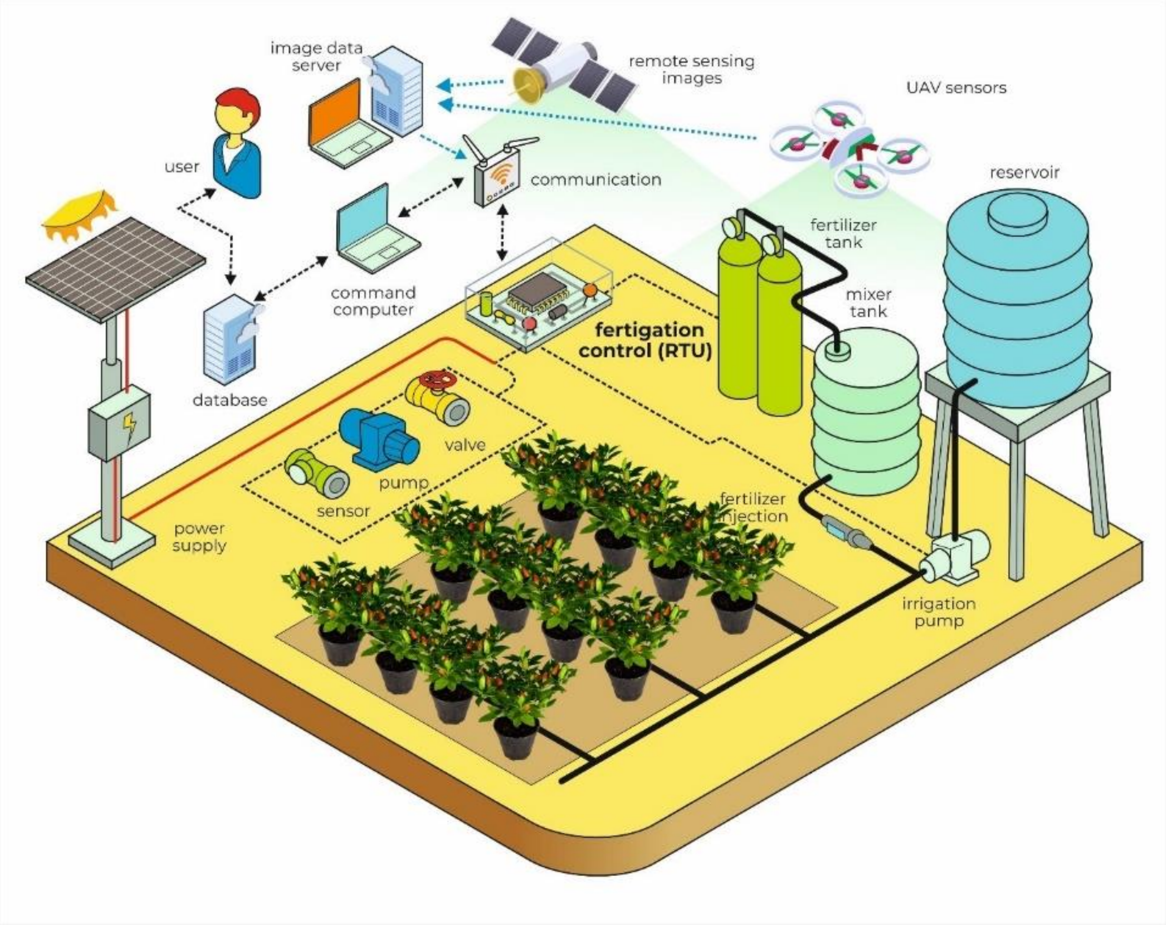
- Automated Irrigation System: Introduction to the core technology, highlighting how automation optimizes water usage based on real-time data, ensuring efficient irrigation tailored to the crops' needs.
- Integration with Fertigation: Explanation of the fertigation component, which allows precise and controlled delivery of water-soluble fertilizers through the irrigation system, ensuring optimal nutrient uptake by plants.
- Soil Moisture and Chemical Monitoring: Overview of the advanced sensors and monitoring tools that continuously assess soil moisture levels and chemical properties, including pH, nutrient concentrations etc.. This data informs the automated irrigation and fertigation system, enabling adjustments in real-time for ideal soil conditions.

**Demonstration and Discussion**

- A live or video demonstration showcasing the system's operation, from sensor data collection through to the automated adjustments in irrigation and fertigation outputs.
- An interactive Q&A session, inviting participants to explore the technology's application in their operations, address technical queries, and discuss potential customization.
- Recap the integrated system's benefits, emphasizing water conservation, enhanced crop yields, and improved soil health.

- Highlight the potential return on investment and environmental benefits of adopting such a comprehensive approach to irrigation and nutrient management.
- Provide guidance on how participants can engage with the supplier for further information, demonstrations, or consultations.
- Share detailed brochures, technical specifications, and contact information for participants to explore the technology further.
- Offer opportunities for personalized consultations or site visits for interested participants to see the system in action.

# 3 Module 3: CSA Integrated Irrigation System and Financial Analysis




**Module 3 Learning Objectives:**

3.1. Participants understand the component of integrated system of soil sensor technology and automatic irrigation-fertilization.

3.2. Participants understand how to analyze the business and financial feasibility of an agricultural business using modern technology.

# 3.1 Sub Module 3.1. Introduction to Implementation of Integrated System Soil Monitoring, Automatic Irrigation with Fertilizer Application

**Learning Objectives**

Participants understand the component of integrated system of soil sensor technology and automatic irrigation-fertilization.

## 3.1.1 Introduction

An agricultural irrigation system emphasizing Climate-Smart Agriculture (CSA) principles utilizes advanced on-site, field-implanted soil sensors. These sensors provide essential real-time data on soil moisture and nutrients, managed via a field controller RTU connected to a central database and user interface. This integration facilitates precision farming by informing timely irrigation and fertigation decisions.

The system adopts drip irrigation, selected for its water efficiency and suitability for farmer self-management, reflecting CSA's commitment to sustainable water use. Fertigation uses the venturi injection method, for its simplicity, affordability, and ease of acquisition, aligning with CSA goals of resource efficiency and sustainable farming practices.

By concentrating on on-site sensor technology, the system showcases a precision agriculture approach that aligns with CSA’s sustainability, efficiency, and environmental stewardship objectives. This model presents a forward-thinking solution for modern agricultural challenges, prioritizing soil health, water conservation, and effective nutrient management to enhance farming productivity and sustainability within a concise framework.

## 3.1.2 Component of integrated system

**Schematics of integrated system**

The architecture of the primary system is designed to optimize agricultural practices through the integration of advanced technology, focusing on efficient irrigation and fertilization. This system comprises several key components, each playing a crucial role in achieving Climate-Smart Agriculture objectives.

Field Sensors:

Positioned directly within the agricultural fields, these sensors are critical for real-time monitoring of soil moisture levels, nutrient content, and other essential environmental parameters. Their data informs the precise management of water and fertilizer, tailoring applications to the specific needs of crops.

Field Controller/Remote Terminal Unit (RTU):

The RTU acts as the command center for the field sensors, collecting and processing data from the sensors. It then communicates this information to the central computer, facilitating automated control over the irrigation and fertilization processes based on real-time field conditions.

Irrigation Network: Drip Line:

The drip line system is a key component of the irrigation network, designed to deliver water directly to the root zone of plants. This method minimizes water wastage, reduces evaporation, and ensures that water is used efficiently throughout the crop area.

Actuators 1: Irrigation:

Actuators in the irrigation system are responsible for the physical operation of valves and pumps. They adjust the flow of water through the drip lines, ensuring that each plant receives the optimal amount of water as determined by the field sensors and RTU.

Actuators 2: Fertilizer Injection System:

Similar to the irrigation actuators, these actuators control the delivery of fertilizers through the system. They precisely inject the required nutrients into the irrigation water, allowing for the efficient and targeted fertilization of crops.

Central Computer:

The central computer serves as the brain of the operation, receiving data from the RTU and using it to make informed decisions about irrigation and fertilization schedules. It can also store historical data, analyze trends, and generate recommendations for improving agricultural practices.

Internet Connectivity:

This component ensures that the system is connected to the internet, enabling remote monitoring and control. Farmers can access real-time data and system controls from anywhere, making it easier to manage their operations efficiently.

User Interface:

The user interface is designed for ease of use, allowing farmers to interact with the system, view data, and make informed decisions about their agricultural practices. It can be accessed through a computer or a mobile device, providing flexibility and convenience.

Schematics of the integrated system is as shown in Figure 3.1, which shows the components of the system as already mentioned above.

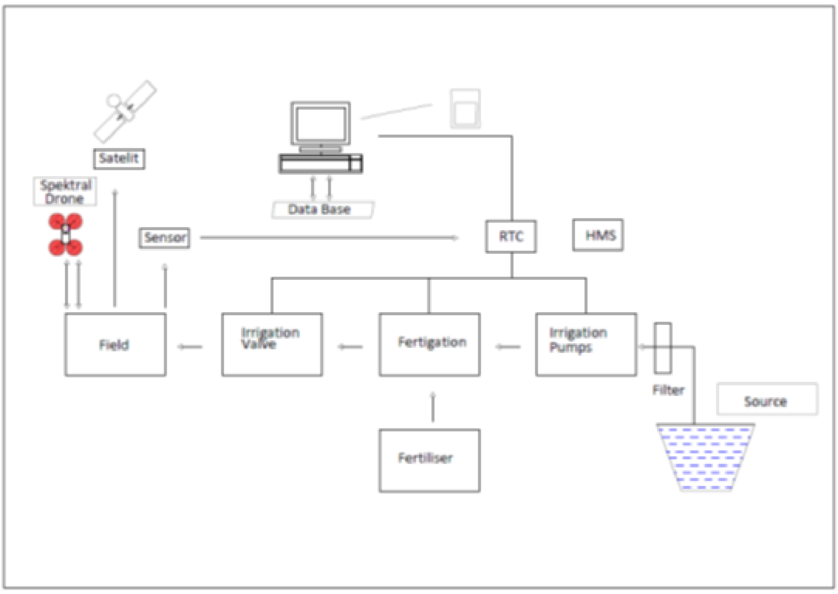



Figure 3.1 Schematic of CSA Integrated Irrigation System.

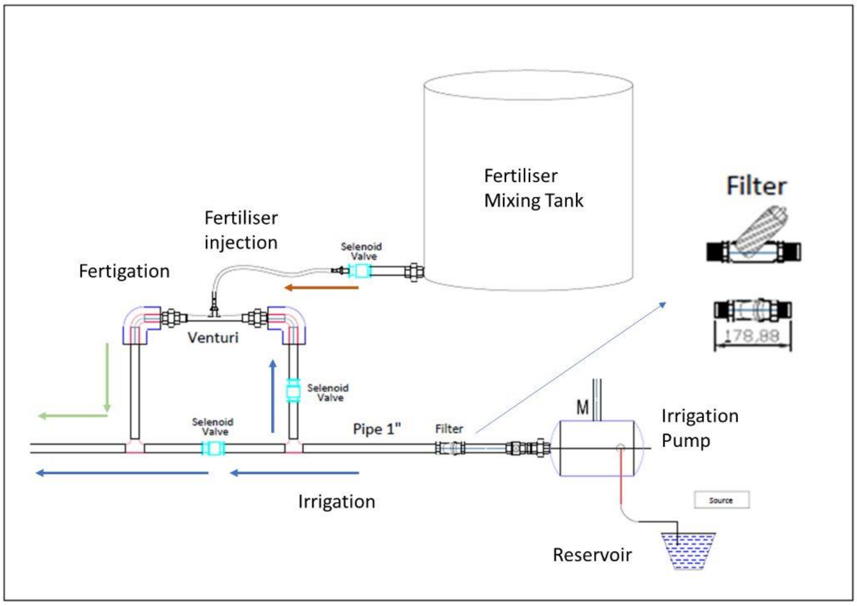



Figure 3.2  Schematic of Water Source and Fertiliser Injection.

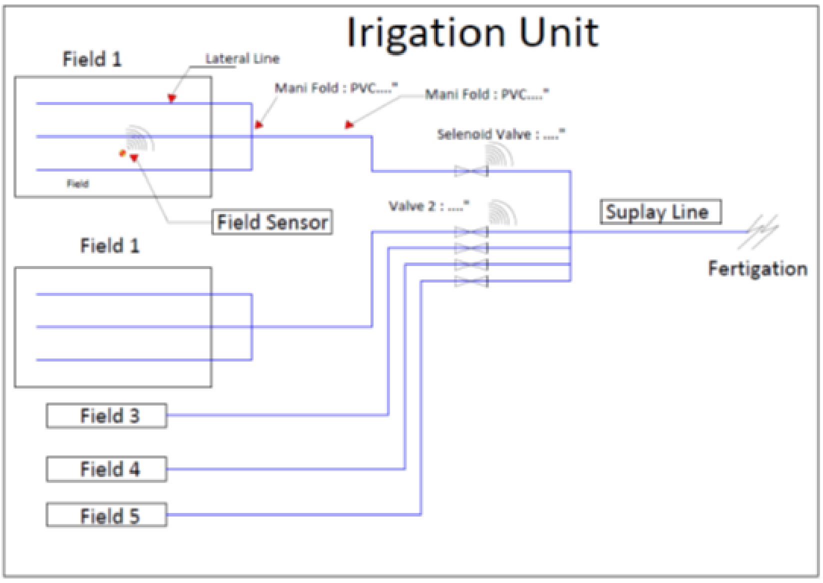



Figure 3.3  Schematic of Irrigation System Network with Separated Fields and Sensors.

Figure 3.2 shows a network of irrigation water sources and fertilizer injection systems, which include filters, pumps, mixing tanks, venturies and solenoid valves

Figure 3.3 shows that irrigation networks can serve multiple irrigation units with suitable pipe installations and irrigation networks. Each unit will be serviced by one branch of the irrigation pipe and controlled by a solenoid valve. In this case, one irrigation station can serve many land maps, but it needs the addition of an irrigation network and a solenoid valve that will regulate to which network water will flow.

**Component and cost**

Examples of components and prices in one integrated system of soil monitoring, automatic irrigation and fertigation are as follows for chilli cultivation on 1 unit land of 400m$^{2.}$

The components of the system to be developed.

1. Reservoir and accessories: water tank 2200 liters, complete system connectors.
2. Pump and accessories: pump, pump control, accessories pump cable, suction & delivery system.
3. Mainline dan Submain: pvc pipe 1 inch, valve 1 inch, disc filter 1 inch, water meter, fittings complete system, complete system connectors.
4. Lateral and accessories: hose HDPE 16mm, hose LDPE 5 mm, valve 16 mm, drip stick 5 mm, flow meter ½ inch, complete system fittings, complete system connectors.
5. Dosing system: ventury injector ¾-½ inch, ventury manifold system, mixing tank 1000 liters, nutrient tank, disc filter ¾ inch, complete system fittings.
6. Control panel and server: microcontroller, soil moisture sensor and chemical monitoring, complete control system connectors, power supply, charge controller, inverter, battery.

List of parts, specifications, and cost:

| Component | Specifications | Cost (IDR) |
|---|---|---|
| Reservoir and accessories | | |
| Water tank | Water tank, capacity 2200 liters | 2.700.000-3.700.000 |
| Complete system connectors | Set socket drat in ¾ - ½ inch | 3.500-4.500 |
| Pump and accessories | | |
| Water pump | Shimizu PS-230 bit.output (W): 200. Input (kW): 0.55. Max suction power(m): 9. Total head max(m): 36. Head (m): 10\|29. Capacity (liters/min): 28\|11. Suction pipe (inch): 1. Thrust pipe(inch): 1. Weight(kg): 16.5 | 1.200.000-1.600.000 |
| Pump control | Relay LY2 12V Omron | 35.000-45.000 |
| Pump cable accessories | Pump cable accessories set | 500.000-700.000 |
| Mainline and Submain | | |
| PVC pipe | PVC pipe 1 inchi AW | 40.000-45.000 |
| Valve | Ball valve 1 inchi | 25.000-150.000 |
| Disc filter | Disc filter 1², filtration grade 120 mesh, max pressure 8 bar, flow rate 6 m$^3$/h | 120.000-170.000 |
| Water meter | Water meter 1² | 500.000-750.000 |
| Complete system fittings | Complete system fittings set | 100.000-200.000 |

| | | |
|---|---|---|
| Connectors complete system | Complete system connectors set | 100.000-200.000 |
| Lateral and accessories | | |
| HDPE hose 16mm | HDPE hose 16mm length 50 meter per Roll | 250.000-350.000 |
| Valve 16 mm | Valve 16 mm | 8.000-15.000 |
| Drip stick 5 mm | Drip stick 5 mm | 700-1.500 |
| Water meter | Water meter ½² | 180.000-350.000 |
| Complete system fittings | Complete system fittings set | 100.000-200.000 |
| Complete system connectors | Complete system connectors set | 100.000-200.000 |
| Dosing system | | |
| Ventury injector ¾-½ inchi | Set ventury injector ¾-½ inchi | 150.000-250.000 |
| Ventury manifold system | Pipe ¾ inchi, filter mesh, check valve, injector hose | 150.000-400.000 |
| Disc filter ¾ inchi | Disc filter ¾², filtration grade 120 mesh, filtration area 90 $cm^2$, max pressure 6 bar, flow rate 4 $m^3/h$ | 65.000-130.000 |
| Mixing tank | Tank capacity 1000 liters | 1.700.000-2.300.000 |
| Nutrient tank | Tank capacity 60 liters | 130.000-250.000 |
| Control panel and server | | |
| Microcontroller | RTCU LX4 pro, wireless communication, internal flash drive 64 Mbyte, li-ion battery 2Ah, | |
| Soil moisture sensor | Sensor RK520-02 | |
| Solenoid valve | Brass Solenoid valve ½² | 145.000-260.000 |
| Complete control system connectors | Complete control system set connectors | 150.000-250.000 |
| Power supply | Solar panel 150 WP | 1.200.000-2.300.000 |
| Inverter | Power inverter pure sine wave 2000 watt DC 12V to ac 220V psw Sunyima – 12V 1600watt | 560.000-750.000 |
| Battery | Battery 12v-60 Ah | 980.000-1.500.000 |
| Charge controller | Solar charge controller 10A 20A 30A | 150.000-350.000 |

### 3.1.3 Activity

1. Create an irrigation system scheme for the cultivated land of a particular crop, determine the irrigation capacity that should be prepared.
2. List components for integrated irrigation systems, soil, monitoring and fertigation.
3. Calculate the estimated investment of the system.

## 3.2 Sub Module 3.2 Feasibility Analysis of Agricultural Businesses in Climate Smart Agriculture (CSA)

**Learning objectives:** Participants understand how to analyze the business and financial feasibility of an agricultural business using modern technology.

### 3.2.1 Introduction

Agricultural business analysis is an analysis that farmers often carry out but still using a recall system. The concept of farming is a concept that investigates everything related to people's agricultural activities and problems that are viewed specifically from the position of the entrepreneur himself or the science of farming, namely investigating the ways in which a farmer as an entrepreneur organizes, organizes and runs the company. Meanwhile, according to Soekartawi (1995), farming science is a science that studies how a person allocates existing resources effectively and efficiently to obtain high profits at a certain time.

Therefore, when implementing the Climate Smart Agriculture concept, to reduce the impact of climate change, various efforts are made so that agricultural businesses do not experience losses. These various businesses include businesses that use local wisdom or use high technology.

This module emphasizes how to analyze a business and its feasibility in using modern technology, namely drip irrigation technology, whose operations use the internet of things (IOT). The scope of use of this technology is on agricultural land, not in greenhouses.

In this module, two parts will be presented, namely (1) farming business analysis, where this analysis is used to calculate business analysis of seasonal commodities such as red chilies, tomatoes and purple eggplant; and (2) feasibility analysis used to analyze overall finances over a multiyear period. These multiyears are related to the use of long-lasting inputs, such as buildings or water tanks or other technological components.

### 3.2.2 Farm Business Analysis

Farming business analysis, sometimes also called farmer income analysis, is one of the analytical tools in calculating the feasibility of a business, such as an agricultural business. Farming analysis is used to analyze or calculate the business feasibility of a seasonal commodity, with a one-time business period, not a multiyear business analysis.

In carrying out an analysis of farmer income, four elements are needed, namely: (1) average inventory, (2) farming income, (3) farming expenses, and (4) income from various sources (Hernanto 1991). The state of average inventory is the sum of the initial inventory value plus the ending inventory value divided by two. Valuing assets in farming can be done using: purchase price, sales value after a certain time, sales value at the time of recording or calculation, and purchase price minus depreciation.

Farming revenue, namely revenue from all farming sources which includes: the amount of additional inventory, the value of sales of produce, and the value of home use and goods consumed. Farming expenses are all operational costs without taking into account interest from farming capital and the value of work managing the farm.

Expenses include: cash outlay, depreciation of physical objects, reduction in inventory value, and value of unpaid labor.

By paying attention to the definitions mentioned above, it is hoped that an analysis of farming income can be developed. This analysis includes income analysis and R/C ratio analysis.

The aim of this farming activity is to achieve production in the agricultural sector which will ultimately be valued in money. This value is obtained after subtracting or calculating the costs that have been incurred.

Based on this value, it is hoped that it will encourage farmers to allocate the value they obtain for various uses, such as production costs for the next period, savings and other expenses to meet family needs.

**Farming Expenditures/Costs**

According to Soekartawi (1986), costs that must be incurred in farming include fixed costs and variable costs. Fixed costs are costs whose value does not depend on the size of production, for example land tax, land rent, depreciation of agricultural building equipment produced. Variable costs are costs that are directly related to the amount of production, such as expenses for medicines, seeds, fertilizer and labor costs (wages).

Fixed costs are costs that have nothing to do with the number of goods produced. Farmers must continue to pay, regardless of the amount of commodities their farming produces. Non-fixed costs or variable costs are costs that change if the area of the farm changes. These costs exist when an item is produced. The sum of these two costs is called the total production cost.

$$TC_i = TVC_i + TFC_i$$

Where:
$TC_i$: *Total Cost*
$TVC_i$: *Total Variabel Cost*
$TFC_i$: *Total Fix Cost*

In terms of costs, costs can be divided into cash and non-cash costs (calculated costs). Cash costs are fixed and variable costs that are paid directly. Meanwhile, non-cash costs are costs that are calculated to determine the total expenses incurred by the farming business.

Cash costs are costs incurred by farmers in cash including credit interest, while non-cash costs (calculated costs) are used to calculate farmers' work income if capital, land rental and labor in the family and the cost of their own seeds are taken into account. The capital used by farmers is counted as loan capital, even though the capital belongs to the farmers themselves. Family labor value is based on the prevailing wage when family members contribute work to the farm. The land used by farmers is calculated as rental land, the amount of which is based on the average land rental cost per hectare in the area.

### Farming Revenue

Farming income is the total product value within a certain period of time, both for sale and for own consumption. This revenue includes all products sold, consumption by farmer households, for payment and for savings (Soekartawi, 1986).

Farming revenue is the result of multiplying the production obtained by the selling price (Soekartawi, 1995). This statement can be formulated as follows:

$$TR_i = Y_i P_{yi}$$

Where:
$TR_i$ : Total Revenue
$Y_i$ : Production from farm business$_i$
$Py_i$ : Price  Y

### Farming Income

After carrying out production, farmers will receive revenue through selling their products. Furthermore, from this revenue, it needs to be emphasized that this revenue is not a profit, because in the revenue there are still several costs that must be taken into account. After costs are calculated, the value of these costs needs to be deducted from revenues to obtain the profit value (Falatehan and Sari 2023). In this case, the farmer's profit is the farmer's profit. According to Soeharjo and Patong, 1973, the main objective of income analysis is to describe the current state of a business activity and describe the future state of planning or action.

Income can be mathematically formulated as follows:

$$\pi = \mathrm{TR_I} - \mathrm{TC_I}$$

Where:
π : Profit (Rupiah)
TRi : Total Revenue
TCi : Total cost (Rupiah)

### Revenue and Expense Ratio (RC Ratio)

Soeharjo and Patong (1973) stated that large income is not an indication that farming is efficient. A farming business is said to be feasible if it has an efficient level of revenue obtained for each cost incurred to reach a certain ratio.

One measure of income efficiency is revenue for every rupiah spent (Revenue-Cost ratio or RC Ratio). The revenue to cost ratio shows how much revenue will be obtained from every rupiah spent in farming production. With this analysis, it can be seen whether a farming business is profitable or not. The following is the formula for finding the RC Ratio:

$$R/_C = \frac{Total\ Revenue}{Total\ Cost}$$

Decision criteria:
R/C > 1, farming is feasible: additional costs incurred will produce additional income that is greater than additional costs or simply farming activities are profitable.
R/C < 1, farming is not feasible: any additional costs incurred will produce additional income that is smaller than the additional costs or simply farming activities are detrimental.

**Calculating Depreciation Costs**

The depreciation costs for agricultural equipment are calculated by dividing the difference between the purchase value and the remainder which is interpreted by the length of time the capital is used, using the straight line depreciation method, the depreciation formula is as follows:

$$\text{Depreciation Cost} = (Nb\text{-}Ns) / n$$

Nb = Purchase value (Rp)
Ns = Interpretation of residual value (Rp)
n = Economic life span, in years

Table 3.1 Model of Farming Revenue and Expenditure

| Component | Information |
|---|---|
| A. Cash Revenue | Price x Harvest sold (kg) |
| B. Calculated Revenue | Price x Consumed harvest (kg) |
| C. Total Revenue | A + B |
| D. Cash Cost | Seed, Fertilizer, Outside Family Workers (TKLK), Land lease, Land Tax |
| E. Costs are taken into account | Family Labor (TKDK), Tool depreciation, Manure (own), Shrinkage |
| F. Total Cost | D + E |
| G. Income On cash costs | C – D |
| H. Income Over total costs | C – F |
| I. Cash Income | A – D |
| J. RCR | C/D |
| I. B/C | I/D |

Source: Hernanto, 1991

### 3.2.3 Business Feasibility Analysis

Calculating a business feasibility study helps farmers and business people to analyze whether or not a business is feasible to run. In a business feasibility study, various factors are taken into consideration that will support the successful running of a business. Feasibility analysis is something related to financial feasibility analysis which includes Net Present Value (NPV), Payback Period (PP), Internal Rate Return (IRR), and Net Benefit-Cost Ratio (Net B/C)

**Net Present Value**

Calculation of the feasibility of a business is related to the total amount of benefits received and exceeding the costs incurred. The NPV method is the calculation of the difference between the cash flows issued by the company, the NPV value calculated using a certain interest rate, the NPV value produced by generating net income is greater than the current investment value, so the NPV value is positive, and it can be said that the investment project is worthy. The value of net cash receipts is smaller than the investment value, so the NPV is said to be negative, so the investment project undertaken can be categorized as not feasible. The NPV calculation formula is:

$$\text{NPV} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Where:
Bt = profit for a year
Ct = investment costs for a year
i = discount rate used
n = economic life of the investment
t = Year

NPV > 0, investment in a business worth running
NPV < 0, investment in a business is not worth running
NPV = 0 requires consideration to continue investing or not

### Internal Rate of Return (IRR)

The rate of return in the Internal Rate of Return determines whether an investment project is considered feasible or not, by comparing the IRR with the expected level of profit. The IRR calculation is carried out using the discount rate with present value. If the IRR value is > 1, then NPV > 0, it can be said that the business is worth continuing. If IRR < 1 then NPV < 0 then the business being run is not worth continuing. If IRR = 1, NPV = 0 then the business being run only bears the costs of the current interest rate. The formula used is:

$$\text{IRR} = i_1 + \frac{\text{NPV}}{\text{NPV}_1 - \text{NPV}_2} x (i_2 - i_1)$$

Where:
i1 = discount rate which produces a positive NPV
i2 = discount rate which produces a negative NPV
NPV1 = positive NPV
NPV2 = negative NPV

### Net Benefit Cost Ratio (Net B/C ratio)

Measuring whether an investment project is feasible or not is by comparing the present value, if the Net B/C value is > 1 then it is said to be feasible and if the Net B/C < 1 then a business is not said to be feasible. The formula used is:

$$\text{Net}\frac{B}{C} = \frac{\sum_{r=0/1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{r=0/1}^{n} \frac{C_t}{(1+i)^t}}$$

Information:
Bt = monthly profit
Ct = costs incurred every month (Rp)
i = interest rate
N = number of years

**Payback Period**

In the feasibility study, the payback period calculation provides an explanation of the investment amount at present value. By knowing the payback period, farmers will know how long the investment they carry out can provide profits to farmers. If the payback period is smaller than the economic life of the investment, then the investment is said to be feasible and if the payback period is greater than the economic life then it can be said to be not feasible. The payback period calculation formula is:

$$PP = \frac{1}{Ab}$$

Information:
I = The amount of investment costs
Ab = Net benefits obtained each year

**Financial Feasibility Risk Mitigation (Sensitivity) Analysis**

From the financial aspect, sensitivity studies are based on changes in economic variables such as prices, both input prices/production facilities, and output prices, as well as changes in interest rates. Sensitivity analysis is basically to find out whether the project is still feasible if there are changes in these economic variables. Sensitivity analysis is based on the trend of changes in the variables input prices, output prices and interest rates.

### 3.2.4 Activity: Practice

Participants are asked to carry out an analysis of their farming business and its financial feasibility.

**Practice**

In this section, the analysis used as an example is the red chili business. The following is an overview of the red chili business:

Farming is carried out on an area of 400 $m^2$. This is done based on the technology used, where this technology is used for a land area of 400$m^2$. The price of red chili seeds is IDR 360,000 per package. Meanwhile, for fertilizer, the total fertilizer used is IDR 900,000 per package. Meanwhile, insecticide use reaches IDR 325,000 per package. In the production process, with a land area of 400 $m^2$, the number of workers used is 40 man-days.

Meanwhile, at the start of the activity, some of the materials needed are 0.5 rolls of mulch with the price of 1 roll being IDR 500,000 per package, next is 95 kg of lime with a price of IDR 2,500, borate IDR 30,000 with 0.5 kg used, then rope 1 kg with the price per kg being IDR 16,000. Other materials needed are a 1.2 m long screen with nutrients of IDR 12,500/m, bamboo sticks with a price per stalk of IDR 15,000 and 720 stakes with a price of IDR 450 per stalk. Land rental costs are IDR 400,000 and other tools are IDR 600,000.

The period for chili plants to complete production is 6 months, so in 1 year you can plant 2 times. After production, the total production of this chili plant is 780 kg with a price of IDR 18,000/kg.

Meanwhile, the costs required to develop drip irrigation technology are:

| No. | Component | Quantity | Unit | Price (IDR) | Age (Year) |
|---|---|---|---|---|---|
| 1 | Reservoir and accessories | 1 | package | 3,704,500 | 10 |
| 2 | Pump and accessories | 1 | package | 2,345,000 | 5 |
| 3 | Mainline and Submain | 1 | package | 1,465,000 | 10 |
| 4 | Lateral and accessories | 1 | package | 3,236,066 | 2 |
| 5 | Dosing system | 1 | package | 2,900,000 | 5 |
| 6 | Control panel and server | 1 | package | 11,300,000 | 2 |
| 7 | Microcontroller | 1 | package | 10,000,000 | 5 |

**Assignment**: With the supplied information above, please calculate the financial feasibility analysis of this business.

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