

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

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

Identify Relevant Technologies for Automatic Irrigation and Fertiliser Application

D3.1.1

This report has been prepared under the DHI Business Management System certified by Bureau Veritas to comply with ISO 9001 (Quality Management)

ISO 9001
Management System Certification
BUREAU VERITAS
Certification Denmark A/S



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

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

Identify Relevant Technologies for Automatic Irrigation and Fertiliser Application

D3.1.1

Prepared for United Nations Environment Programme (UNEP)
 Represented by Ms Clara Landeiro

Current Revision Approvals

	Name / Title	Date
Prepared by	Dr. Satyanto Krido Saptomo, Dr. A. Faroby Falatehan, Sriwulan Ferindian F., Dr. Arien Heryansyah	Aug 23, 2023
Reviewed by	Syed Mohazri Syed Hazari	Sep 08, 2023
Approved by	Maija Bertule	Sep 11, 2023

Classification

<input type="checkbox"/> Open	<input checked="" type="checkbox"/> Restricted	<input type="checkbox"/> Confidential
-------------------------------	--	---------------------------------------

This page is intentionally left blank

Document Information

Project No.	11828079		
Project Title	Identification of Technical Practices for Climate-Smart Agriculture (CSA) in Indonesia: A Case Study in the Sukabumi Regency, West Java		
Subject	Output 3 – Identify Technologies for Automatic Irrigation and Fertiliser and Design an Integrated System for the Suitable Conditions as per the Geographic Location Selected		
Client	United Nations Environment Programme (UNEP)		
Document No.	11828079-RPT-405	Rev	01

Distribution	Type of Data	No of copies
United Nations Environment Programme (UNEP)	Digital	1
Directorate General of Climate Change Indonesia	Digital	1
National Research and Innovation Agency (BRIN) Indonesia	Digital	1
DHI Water & Environment (M) Sdn. Bhd.	Digital	1

Document Revision History

Rev	Rev Date	Description of Change/ Reason for Issue	Prepared by	Checked by	Approved by
01	Sep 08, 2023	Draft	SKS, AFF, SFF, AH	SMH	MABE

The information contained in this document produced by DHI Water and Environment (M) Sdn. Bhd. is solely for the use of the Client identified on the cover sheet for the purpose for which it has been prepared. DHI Water and Environment (M) Sdn. Bhd. makes no representation, undertakes no duty, and accepts no responsibility to any third party who may use or rely upon this document or the information.

All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of DHI Water and Environment (M) Sdn. Bhd.

© DHI Water and Environment (M) Sdn. Bhd.

This page is intentionally left blank

CONTENTS

1.	Introduction.....	1-1
1.1.	Irrigation Technology	1-1
1.1.1.	Furrow Irrigation.....	1-4
1.1.2.	Sprinkler Irrigation	1-5
1.1.3.	Drip Irrigation	1-6
1.2.	Fertigation Technology	1-7
1.3.	Irrigation and Fertilization Technology in Sukabumi	1-8
2.	Catalogue of Technologies	2-1
2.1.	Timer Based Automatic Fertigation	2-1
2.1.1.	DGT by Senmatic Irrigation and Fertilizer Mixer	2-3
2.1.1.1.	Characteristics	2-4
2.1.1.2.	Characteristics of Architecture of Communication :	2-4
2.1.1.3.	Performance Standards.....	2-4
2.1.2.	Rivulis Fertigation	2-5
2.1.2.1.	Characteristics	2-6
2.1.2.2.	Communication Architecture:	2-7
2.1.2.3.	Performance Standards.....	2-7
2.2.	Sensor Based Automatic Fertigation	2-8
2.2.1.	JINGXUN	2-9
2.2.1.1.	Characteristics	2-10
2.2.1.2.	Characteristics of Architecture of Communication	2-12
2.2.1.3.	Performance Standards.....	2-12
2.3.	Smart fertigation	2-12
2.3.1.	Netafim Nutrigration Fertikit 3G	2-13
2.3.1.1.	Characteristics	2-16
2.3.1.2.	Characteristics of Architecture of Communication	2-16
2.3.1.3.	Performance Standards.....	2-17
2.3.2.	JAIN Irrigation	2-17
2.3.2.1.	Characteristics	2-18
2.3.2.2.	Characteristics of Architecture of Communication	2-18
2.3.2.3.	Performance Standards.....	2-19
3.	References.....	3-1

FIGURES

Figure 1.1	Furrow Irrigation (source: https://dpu.kulonprogokab.go.id/)	1-5
Figure 1.2	Sprinkler Irrigation (source: https://www.dsirrigation.com/)	1-5
Figure 2.1	Schematic diagram of the Senmatic Fertigation Solutions technology.....	2-4
Figure 2.2	The Rivulis Fertigation Machines C6100	2-6
Figure 2.3	The Rivulis Fertigation working scheme for by-pass operation	2-6
Figure 2.4	JINGXUN Fertigation Technology	2-10
Figure 2.5	JINGXUN irrigation controller working scheme.	2-10
Figure 2.6	JINGXUN V2/V4 irrigation controller.....	2-10
Figure 2.7	Fertikit 3G Nutrigration Unit	2-14
Figure 2.8	Typical installation of Fertikit 3G	2-15
Figure 2.9	Growsphere workspace	2-15
Figure 2.10	JAIN Irrigation Total Approach.....	2-17

TABLES

Table 1.1	Micro-irrigation characteristics (Draft KP09 PUPR, 2023)	1-2
Table 1.2	Advantages and disadvantages of each type of fertigation	1-8
Table 2.1	Technical Specifications of the JINGXUN Fertigation Technology	2-11

1. Introduction

With climate change expected to lower agricultural productivity, there is need for technology to adapt to, and if possible, mitigate climate change ((Arora, 2019)). In the age of globalization and rapid technological advancements, the agricultural sector is not exempt from innovation. The search for technologies that can enhance efficiency, effectiveness, and consistency in water and nutrient delivery to plants is necessary in order to increase productivity and resilience of crops to climate change.

This document catalogues existing relevant technologies that could meet these needs. Various technologies have been reviewed and selected here that can not only integrate irrigation and fertilisation, but also automate the process. Their suitability to local land requirements is also assessed, using a case study of Sukabumi Regency in West Java, Indonesia.

Indonesia has developed irrigation covering an area of 7.2 million Ha. This irrigation has experienced damage covering an area of 1.62 million Ha (22.5%), of which 0.37 million (5.1%) was seriously damaged. and 1.25 million (17.4%) had minor damage. This damage is caused by natural disturbances and weak Operation and Maintenance (OP) of irrigation infrastructure. Pressurized irrigation was introduced to improve the performance of irrigation on food production, about 1980.

1.1. Irrigation Technology

Irrigation technology relates to the use of technology to meet the water needs of plants. Generally, irrigation technology can be divided into two (2) types, namely surface irrigation and subsurface irrigation. Surface irrigation sends water supply to plants by infiltrating the medium, e.g., soil, while subsurface irrigation directly delivers water to the root zone of plants. International Commission of Agricultural and Biosystems Engineering divided irrigation methods into 4 categories (Allen et al., 1999):

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, and ebb and flow.

Irrigation have initially followed a system design based on time and duration, i.e., when to give water and how long to give water. Now, new technologies are being developed that incorporate a time-based automatic system that can provide water, regardless of the conditions in the field. With the development of sensor technology,

this irrigation system can be automated based on the condition of water availability and even nutrients in the field.

In recent development of irrigation planning criteria (KP Irigasi) in Indonesia Sprinkler, drip, and furrow irrigation, are referred to micro-irrigation (*STANDAR PERENCANAAN IRIGASI KP-09 IRIGASI TERAPAN (Draft), 2023*). Although irrigation technology has developed rapidly with the discovery of various materials and types of applicators, the main principles remain unchanged, namely uniformity, total efficiency, and high productivity. The designs follow a manual published by the Food and Agriculture Organization (FAO) (Brouwer et al., 19985) and those of irrigation technology companies. Micro-irrigation techniques are applicable to all crop types and land conditions (see Table 1.1). These techniques are particularly beneficial for crops that are sensitive to water stress, such as fruits, vegetables, and flowers. Micro-irrigation can also be used to grow crops in areas with limited water resources. In principle, micro-irrigation techniques address the following main concerns:

- **Water utilization efficiency:** Micro-irrigation systems deliver water to the soil in the plant area and even directly to the roots of plants for those which has emitter inserted into the soil, where it is most needed. This reduces evaporation and runoff, which can save up to 50% in water use.
- **Fertilizer application efficiency:** Micro-irrigation systems can be used to deliver fertilizers directly to the roots of plants, where they are most effective. This reduces nutrient runoff and leaching and avoids polluting nearby water bodies.
- **Chemical usage efficiency:** Micro-irrigation systems can be used to deliver pesticides and herbicides directly to the target pests and weeds. This reduces the amount of chemicals that are applied to crops and minimizes negative impact on human health and the environment.

Table 1.1 Micro-irrigation characteristics (Draft KP09 PUPR, 2023)

Aspects		Furrow	Sprinkler	Drip
Water source	Sources	Groundwater and Surface Water	Groundwater and Surface Water	Groundwater and Surface Water
	Water Debit	Medium-Large	Medium-Large	Small
	Water quality	Suspended Solid (SS): about 400 mg/L	Suspended Solid (SS): Medium	Low SS
Land conditions	Topography	Ramps (0.25%-6.25%)	Ramps - Steep	Ramps
		Flat	-Flattening	Flat – Wavy
	Soil texture	Medium – Fine	Rough - Medium	Coarse – Fine
	Infiltration rate	Small – Medium	Medium-Large	Small – Medium
	Climate type	Wet – Dry	Windy	Dry

Aspects		Furrow	Sprinkler	Drip
	Plant physiology	-	Water splash resistant.	Small canopy
	Plant water requirements	Evapotranspiration (ET) x Area	ET x Area	ET x Canopy Area + Leaching
	Duration and interval of irrigation	Soil Texture + Land slope	Irrigation rate + Infiltration + water available in the root zone	Wet area
	Types of plants	Annuals, annuals, plants that do not tolerate stagnation	Not tall, Flowers do not fall off easily, annuals, or annuals	Annuals, vegetables or fruit, are of high value.
Specifications	Water rate	0.25 – 3.0 litres/sec/furrow	0.25 – 50 litres/second	2-20 litres/hour
	Head	5-25 cm	2 – 6 bars	<1 bar
	Duration of work	Fast	Medium – Fast	Slow
	Water feeding	Intermittent	Intermittent	Intermittent or Continuous
	Reservoir	Positive head	Head Negative	Positive head
Performance	Complexity	Simple	Simple – Complicated	Complicated
	Operation	Medium	Easy-Medium	Easy
	Efficiency	Low - Medium	Medium – High	High
	Effectiveness	Medium - High	Medium – High	High
Financial	Investment	Low - Medium	Medium – High	High
	Operating cost	Low	High	Medium
	Maintenance	Easy	Medium	High
	Product selling values	Low - Medium	Medium – High	High
Social	Human Resources	Low	Low – Medium	Medium – High
	Technology level	Low	Low – Medium	Medium - high

Aspects		Furrow	Sprinkler	Drip
	Institutional	Medium - Good	Good	Good

1.1.1. Furrow Irrigation

Furrow irrigation is a practice that has long been used in Indonesia. Water is drained from its source (groundwater, rivers, or irrigation canals) using open channels (soil or lining), or piping systems. Furrows, i.e. channels/trenches, are dug in rows between crops so that water can accumulate and be evenly distributed along the crop rows. In technical irrigation areas (irrigation commands area, managed by the government), this flow system is usually managed freely by farmers or farmers' associations using water sources from irrigation channels, while in independent irrigation (non-government managed irrigation), farmers usually use pumps to draw water from their water sources, such as groundwater, lakes, or even sewers. Technology, design and policy are evolving among farmers and other irrigation practitioners.

Furrow irrigation has some advantages and disadvantages compared to other irrigation methods.

Some of the advantages of furrow irrigation are:

- It has lower initial investment of equipment and lower pumping costs per acre-inch of water pumped.
- It can save water and money by recirculating irrigation runoff water and reducing chemical leaching.
- It can ensure higher crop yields by providing adequate moisture and aeration to the root zone.

Some of the disadvantages of furrow irrigation are:

- It requires more labor and skill to maintain water flow and avoid surface runoff or excessive infiltration.
- It is not suitable for sandy soils or soils with high salinity, as they can cause uneven water distribution and salt accumulation.
- It can cause soil erosion and compaction by the repeated movement of water and farm equipment in the furrows.



Figure 1.1 Furrow Irrigation (source: <https://dpu.kulonprogokab.go.id/>)

1.1.2. Sprinkler Irrigation

With the sprinkler irrigation the water is delivered in the form of raindrops precipitated over the entire area. There are many variations of this method in terms of the discharge and diameter coverage, the height of the water jet above ground (overhead, under the foliage) (Phocaidis, 2007). The type of sprinkler mechanism technology is developing rapidly in tropical and sub-tropical regions, especially areas that are either too hot or too cold, and where water sources are limited. The Middle East, Australia, and the Americas are the epicentres of the development of this irrigation technology. In Indonesia, sprinkler irrigation is widely used by corporations to increase yields and lower costs, especially in large plantation areas. . Sprinkler irrigation technology are also used for exotic commodities, such as chili, flowers, and medicinal plants for areas <10Ha.



Figure 1.2 Sprinkler Irrigation (source: <https://www.dsirrigation.com/>)

Advantages of sprinkler irrigation:

- **Water efficiency:** Sprinkler irrigation can be more water-efficient than other irrigation methods, such as flood irrigation or furrow irrigation. This is because sprinkler irrigation delivers water directly to the plants, rather than allowing it to run off or evaporate.
- **Uniform water distribution:** Sprinkler irrigation can provide a more uniform distribution of water than other irrigation methods. This can help to improve crop yields and quality.
- **Reduced soil erosion:** Sprinkler irrigation can help to reduce soil erosion. This is because sprinkler irrigation does not require the soil to be tilled, which can leave the soil vulnerable to erosion.
- **Versatility:** Sprinkler irrigation can be used on a variety of crops and soil types. It can also be used on uneven surfaces.
- **Automation:** Sprinkler irrigation systems can be automated, which can save time and labor costs.

Disadvantages of sprinkler irrigation:

- **Cost:** Sprinkler irrigation systems can be more expensive to install than other irrigation methods.
- **Wind susceptibility:** Sprinkler irrigation systems can be susceptible to wind. This can cause the water to be unevenly distributed or to evaporate.
- **Disease susceptibility:** Sprinkler irrigation can increase the risk of plant diseases. This is because sprinkler irrigation can keep the leaves of plants wet for longer periods of time, which can create an environment that is favorable to disease growth.
- **Salinity:** Sprinkler irrigation can increase the salinity of the soil. This is because sprinkler irrigation can concentrate salts in the soil, which can reduce crop yields.

1.1.3. Drip Irrigation

In drip irrigation water is applied to each plant separately in small, frequent, precise quantities through dripper emitters. It is the most advanced irrigation method with the highest application efficiency (Phocaides, 2007). The water is delivered continuously in drops at the same point and moves into the soil and wets the root zone vertically by gravity and laterally by capillary action. It has become increasingly popular in recent years, particularly in the European Union, for intensive horticulture, ornamentals, and fruit tree cultivation. Drip irrigation in Indonesia is developing along with the development of high-value agricultural products that are out of season or their natural geographical conditions. Drip irrigation is usually used by agribusiness companies that target special markets, such as the expatriate community or export markets.



Figure Drip irrigation (source: <https://www.dsirrigation.com>)

Drip irrigation has several advantages over traditional irrigation methods such as flooding irrigation, namely:

- It is more water-efficient, which can help to conserve water resources.
- It is more efficient in terms of fertilizer use, which can help to reduce nutrient runoff and pollution.
- It is less likely to cause soil erosion than traditional irrigation methods.

Among the disadvantages of drip irrigation are:

- It can be more expensive to install than traditional irrigation methods.
- It requires more maintenance than traditional irrigation methods.
- It can be more susceptible to clogging than traditional irrigation methods.

Automatic sensor-based drip irrigation systems were proposed by many researchers. The architecture and components proposed for remote hilly areas by (Singh & Thakur, 2018) consist of drip irrigation system, solar pumping module, using single board computer which are Raspberry Pi 3 module and Arduino UNO R3 module; and sensor unit circuit sensors (light, humidity, soil moisture, and temperature sensors). (Ramani et al., 2020) propose an automatic drip irrigation system equipped with soil moisture sensor, temperature sensor, solar panel, submersible pump, and using a GSM network for data transmission. Drip irrigation system integrated Generic IoT framework is also proposed by (Prabha et al., 2018). It mainly consists of temperature and pH sensors, communication module (GPRS), knowledge module, and service module. Automatic drip irrigation system is also proposed by (Al-Ali et al., 2020), (Rosma et al., 2021), (Kusumawardani et al., 2020) and many others, with similar architecture.

1.2. Fertigation Technology

Fertigation is a process that combines fertilization with irrigation, whereby fertilizer is added to an irrigation system. Fertigation technology is evolving to improve cost efficiency and increase productivity.

There are two groups of fertigation technology, namely:

- based on Electroconductivity (EC) and acidity (pH) which are related to soil nutrition content. In this group the dose of fertilizing is determined in advance by

monitoring EC and pH. Then the fertilizer solution is superimposed into the irrigation system using a venturi injector, a device that uses the Venturi effect to create a vacuum that draws fluid into a stream of flowing liquid to inject fertilizer or other chemicals into irrigation water.

- based on the amount of irrigation water discharge. In this group, fertilization dose is a function of irrigation discharge, so when the discharge is large, the dose of fertilizer given is also large. Table 1.2 summarises the advantages and disadvantages of both types of fertigation technology.

Table 1.2 Advantages and disadvantages of each type of fertigation

Types of fertigation	Advantages	Disadvantages
EC and pH-based venturi injection	<ul style="list-style-type: none"> • Can provide nutrient solutions with concentrations according to plant needs. • The dosing system is more accurate and consistent because fertilizer application can be done independently. 	<ul style="list-style-type: none"> • High initial investment cost • Need regular maintenance and calibration.
Based on the amount of water discharge	<ul style="list-style-type: none"> • The amount of fertilizer supplied to plants can be measured. • Suitable when use non EC responsive fertilizer 	Chance of overfertilizing the plant.

1.3. Irrigation and Fertilization Technology in Sukabumi

Agricultural land in Sukabumi Regency consists of block less than 1 ha, where land ownership is not always close together. The depth of impermeable layer is more than 1m, except on paddy field. Each block was connected with a field embankment or 2-wheeled vehicles farm road. The block was intercropping planted with a variety of crops with different planting period. Cultivated crops are adapted to market conditions and seasons.

Water supply in Sukabumi Regency is dominated by surface water, from rivers or reservoirs. Water is distributed through channels or piping systems, where water is organized according to a pre-scheduled allocation. On some block, especially those far from water sources, the quantity of water becomes less than necessary. This results in a delay in the beginning of planting, reduced harvests, and even no harvest.

There is little information about irrigation in Sukabumi, except for those based on surface irrigation technology for rice fields, such as development, operation and maintenance of irrigation. There are 157 Irrigation area under the authority of the Government, covering an area of 28650 Ha. All of them using surface water as water resources. The irrigation system used is still simple, depending on land area and commodity prices. Farmers take water from irrigation networks and then deliver water to the field by gravity (furrow irrigation), or manual

watering. Some farmers use field reservoirs to facilitate manual watering. Some other farmers attempted to use sprinklers to provide water on their fields but did not continue because the harvest was no different from manual irrigation.

Netafim Indonesia, a global company that specializes in smart greenhouse and precision irrigation systems, in collaboration with Sekolah Vokasi IPB, a vocational school of IPB University, held a seminar in May 2022, aimed to introduce the latest technology of greenhouse and precision irrigation that are systematic and integrated, and to demonstrate how they can improve agricultural productivity, quality, and sustainability. The seminar featured speakers from the company and Sekolah Vokasi IPB, who explained the benefits, challenges, and components of greenhouse and precision irrigation systems. The seminar also showcased a project of greenhouses construction in the Teaching Farming area of Sekolah Vokasi IPB, one of the greenhouse. is in Sukabumi, which uses sensors, microcontrollers, GSM modules, LCD displays, buzzers, LEDs, and solar panels to monitor and control the irrigation and fertigation processes. (*SV-IPB Bersama Netafim Indonesia Kenalkan Teknologi Terkini Green House Dan Irigasi Presisi Yang Tersistemasi - Sekolah Vokasi IPB*, n.d.)

The seminar and the project in Sukabumi indicate that there are ongoing efforts to develop and apply modern irrigation systems in the region, which can potentially enhance the water use efficiency, crop yield, and environmental sustainability of agriculture. However, there are still many challenges to overcome, such as the high initial cost, the lack of technical skills, the social acceptance, and the adaptation to local conditions. Therefore, it is important to promote more research, education, and collaboration among various stakeholders, such as farmers, researchers, companies, and government agencies, to foster the innovation and adoption of modern irrigation systems in Sukabumi.

2. Catalogue of Technologies

This catalogue provides an overview of some of the existing technologies that integrate the automation of watering and fertilizing according to land requirements, that can be used to improve performance of fertigation (irrigation and fertilization), which is the application of water and nutrients to crops through irrigation systems.

Fertilizer injection is the process of adding fertilizer solution to the irrigation water in a fertigation system. It can be done by using different types of injectors, such as venturi, positive displacement, or pressure differential injectors. The injector must be calibrated to deliver the desired amount and ratio of fertilizer to the plants. Fertilizer injection can improve the efficiency and uniformity of nutrient delivery, reduce labor and energy costs, and prevent nutrient leaching and runoff

The selection of technology and example of technological products requires the consideration of multiple factors. One factor relates to the category of automatic fertigation, which includes various subcategories such as time-based systems, sensor-based solutions, and smart irrigation technologies. Another factor determines that the product should integrate both automatic functionality and the combination of irrigation and fertigation, enabling a smooth and effective agricultural process.

A common configuration of an automatic fertigation system is to use in-line injection methods, which can range from simple mechanical injectors driven by water flow to fully automated nutrient control systems. In-line injection systems can deliver precise amounts of fertilizers and water to the plants according to their needs, and can be adjusted in real time based on sensor feedback. So technology must be sought that involves a mixer system and injection of fertilisers into irrigation.

To widen the search, products should be sourced from providers in different regions, covering Asia, Europe, and America, allowing for a diverse range of options. Furthermore, the product should come with a comprehensive technology scheme for both irrigation and fertilization. This scheme ensures that the product covers all essential aspects of these agricultural processes. Lastly, the popularity of the product in the field of fertigation is an important consideration. A popular and respected product is more likely to have a record of success and user satisfaction.

In summary, the technology should: (a) have automatic irrigation and fertilization solutions, shown with a complete fertigation technology scheme; (b) be able to facilitate drip and /or sprinkler irrigation; (c) have one of levels of automation: time-based, sensor-based, or smart irrigation; and (d) be from various place of origins.

2.1. Timer Based Automatic Fertigation

Timer based automatic fertigation is a technology that 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.

a. Characteristics of the technologies

A timer based automatic irrigation system is a system that uses a timer to control the irrigation of plants according to a predefined schedule. The system consists of a water source, a pump, a valve, a sprinkler or drip system, and a timer. The timer can be

programmed to turn on and off the valve at specific times and durations, depending on the water needs of the plants. The system can also have sensors to monitor the soil moisture, temperature, and rainfall, and adjust the irrigation accordingly. The components are typically:

1. A timer: This is the main component of the system, and it is responsible for controlling the flow of water. Can be a si
2. A water valve: This valve opens and closes to control the flow of water to the plants.
3. A water source: This could be a garden hose, a well, or another source of water.
4. Irrigation lines: These lines carry the water from the water source to the plants.
5. Emitters: These are devices that distribute the water to the plants.

b. Characteristics of the architecture of communication

A timer based automatic irrigation system can have different types of communication architectures, depending on the complexity and scale of the system. Some examples are:

- A simple wired system, where the timer is connected to the valve and pump by wires, and the sensors are connected to the timer by wires. This system is easy to install and maintain, but has limited flexibility and scalability.
- A wireless system, where the timer, valve, pump, and sensors communicate with each other by radio signals or Wi-Fi. This system is more flexible and scalable, but requires batteries or solar panels to power the devices, and may have interference or security issues.

c. Performance standards

The standard performance of a timer based automatic irrigation system depends on the design and configuration of the system, as well as the environmental and plant factors. Some indicators of performance are:

- Water efficiency: The ratio of water used by the plants to water applied by the system.
- Crop productivity: The amount of crop produced per unit area and/or per unit volume of water, a higher crop yield means higher productivity and profitability. And also the crop quality.
- Energy consumption: Timer based system requires electricity for the timer device, pumps and valves for a simple system.
- Maintenance cost: The amount of money spent on repairing or replacing the components of the system.

d. The optimal working condition of a timer based automatic irrigation system varies depending on the type of crop, soil, climate, and season. Some general guidelines are:

- The timer should be set to irrigate at the right time of day to avoid evaporation loss and plant stress.
- The timer should be set to irrigate at the right frequency and duration, usually based on the evapotranspiration rate (ET) of the crop, which is affected by temperature, humidity, wind speed, solar radiation, and plant type.

- The timer should be set to irrigate at the right amount or depth, usually based on the field capacity (FC) and wilting point (WP) of the soil, which are affected by soil texture, structure, organic matter, and salinity.
- The timer should be adjusted according to the rainfall events, either manually or automatically by using a rain sensor or a weather station data.
- The timer should be checked regularly for accuracy and functionality, and replaced or repaired if needed.

There are many existing products of timer based automatic irrigation systems in the market, ranging from simple to sophisticated models. Some examples are as follows:

2.1.1. DGT by Senmatic Irrigation and Fertilizer Mixer

DGT by Senmatic is a division of Senmatic, a company that specializes in sensor and horticulture technology. DGT by Senmatic delivers complete and configurable solutions for horticultural applications such as electronic and mechanical climate control, irrigation and fertilizer mixing, and LED lighting

DGT by Senmatic irrigation and fertilizer mixing (fertigation) solutions include the following products:

- Compact and advanced irrigation and fertilizer mixers comprising high precision software, touchscreen and a modular construction, developed for ease of use and high reliability
- Mixer solutions where everything is customizable – the pump, number of fertilizer tanks and return tank (for water reuse) – for easy system expansion later
- Bio-mixer for precise irrigating with biomass
- System for recycling return water for optimization of water resources
- Easy and rapid EC and pH measurement with alarms, including hand-held measurement available as an accessory

This technology is applied for in house horticulture, combination of the above products creates an water-reuse automatic fertigation system as in (Figure 2.1). The system takes fresh water and mix with reuse water to fertilizer mixer, where the redefined amount of fertilizer will be added to the water. The fertilised water then will be delivered to the plant/culture through valve and flow sensor. The excess water from the culture will be collected in a basin. Used water from the basin is then treated with filtration and ultraviolet (UV) before being reused together with fresh water.

The website of this technology is accessible at:

- <https://www.senmatic.com/horticulture/products/irrigation-fertilizer-mixers/>

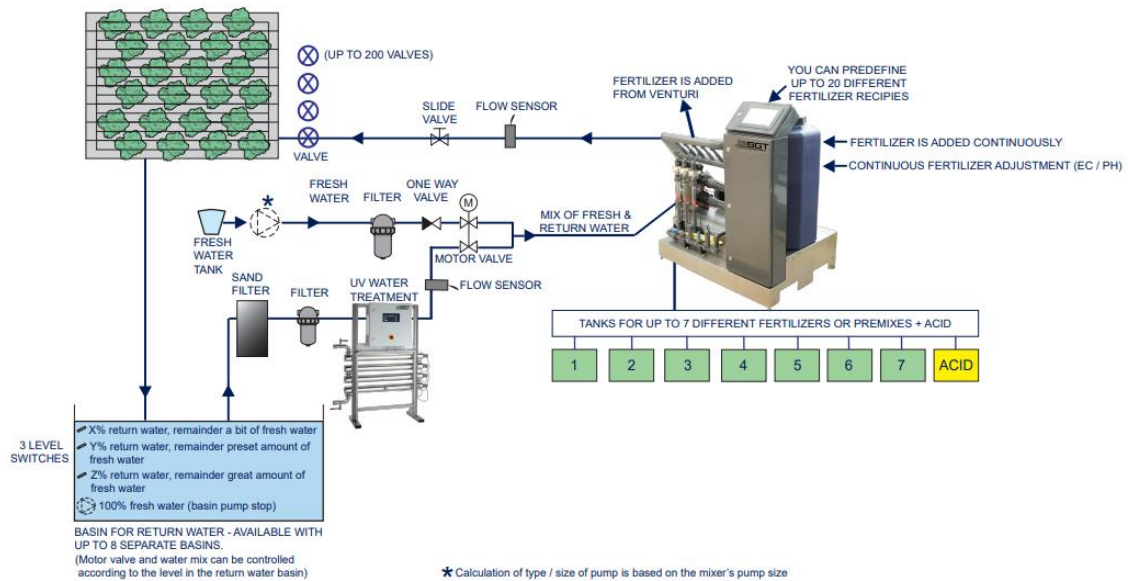


Figure 2.1 Schematic diagram of the Senmatic Fertigation Solutions technology

2.1.1.1. Characteristics

The DGT by Senmatic irrigation and fertilizer mixer uses AMI Penta Mixer (https://www.senmatic.com/media/431174/ami-penta_uk_20012023.pdf), ensures that water is delivered to the plants at exactly the right time, in the right amounts, and with the correct nutrients in the correct proportion, concentration and with the pH value constantly adjusted. The irrigation controller manages requirements from drip over water distribution systems to complete fertilizer mixers with a touchscreen, allowing complete personification of the interface.

The multi languages controller is easy to operate with well-arranged menus shown on a large 10.1" touch screen. This minimizes the risk of human errors in nurseries employing people of different nationalities.

2.1.1.2. Characteristics of Architecture of Communication :

Data communication:

- Communication: Ethernet
- Communication to EXP: Powerlink on Ethernet
- Sensor and peripherals communications:
 - Digital inputs: 8
 - Analog inputs: 4
 - Digital outputs: 8

2.1.1.3. Performance Standards

- Power uses : Supply voltage: 1 x 230 V AC - +10/-15 %, 50/60 Hz
- Large capacity and flexibility:
 - AMI Penta can control up to 100 groups with individual start conditions, to manage fertigation on wide area divided by irrigation units or plots with various cultures and stage of cultivation.

- For each group you can choose between 20 different fertilizer recipes with information about EC, pH and the fertilizer mix.
- Each group can control up to 30 valves, and these can be chosen freely between the 200 valves available today in the mixer.
- Up to 9 valves can irrigate at the same time which gives a maximal utilization of the capacity. Irrigation time and irrigation volume can be set individually for each valve.
- Optimizing of water resources:
 - To get the same water mix to all valves in the same group, you can mix fresh water sources and return water in ratio percentage.
 - Depending on how much water is available in a basin, the mixer automatically changes the mixing ratio.
- Automatic filter cleaning:
 - When using rainwater and return water, the filters for incoming water can often clog. This can affect the water pressure and thereby the amounts of water led to the fertilizer mixer. Automatic filter cleaning ensures rinsing of the filter according to a time schedule.
 - By using up to 3 filters, it is possible to use both the filters and continue to water at the same time.
- Alarms function to prevent unpreferable conditions for the cultures e.g EC, pH, flow and other user-defined alarms.
- Separate choice of units: Volume: Liter, m³, gallon; Flow: l/min, 0m³/h, gpm; Temperature: °C, °F; Irrigation time: mm:ss, hh:mm; Energy: kJ, Wh
- Advantages of the return water system:
 - The return water basin has three sensors that control the water mixing and prevent overflow and water damage.
 - The return water is reused to save water and reduce costs and environmental impact.
 - The mixer can handle up to 8 return water basins and has a pre-installed software for water control.

2.1.2. Rivulis Fertigation

The C6100 Rivulis Fertigation Machine (Figure 2.2) is a device that offers precise fertigation for various types of crops. It is a cost-effective solution that has a modular design for easy expansion. It can integrate with other control systems, including central controllers, for more convenience and efficiency. It has flexible configurations that can be adjusted according to the system needs of the users. The C6100 is suitable for open field, orchards, vineyards and soilless crops, as it can optimize the crop yield and quality.. The website of this technology is accessible at:

- https://www.rivulis.com/category_product/products/fertigation-and-automation/



Figure 2.2 The Rivulis Fertigation Machines C6100

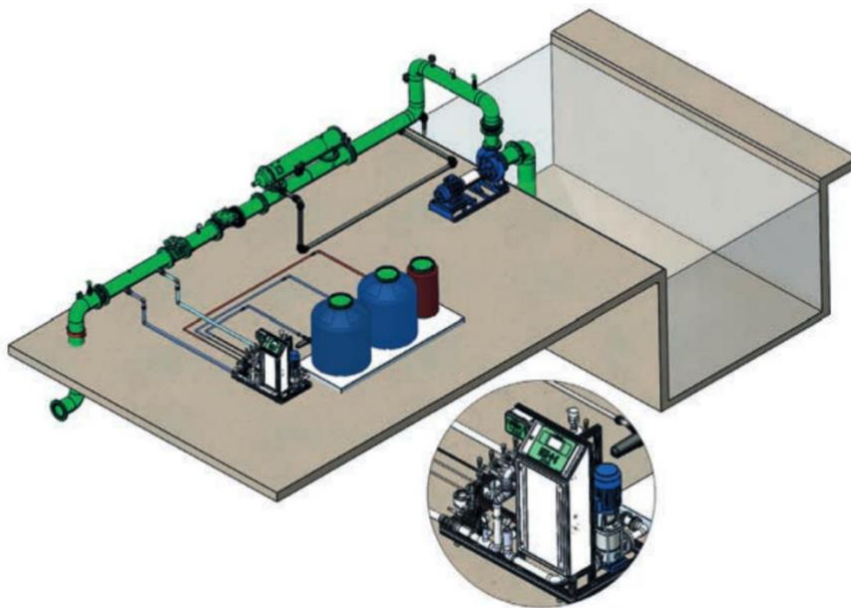


Figure 2.3 The Rivulis Fertigation working scheme for by-pass operation

The fertigation machine that is suitable for a specific application depends on various factors, such as the number of fertilizers to be applied, the required fertilizer injection flow rate, and the preference for a bypass system or a system with its own tank. There are two types of fertigation machines available: bypass or inline mixing tank based fertigation machine. The Rivulis C6100, C7100 and C9100 are examples of bypass fertigation machines, which apply fertilizers proportionally to the irrigation flow rate (Figure 2.3).

2.1.2.1. Characteristics

The Rivulis C6100 is a bypass fertigation machines which fertigate proportionally to the irrigation flowrate, has features as follows:

- A user-friendly interface with a color touchscreen display
- Real-time monitoring of EC and pH levels
- Automatic injection of fertilizer according to a predetermined schedule
- The ability to control up to 50 irrigation zones
- A wide range of irrigation and fertilization options

The Rivulis C6100 is a powerful and versatile fertigation machine that can help farmers to improve the efficiency and productivity of their irrigation operations.

2.1.2.2. Communication Architecture:

The Rivulis C6100 fertigation machine uses a variety of communication technologies to connect with other devices and systems. These include:

- Ethernet: The C6100 can be connected to a local network using an Ethernet cable. This allows farmers to remotely monitor and manage their irrigation system using a computer or mobile device.
- RS-485: The C6100 can also be connected to other devices using the RS-485 serial communication protocol. This is commonly used to connect the C6100 to soil moisture sensors, weather stations, and other irrigation equipment.
- Modbus: The C6100 supports the Modbus communication protocol. This allows it to be integrated with a variety of third-party software and hardware systems.
- Built-in GSM modem. This allows farmers to monitor and manage their irrigation system remotely even if they do not have access to a network connection.

The C6100's communication capabilities make it a versatile and easy-to-integrate solution for a variety of irrigation applications.

- Remote monitoring and management
- Integration with other systems
- Flexibility:

2.1.2.3. Performance Standards

The Rivulis C6100 fertigation machine is designed to meet high standards of performance, energy efficiency, and safety. Here is a summary of some of the key performance standards of the C6100:

Energy efficiency. The C6100 is designed to be energy efficient. It uses a variety of features to reduce energy consumption, such as:

- A variable frequency drive (VFD) to control the speed of the irrigation pump
- A high-efficiency fertilizer injector
- A low-power control system

Safety. The C6100 is designed to be safe. It features a number of safety features, such as:

- An emergency stop button
- A low-voltage protection circuit
- A high-pressure protection switch

The C6100 is designed to be accurate and reliable. It features a number of features to ensure accurate and reliable irrigation and fertilization, such as:

- A high-precision flow meter
- A high-accuracy pH meter
- A real-time monitoring system

2.2. Sensor Based Automatic Fertigation

Sensor based automatic fertigation is a technology that 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.

a. Characteristics of the technologies

- **Sensor-Driven Fertigation:** This technology uses sensors to measure the soil moisture and nutrient levels, and delivers water and fertilizer through drip irrigation systems. The sensors can be placed at different depths and locations to capture the variability of soil conditions. The fertigation system can be programmed to apply different amounts and types of fertilizer depending on the crop stage and soil status.
- **Real-time Data Feedback:** The sensors send data to a control unit, which processes the information and adjusts the irrigation and fertigation parameters accordingly. The control unit can also store historical data and use it to optimize the irrigation and fertigation schedules. The data can be accessed remotely through a web or mobile app.
- **Adaptive Nutrient Delivery:** The technology can adjust the nutrient delivery based on the crop needs and soil conditions. For example, nitrogen fertilizer can be applied more frequently during the vegetative growth stage, while phosphorus and potassium fertilizer can be applied more during the flowering and fruiting stages. The technology can also prevent over-fertilization, which can harm the environment and reduce crop quality.
- **Crop-Specific Settings:** The technology can be customized for different crops, such as vegetables, fruits, flowers, or cereals. Each crop has different water and nutrient requirements, which can be programmed into the control unit. The technology can also account for crop rotation, intercropping, or mixed cropping systems.

b. Characteristics of the architecture of communication

- **Sensor Network** The technology uses a network of wireless sensors that communicate with each other and with the control unit. The sensors can use different communication protocols, such as ZigBee, LoRaWAN, or NB-IoT. The sensors can also use solar power or batteries to operate.

- **Data Transmission to Control Unit:** The control unit receives data from the sensors through a wireless or wired connection. The control unit can be a microcontroller, a computer, or a cloud server. The control unit analyzes the data and sends commands to the irrigation and fertigation systems.
- **Mobile App Integration:** The technology can be integrated with a mobile app that allows users to monitor and control the irrigation and fertigation systems from anywhere. The mobile app can display real-time data, historical trends, alerts, and recommendations. The mobile app can also enable users to manually override the automatic settings or adjust them according to their preferences.
- **Alert System:** The technology can send alerts to users when there are abnormal conditions, such as low battery, sensor failure, water leakage, or pest infestation. The alerts can be sent through SMS, email, or push notifications. The alerts can also suggest corrective actions or preventive measures.

c. Performance standards

- **Energy Efficiency:** The technology can reduce energy consumption by optimizing the irrigation and fertigation schedules and avoiding wastage of water and fertilizer. The technology can also use renewable energy sources, such as solar panels or wind turbines, to power the sensors and the irrigation and fertigation systems.
- **Safety Measures:** The technology can prevent over-fertilization, which can cause environmental pollution, soil salinization, or crop damage. The technology can also prevent over-irrigation, which can cause waterlogging, soil erosion, or root rot. The technology can also detect and prevent leaks or malfunctions in the irrigation and fertigation systems.

Crop Yield Improvements: The technology can increase crop yield by providing optimal water and nutrient supply to the crops. The technology can also improve crop quality by enhancing crop growth, development, and health. The technology can also reduce crop losses due to drought, pests, diseases, or weeds

2.2.1. JINGXUN

This technology integrates automatic drip irrigation or sprinkler system with EC and pH-based fertigation system. The website of this technology provider is accessible at:

- <https://jxiotet.com/smart-agriculture/irrigation/15.html>

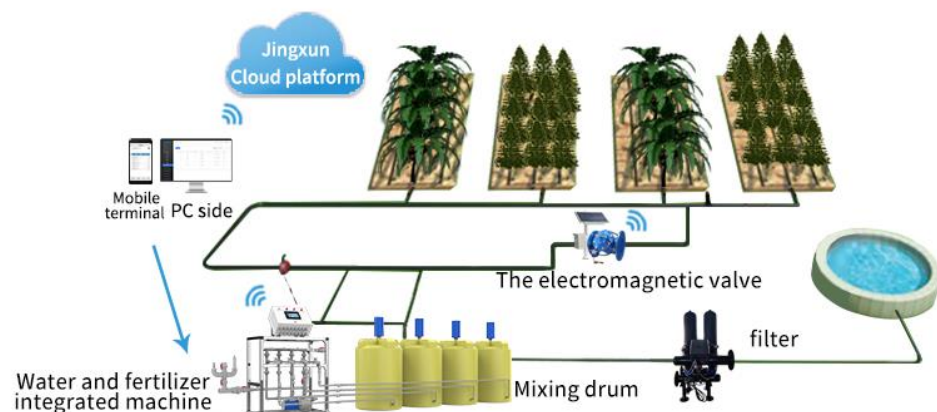


Figure 2.4 JINGXUN Fertigation Technology

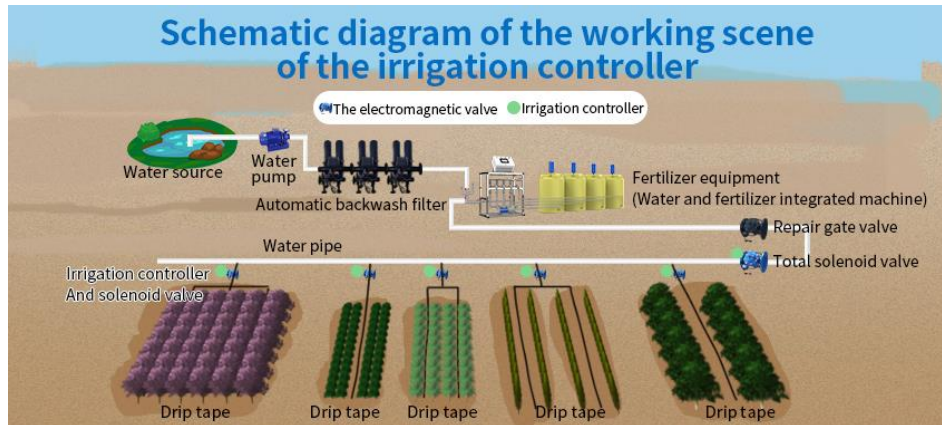


Figure 2.5 JINGXUN irrigation controller working scheme.



Figure 2.6 JINGXUN V2/V4 irrigation controller

The fertigation technology in Figure 2.4 consist of : Water and fertilizer integrated machine, fertilizer mixing tanks/drum, filter, water source/reservoir, irrigation network, electromagnetic valve and the irrigated field. Water from reservoir will be pumped and delivered to water and fertilizer integrated machines through filter, and mixed with fertilizer. The water-fertilizer mix is then supplied to the irrigation network and transmitted to the field, through the wireless electromagnetic valve. The system is connected to mobile terminal or PC and to Jingxun Cloud platform. The irrigation can be controlled remotely by activation of solenoid valves in the pipe networks (Figure 2.5), by using V2 or V4 irrigation controller (Figure 2.6) to remotely control the valves.

2.2.1.1. Characteristics

This technology has several advantages, including:

- Increased efficiency: Water and fertilizer integration technology can save up to 50% of water and fertilizer compared to traditional irrigation methods.
- Improved crop yields: By applying water and fertilizer directly to the roots of the plants, this technology can help to improve crop yields by up to 30%.
- Reduced environmental impact: Water and fertilizer integration technology can help to reduce soil erosion and water pollution by preventing the runoff of fertilizer into nearby waterways.

- Water and fertilizer integrated machines are the key to this technology. These machines come in a variety of sizes and configurations, but they all work on the same basic principle of mixing water and fertilizer together and applying them to the plants through a pressurized irrigation system..

Fertigation (Water and Fertiliser) Integrated Machine's Features:

- It has an English operating system, user-friendly interface, security password setting for convenient user authority management and system security.
 - It supports operation of the irrigation amount or irrigation time control system, and automatic control of the soil moisture sensor. It can control up to 50 irrigation solenoid valves, with 10 as the standard number.
 - It has a standard 3-way fertilizer injector, which can be expanded to 8 channels according to the user's needs. It can set EC/pH value according to fertilizer ratio or adopt standard formula (agricultural expert system) for automatic fertilization.
 - It has a real-time EC/pH value detection control and automatic correction function. It can also control the liquid supply of each supply pipe.
 - It has a real-time monitoring of changes in various input and output parameters, automatic saving for viewing various window screens, alarm event records, important parameter history records, and real-time curves.
 - It has a system failure alarm output and an extension of irrigation and fertilization technology.
 - It has a header control function of water source and an irrigation mode that allows zone circulation, timing and quantitative control, automatic adjustment of irrigation time according to different periods, and customized control software according to user requirements.

Error! Reference source not found. summarises the technical specifications of the JINGXUN Fertigation Technology.

Table 2.1 Technical Specifications of the JINGXUN Fertigation Technology

Parameter name	Parameter content
Power supply	380V (customizable)
Inlet\Water and Fertilizer Pipeline Interface	DN25/DN32
Mixing fertilizer mixing tank water interface	DN25
Fertilizer interface	DN15
Fertilizer injection flow	0 – 25 L
Maximum pressure of fertilizer injection	55 kg
Water pump	Industrial grade 304 stainless steel water pump
Screen size	154 x 85 mm / 800 x 480 px
Water volume	0.7-1.1m3/h

Irrigation Controllers (V2/V4) Features:

- A highly integrated irrigation controller is a powerful and versatile tool that can be used to manage and monitor irrigation systems in a variety of settings. It is particularly well-suited for remote or hard-to-reach areas, as it can operate for long periods of time without mains power and can communicate over long distances using LORA technology.

This type of controller offers a wide range of features, including:

- Comprehensive irrigation control: The controller can control solenoid valves, frequency converters, and other devices to automate irrigation tasks and optimize water usage.
- Advanced LORA communication: LORA is a low-power, wide-area network technology that enables the controller to communicate over long distances, even in challenging environments.
- Integrated data management: The controller can collect, process, store, and transmit data on irrigation system performance, soil moisture levels, and other environmental factors.
- Long battery life: The controller has a built-in battery with ultra-low power consumption, enabling continuous operation for 1 to 3 years without mains power.
- Remote monitoring and management: The controller can be monitored and managed remotely using a smartphone app or web interface.
- Robust design: The controller is waterproof, explosion-proof, and has strong anti-interference ability, making it suitable for use in a variety of outdoor environments.

2.2.1.2. Characteristics of Architecture of Communication

The communication between devices/machines is wireless, using LoRa and probably WiFi and wireless internet.

2.2.1.3. Performance Standards

JINGXUN Fertigation Technology is suitable for drip irrigation, sprinkler irrigation and other irrigation modes. It can be used in conjunction with irrigation controllers, irrigation frequency controllers, irrigation billing systems, etc., and is widely used in farmland irrigation, orchard irrigation, greenhouse irrigation and other scenarios.

Water and fertilizer integrated machines requires power supply of 380V, while the other devices such as electromagnetic valves and sensors can be battery-powered and/or charged by solar panel.

2.3. Smart fertigation

Smart fertigation is a technology that 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.

- a. Characteristics of the technologies
 - IoT Integration: IoT-based smart fertigation systems use sensors to collect data on soil moisture, nutrient levels, and other environmental factors. This data is then transmitted to a cloud-based platform, where it is analyzed to generate fertigation recommendations.
 - Real-time Data Collection: IoT-based smart fertigation systems collect data on soil and plant conditions in real time.
 - AI-powered Fertigation Recommendations: IoT-based smart fertigation systems use AI algorithms to generate fertigation recommendations based on the specific needs of the crop and the prevailing environmental conditions. This helps farmers to optimize water and fertilizer use and improve crop yields.
 - Cloud-Based Control: IoT-based smart fertigation systems are typically controlled through a cloud-based platform. This allows farmers to remotely monitor and manage their fertigation systems from anywhere.
- b. Characteristics of the architecture of communication
 - IoT Connectivity: IoT-based smart fertigation systems use a variety of IoT connectivity technologies, such as WiFi (Al-Ali et al., 2020; García et al., 2021), LoRa (Abu et al., 2022; Jiang et al., 2020) and cellular networks (Sahitya et al., 2022; Sanjana Pandey, 2021), to transmit sensor data to the cloud-based platform.
 - Cloud Platform: The cloud-based platform is the central component of an IoT-based smart fertigation system. It is responsible for collecting and analyzing sensor data, generating fertigation recommendations, and controlling the fertigation system.
 - Mobile App Control: Most IoT-based smart fertigation systems can be controlled through a mobile app. This allows farmers to easily monitor and manage their fertigation systems from anywhere.
 - Sensor Data Analysis: IoT-based smart fertigation systems use AI algorithms to analyze sensor data and generate fertigation recommendations. This helps farmers to optimize water and fertilizer use and improve crop yields.
- c. Performance standards (energy use, safety, and similar)
 - Energy Efficiency IoT-based smart fertigation systems are typically very energy-efficient. They use sensors and other low-power devices, and they can be configured to operate only when needed.
 - Safety and Security Protocols: IoT-based smart fertigation systems typically use a variety of safety and security protocols to protect against unauthorized access and data breaches.
 - Crop Health and Yield Optimization: IoT-based smart fertigation systems can help farmers to improve crop health and yield by optimizing water and fertilizer use. They can also help to reduce crop pests and diseases by providing early warning signs of potential problems.

2.3.1. Netafim Nutrigation Fertikit 3G

Netafim nutrigation is a term that refers to the process of applying precise amounts of water and nutrients to the plants through irrigation systems used by Netafim. Nutrigation can help growers achieve higher and better yields with less water,

fertilizer, labor and land, while reducing environmental pollution and enhancing crop quality. The Fertikit 3G Nutrigation (Figure 2.7) is a customizable unit that can inject fertilizers or acids into irrigation water. It can adapt to various combinations of injection channels, boosters, controllers, peripherals and accessories to suit different needs and limitations. Its main functions are to mix fertilizers or acids with water uniformly, to adjust the electrical conductivity and pH of the mixture, and to pre-treat the water if needed. The website of this technology provider is accessible at:

- <https://www.netafimusa.com/agriculture/digital-farming/netbeat/fertigation/product/>
- <https://www.netafimusa.com/bynder/789F15C0-456A-4A3F-AA320763C0112920-a122-fertikit3g.pdf>



Figure 2.7 Fertikit 3G Nutrigation Unit

TYPICAL INSTALLATION OVERVIEW

The drawing represents the infrastructure suitable for a FertiKit 3G.

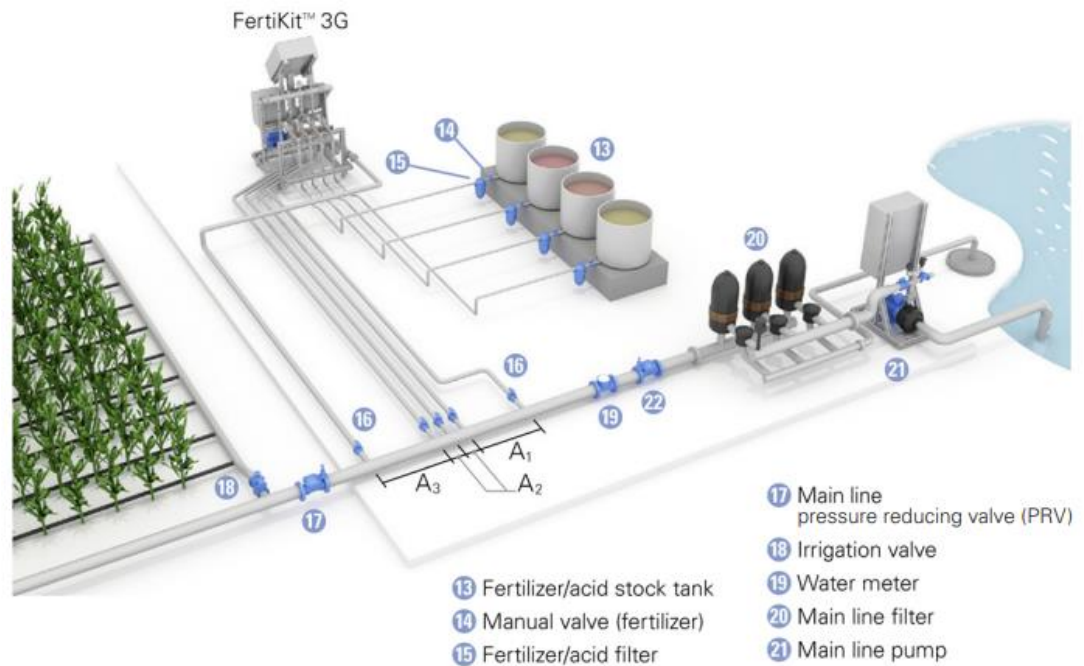


Figure 2.8 Typical installation of Fertikit 3G

As shown in Figure 2.8 Fertikit 3G is connected to water source and fertilizer tanks. Water from the source is mixed with proper dosage of nutrient/fertiliser and delivered to the field by drip/sprinkler irrigation emmitter. Fertikit 3G can be combined with Grow Sphere to enhance the system to Smart Fertigation system.

Grow Sphere™ (Figure 2.9) is Netafim’s operating system for precision irrigation and fertigation. It simplifies, optimizes, and reduces the resources needed for irrigation and fertigation. It also improves crop quality and yield. It works with sensors, controllers, cloud platform, app, and crop models. It can fit any level of irrigation automation.

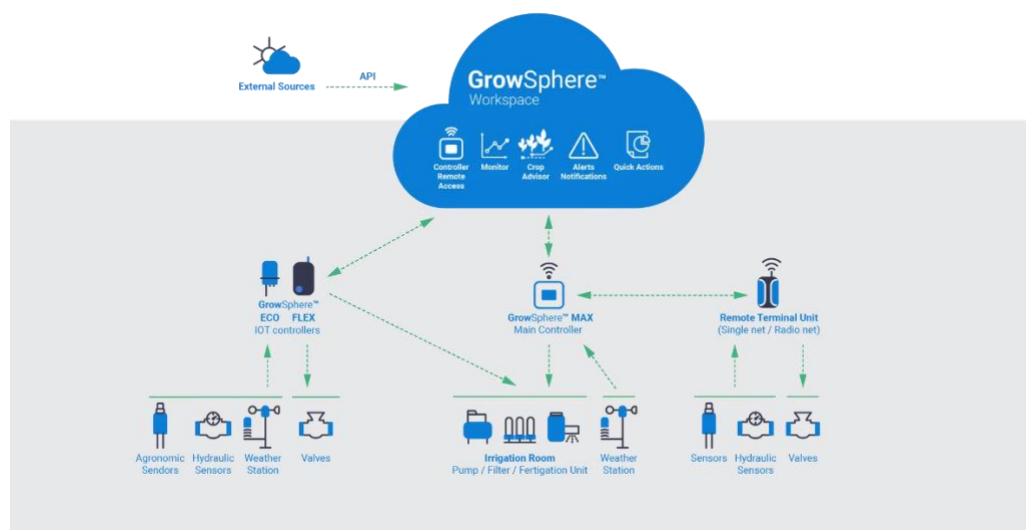


Figure 2.9 Growsphere workspace

2.3.1.1. Characteristics

The FertiKit 3G is a modular system that can precisely inject water and nutrients into plants through irrigation systems, such as drip or sprinkler. It is suitable for both soil and substrate applications and offers the following features and benefits:

- Efficient use of water, fertilizers, and energy
- Wide range of irrigation water capacities
- Quantitative or proportional nutrient injection
- Venturi operation without moving parts
- Easy installation and maintenance in existing irrigation systems
- Quick and accurate nutrient recipes based on dosing channels
- High-quality components and materials, including PVC NPT Schedule 80, aluminum, and corrosion-resistant frame and legs
- Pre-assembled with NMC Pro Controller and NMC Air for remote control and monitoring
- Integration with various accessories and peripherals for enhanced functionality
- Proven performance in all environmental conditions

2.3.1.2. Characteristics of Architecture of Communication

The communication architecture of the FertiKit 3G consists of the following components:

- **NMC Pro Controller:** This is the main controller of the FertiKit 3G, which manages the operation modes, dosing channels, sensors, and peripherals. It has a user-friendly interface with a touch screen and multilingual support. It can communicate with external devices via RS485, Ethernet, or Wi-Fi.
- **NMC Air:** This is a wireless communication device that connects the NMC Pro Controller to the cloud platform. It can transmit data and receive commands from the cloud platform via cellular network or Wi-Fi.
- **Cloud Platform:** This is a web-based platform that stores and analyzes the data from the FertiKit 3G and other sensors. It also allows users to access and control the FertiKit 3G from any device, such as a computer, tablet, or smartphone. It can also send alerts and notifications to users via email or SMS.
- **Grow Sphere Workspace:** This is an application that runs on the cloud platform and provides users with a comprehensive dashboard to manage their irrigation and fertigation activities. It can also integrate with Grow Sphere Crop Advisor, which provides real-time data and insights on crop health, water quality, and resource usage. It can also optimize the irrigation and fertigation schedules and programs based on crop needs and environmental conditions.

2.3.1.3. Performance Standards

The FertiKit 3G is a modular fertigation system that is designed to be energy-efficient. The FertiKit 3G uses a venturi principle to inject water and nutrients into plant without any moving parts, which reduces energy consumption. Additionally, the FertiKit 3G is equipped with a variable frequency drive (VFD), which allows it to adjust its speed to match the flow of water in the irrigation system. This further reduces energy consumption.

Safety. The FertiKit 3G is equipped with a variety of safety features to protect users and the environment. These safety features include:

- **Pressure sensors:** Pressure sensors monitor the water pressure in the irrigation system and shut off the system if the pressure exceeds a certain threshold. This helps to prevent leaks and bursts.
- **Safety switches:** Safety switches shut off the irrigation system if a problem is detected, such as a power outage or a clogged nozzle. This helps to prevent accidents and damage to the irrigation system.
- **Backflow preventers:** Backflow preventers prevent water from flowing back into the water supply. This helps to protect the water supply from contamination.

2.3.2. JAIN Irrigation

Drip irrigation system and constant rate nutrient doses application are based for this technology. The website of this technology is accessible at:

- <https://peeyesassociates.com/jain.pdf>

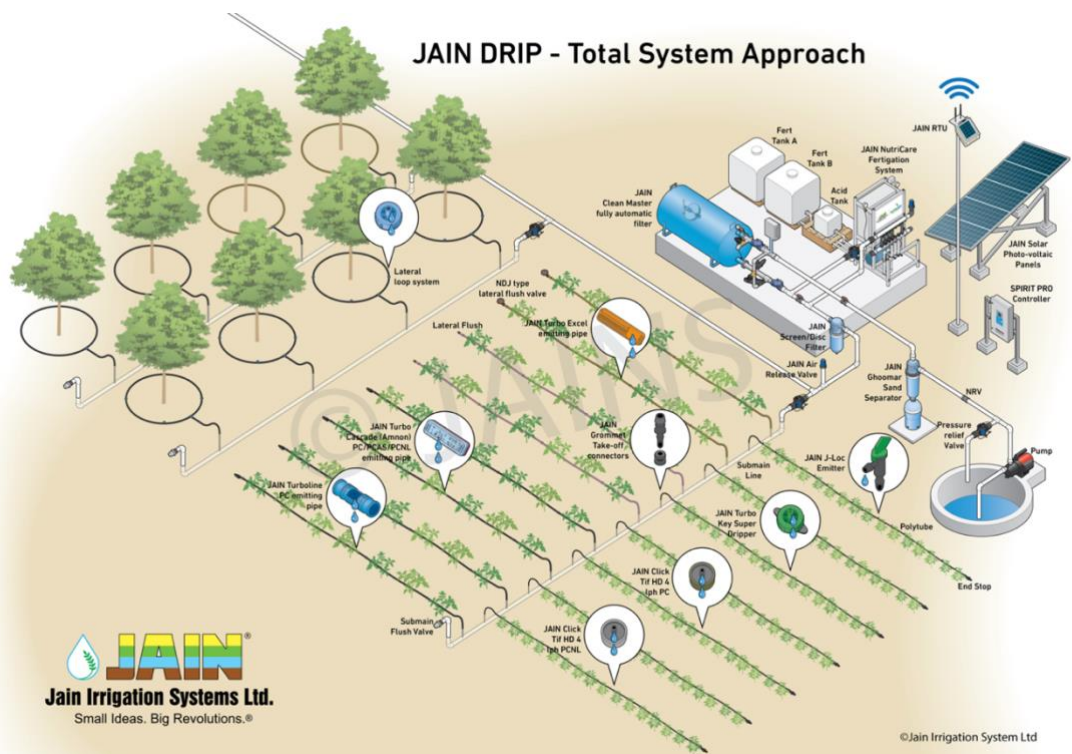


Figure 2.10 JAIN Irrigation Total Approach

Jain Drip Irrigation Total Approach (Figure 2.10) integrates components that Drawing up an automated fertigation system which are: drip/sprinkler irrigation network, irrigation pumps, water source, clean water tank, fertilizer tanks, fertigation mixer, smart IoT controller, sensors and solar power supply. The systems components are interconnected wirelessly, and the Remote Terminal Unit (RTU) connects to central computer by wireless internet connection.

2.3.2.1. Characteristics

- Water saving solution: The system uses artificial intelligence and predictive analytics to control irrigation and fertilization, which can help farmers to save water.
- Real-time data processing: The system processes over a billion pieces of information hourly on how soil moisture responds to rain or irrigation events based on the different plant factors, soil types, weather and environmental conditions at the site-specific location. This allows the system to make informed decisions about irrigation and fertilization in real time.
- Automated irrigation and fertilization: The system connects to irrigation control that automatically acts upon the algorithm to implement the best strategies for minimizing water usage and managing nutrient loss.
- Comprehensive data collection: The system measures evapotranspiration and other environmental calculations from multiple sources to provide the most thorough information for its algorithms. This ensures that the system is making decisions based on the most accurate and up-to-date data possible.
- Remote monitoring and control: The system sends out a watering schedule to all models of existing ET water smart controllers and other units in the field over a secure cellular wireless network. This allows farmers to remotely monitor and control their irrigation system, even when they are not on-site.
- Extensibility: The system is designed to be extensible, allowing farmers to easily integrate new data sources and technologies as they become available.
- Customization and support: The system is totally customized to meet the specific needs of each farm. Jain also provides training and after-sales services to farmers to help them get the most out of their system.

2.3.2.2. Characteristics of Architecture of Communication

The communication architecture of Jain irrigation is a system that uses artificial intelligence and predictive analytics to control irrigation and fertilization based on various factors, such as soil moisture, weather, crop type, and environmental conditions. It consists of five parts: IoT nodes, local gateways, main gateway, cloud server, and application. The communication type and characteristic of Jain irrigation are as follows:

- The communication type is wireless, using cellular network and radio frequency .
- The communication characteristic is bidirectional, allowing data transmission and command reception between the cloud server and the irrigation control .

- The communication characteristic is secure, using encryption and authentication methods to protect the data and commands from unauthorized access.
- The communication characteristic is reliable, using error detection and correction methods to ensure the data and commands are delivered correctly.
- The communication characteristic is scalable, allowing the system to accommodate more data sources and irrigation units as needed .

2.3.2.3. Performance Standards

Energy Use: Jain irrigation systems are designed to be energy-efficient by incorporating technologies like variable frequency drives and high-efficiency pumps to reduce energy consumption.

Safety: Jain irrigation systems prioritize safety for users and the environment through features such as pressure sensors and safety switches.

Water Conservation: Jain irrigation systems are designed to conserve water by delivering it directly to the roots of plants and minimizing evaporation.

Uniformity of Application: Jain irrigation systems aim for even water and fertilizer distribution to improve crop yields and reduce environmental impact.

Reliability: Jain irrigation systems are designed to be reliable and durable, using high-quality materials and offering comprehensive warranties..

- **Specific Performance Standards:**
 - Drip irrigation systems achieve water savings of up to 70% and can improve crop yields by up to 20%.
 - Sprinkler irrigation systems achieve water savings of up to 50% and can improve crop yields by up to 15%.
 - Micro-irrigation systems achieve water savings of up to 80% and can improve crop yields by up to 25%.
- **Safety Features:**
 - Pressure sensors monitor water pressure and can shut off the system to prevent leaks and bursts.
 - Safety switches shut off the system in case of issues like power outages or clogged nozzles to prevent accidents and damage.
- Backflow preventers protect the water supply from contamination.

3. References

- Abu, N. S., Bukhari, W. M., Ong, C. H., Sukhaimie, M. N., Wibowo, S., & Kassim, A. M. (2022). Automated Agricultural Management Systems Using Smart-Based Technology. *International Journal of Emerging Technology and Advanced Engineering*, 12(5). https://doi.org/10.46338/ijetae0522_14
- Al-Ali, A. R., Nabulsi, A. Al, Mukhopadhyay, S., Awal, M. S., Fernandes, S., & Ailabouni, K. (2020). IoT-solar energy powered smart farm irrigation system. *Journal of Electronic Science and Technology*, 30(40). <https://doi.org/10.1016/J.JNLEST.2020.100017>
- Allen, R. G., Amsler, J., Bagarello, V., Ramos, A. B., Chisci, G., Depeweg, H., Wrachien, D. De, Dongen, M. W. van, Cortes, C. F., Ferro, V., Greppi, M., Hes, M. B. A., Hoogeveen, A., Jaarsma, C. F., Juan, J. A. de, Serra, A. L., Olalla, F. M. de S., Beltran, J. M., Preti, F., ... Wolleswinkel, A. P. (1999). *CIGR Handbook of Agricultural Engineering Volume I* (H. N. van Lier, L. S. Pereira, & F. R. Steiner (Eds.)). the American Society of Agricultural Engineers.
- Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability*, 2(2), 95–96. <https://doi.org/10.1007/s42398-019-00078-w>
- Brouwer, C., Prins, K., Kay, M., & Heibloem, M. (19985). *Irrigation Water Management: Irrigation Methods*. Food and Agriculture Organization (FAO). <https://www.fao.org/3/s8684E/s8684e00.htm#Contents>
- García, L., Parra, L., Jimenez, J. M., Parra, M., Lloret, J., Mauri, P. V., & Lorenz, P. (2021). Deployment strategies of soil monitoring wsn for precision agriculture irrigation scheduling in rural areas. *Sensors*, 21(5), 1-3García, L., Parra, L., Jimenez, J. M., Parra, M. <https://doi.org/10.3390/s21051693>
- Jiang, P., Xia, H., He, Z., & Wang, Z. (2020). Design of a water and fertilizer control system based on LoRa wireless communication technology. *Computers and Electronics in Agriculture*, 169, 105207. <https://doi.org/10.1016/j.compag.2020.105207>
- Kusumawardani, M., Sarosa, M., & Hapsari, R. I. (2020). Penggunaan Irigasi Tetes Pada Kebun Jeruk Berbasis Internet of Things (Iot). *Seminar Nasional Penelitian Dan Pengabdian Masyarakat*.
- Phocaides, A. (2007). *HANDBOOK ON PRESSURIZED IRRIGATION TECHNIQUES*. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.
- Prabha, R., Sinitambirivoutin, E., Passelaigue, F., & Ramesh, M. V. (2018). Design and Development of an IoT Based Smart Irrigation and Fertilization System for Chilli Farming. *2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 1–7. <https://doi.org/10.1109/WiSPNET.2018.8538568>
- Ramani, J. G., LakshmiPriya, A., Madhusudan, S., Kishore, P. J. R., Madhisha, M., & Preethi, U. (2020). Solar Powered Automatic Irrigation Monitoring System. *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 293–297. <https://doi.org/10.1109/ICACCS48705.2020.9074220>
- Rosma, I. H., Sukma, D. Y., & Solihin, I. M. (2021). Otomatisasi Sistem Fertigasi Tetes untuk Tanaman Berbasis Mikrokontroler. *Jurnal Teknik Elektro*, 13(1), 34–41. <https://doi.org/10.15294/jte.v13i1.31123>

Sahitya, G., Krishnasree, V., & Kaushik, C. (2022). Review on Various Approaches of Automatic Drip Irrigation Systems for smart Agriculture. *Journal of Electronics and Informatics*, 3(4). <https://doi.org/10.36548/10.36548/jei.2021.4.002>

Sanjana Pandey, B. (2021). IoT Based Smart Irrigation System Using Soil Moisture Sensor and Esp8266Nodemcu. *International Journal of Computer Science and Information Technology Research*, 9(2).

Singh, D., & Thakur, A. (2018). Designing of Smart Drip Irrigation System for Remote hilly Areas. *2018 Fifth International Conference on Parallel, Distributed and Grid Computing (PDGC)*, 90–94. <https://doi.org/10.1109/PDGC.2018.8745934>

STANDAR PERENCANAAN IRIGASI KP-09 IRIGASI TERAPAN (Draft). (2023). KEMENTERIAN PEKERJAAN UMUM DAN PERUMAHAN RAKYAT DIREKTORAT JENDERAL SUMBER DAYA AIR.

SV-IPB Bersama Netafim Indonesia Kenalkan Teknologi Terkini Green House dan Irigasi Presisi yang Tersistemasi - Sekolah Vokasi IPB. (n.d.). Retrieved October 15, 2023, from <https://sv.ipb.ac.id/2022/05/30/sv-ipb-bersama-netafim-indonesia-kenalkan-teknologi-terkini-green-house-dan-irigasi-presisi-yang-tersistemasi/>