SUN SpACE

Co-funded by the Erasmus+ Programme of the European Union

SUstainable developmeNT Smart Agriculture Capacity
« SUNSpace »

Project Reference No	598748-EPP-1-2018-1-FR-EPPKA2-CBHE-JP (2018-3228/001-001)
Nature	Internal report
Dissemination Level	Restricted
Date	25 January 2022
Review date	November 2022
Status	Closed
Editor(s)	KEC
Document Description	The purpose of this document is to develop WP2/T2.4 “Guideline (meta-model) for Working Condition Pilot”. This document presents the background on the pilots including vegetable production in green house, fish production, and soil nutrients and agro health; and process of Smart Labs and Agro-Health Lab implementation. The process of the installation of equipment, selection of farmers for training, conduction of trainings, KPIs, collaborator with KEC and AEC in the implementation of the project taking account to the sustainability of the smart labs are included in the document.

1 Contents

1 Working Condition Pilot (Nepal: KEC and AEC)

The working condition pilot is focused on the automation of smart green house for seasonal vegetable production, fish production, soil nutrient measurement and Agro-Health (pesticides residue, sugar content of fruits, pulp hardness of fruits).

The pilot sites are located in Kantipur Engineering College, Dhapakhel, Lalitpur and in Acme Engineering College, Sitapaila, Kathmandu. KEC Pilot consists of smart green house and Agro-Health Laboratory. The pilot in KEC focuses on the quality improvement of fruits and vegetables (tomatoes, beans and cucumber) by reducing the use of chemical and pesticides in the farms and optimal use of fertilizers. AEC pilot consists of smart green house and automated fish pond. The pilot in AEC focuses on addressing the skill of farmers in automation in their farms including the automation in aeration of fish pond.

The main objective of this pilot is to make local farmers aware of the use and benefit of new technologies and ICT in farming. The pilot also aims to train farmers by developing training materials and tools as per their need. The farmers shall learn to adopt improved and smart farming practice with lower cost of production by optimum use of resources, generating better income, and taking care of the human health and the environment.

Presently, most of the farmers of Nepal are not familiar with the application and benefits of ICT in farming. Therefore, this pilot will be one important contribution towards the use of ICT in improving the life standard of the farmers in Nepal.

1.1 Situation Analysis in Nepal

Nepal is a geographically diversified country, ranging from mountains, hills to the plane region. Due to the varying climatic condition, each has its own nature of farming. With conduction of survey from the farmers of hilly and plain reason, it is found that maximum of farming is based on traditional style using locally available fertilizers like cow dung and the limited amount of pesticides. Most of them have rely on rainwater for irrigation, which is unpredictable.

Chemicals used to kill unwanted plants, insects and animals in agriculture and household are called pesticides. However, majority of the pesticides kill untargeted organisms along with the targeted ones. The main pesticides used are herbicides for killing weeds; insecticides for killing insects; fungicides for destroying fungi; and rodenticides for killing rodents. Use of pesticides without proper knowledge about their types, level of poisoning, safety precautions and potential hazards to the health and environment has led to their excessive use harming the health of the farmers, farm workers, consumers and the environment. Using pesticides in excessively, also without proper safety gears and random disposal of the pesticide containers is responsible for growing number of health complications including cancers, tumour, kidney diseases, hypertension, mental illness, etc. Similarly, most of the farmers are unaware of the soil condition in their farm, resulting in low productivity of crops with undesired quality. On the other hand, the increase in awareness among the consumers regarding the food safety and quality, the demand for agricultural product without pesticide residue and better quality is increasing. But, the laboratories (both in public and private sectors) for determining food

quality and safety levels in Nepal are limited and many of them are non-functional. Many youths returned from gulf countries, Europe, USA, Israel, etc., are willing to implement smart farming practice in Nepal but the technology and equipment needed in agriculture has to be imported and are also very expensive.
The same situation is in fish farming as well. In this case, in the fish pond, when oxygen level gets low fish start to dye and the farmers are unaware of the condition. The problem of middleman also persists in this farming.

Therefore, Kantipur Engineering College and Acme Engineering College, with the support of Erasmus+ SUNSpaCe project is in the direction to work with the farmers in Nepal and make them aware about the chemicals and pesticides they use in their farm, automation in farms, automation in fish pond and make farmers aware of smart farming practices and its benefits.
The colleges will also develop themselves as a training centre for the farmers willing to adopt smart and safe farming practices.

1.2 Use Case Building

During the initial phase of the project, several farms and farmers in Kathmandu, Dhading, Lamjung, Kritipur, Bhaktapur, Lalitpur and Chitwan were visited and their interest in smart farming and use of technology was accessed and surveyed. It was found that many of the farmers interested in smart farming belonged to vegetable and fruit farming groups. Vegetable Crop Development Centre, a governmental organisation in Kumaltar, Lalitpur, Nepal already has a list of more than 10 thousand farmers and has been a link for us to communicate with the farmers.

Many farmers in Nepal follow traditional farming with almost no use of technology and lack basic ideas regarding the adverse effect of excess uses of pesticides and fertilizers in their crop. The lack of knowledge regarding the use of such chemicals has put the health of consumers as well as themselves in jeopardy also causing environmental pollution. Thus, we have selected Smart Greenhouse, Fish Production, and Agro-Health (Soil Nutrient & Pesticides Testing Laboratory) as a use case to attract farmers towards smart farming and make them aware about the adverse effect of the chemicals they use in their farms.

1.3 Objective of the Working Condition Pilot

- To build the capacity of academicians, researchers, farmers of the vicinity of Katmandu Valley in smart farming technologies to increase the vegetable production, fish production and soil nutrients measurement.
- To create awareness in the use of IoT in farming and farm management.
- To encourage farmers to adopt smart farming practices for resource optimization and by passing middle men to sell their agriculture produce.

1.4 Expected outcome of the pilot

- Develop the capacity of 20 smart farmers, 12 academicians and researchers, for the use of smart technology in farming in Nepal. The smart farmers and academician trained in the first phase shall train 100 farmers in Nepal.
- Conduct four hybrid type trainings: First Phase- Training of the trainers; Second and Third Phase- Training of the farmers, and the Forth Phase is for the cross pilot training. The materials developed by the consortium with four modules (digital agriculture, smart farming, standardization and agro-business) was used as a teaching material.
- Enhance the capacity of farmers towards the use of smart farming practice in their farms.
- Promote awareness regarding agro health and food quality.
- Motivate students in engineering to work for the up gradation of agriculture in Nepal.

1.5 *Expected impact of the pilot*

- Optimization in the use of resources as energy, water, fertilizers and pesticides in farming by the use of sensors and system of automation.
- Need of fewer manpower in farming by the use of automation in farms resulting in better income for better living standard.
- Promote smart and safe farming practice among the youths in Nepal.
- Increase the growth of seasonal vegetable in controlled environment (greenhouse) and fish in the fish pond.
- Removal middle man from the business chain and increase the profit from marketing.

1.6 *Description of Smart Lab*

1.6.1 Process of installation of smart lab

Two smart greenhouse are constructed in Kantipur Engineering College and Acme Engineering College; one automated model fish pond is installed in Acme Engineering College; and one Agro-Health lab is installed in Kantipur Engineering College. Green house is installed for vegetable production and as a demo site for training farmers to use the smart technology in Nepal. Weather stations are installed in Kantipur Engineering College and Acme Engineering College for weather information. Agro-Health lab at Kantipur Engineering College is to train farmers to determine soil nutrient parameters, Brix measurement of fruits, pulp hardness of fruit, and to determine the pesticide residue in fruits and vegetables. The automated fish pond installed at Acme Engineering College is to demonstrate and train farmers to use automation in aeration in pond for better fish production.

Table 1: List of Sensors and Equipment in Smart Green House (2 Sets)

Equipment	Description
Weather Station	To monitor outdoor parameters • Air temperature • Relative humidity • Rainfall • Wind speed and direction

	• UV light index To monitor indoor parameters • Air temperature • Relative humidity
Sensors in Green House for air parameters	To monitor • Indoor air temperature • Relative air humidity • CO2 concentration (indoor and outdoor) • UV index
Sensors in Green house for soil parameters	To monitor • Soil temperature • Soil moisture • Soil pH • Soil EC
Equipment	• Farm Control Unit • Water pumps • Exhaust Fan • Heater • Lights • Sprinkler system • Drip irrigation system • Misting system

Table 2: List of Sensor and Equipment in Fish Pond

Equipment	**Description**
Water Sensor	To monitor • Oxygen Concentration • Water Temperature

Table 3: List of Equipment at Agro-Health Lab

Equipment	**Description**
UV-Vis Double Beam Spectrophotometer	To determine the pesticide and other chemicals residue in fruits and vegetables
Soil Nutrient Parameter Kit	To determine 14 soil nutrients parameter (N, K, P, S. Zn, S, etc.), soil pH and soil EC
Fruit Durometer	To determine the pulp hardness of fruit to know the exact harvest time.
Fruit Refractomer	To determine the sugar content of fruits (Degree Brix)
NPK Sensor	To determine soil N, P and K directly using sensors

Table 4: List of Equipment in the Training Center

Equipment	**Description**
Training Set	For training 100 farmers • Multimedia

	• Computers • Server

The data collected from the installed sensors in the farm is stored in the cloud. The users can access the data through mobile applications as well as through web. The data collected is analysed for temperature automation, drip irrigation automation, sprinkler automation, mist automation, light automation, etc.

1.6.2 Implementation of Smart Lab

A. Smart Green House

The smart green house is installed to grow crops in controlled environment and to develop it as a demonstration site to train farmers and students willing to learn automation in farms.

Figure1: Greenhouses installed in KEC and AEC premises

Dimension of the green house: 2.5 m (height) x 6 m (length) x 6 m (breadth)
Type: Naturally ventilated poly house

The sensors of Smart Green House senses and send the data to smart lab where smart lab controls the parameters in greenhouse as the following picture.

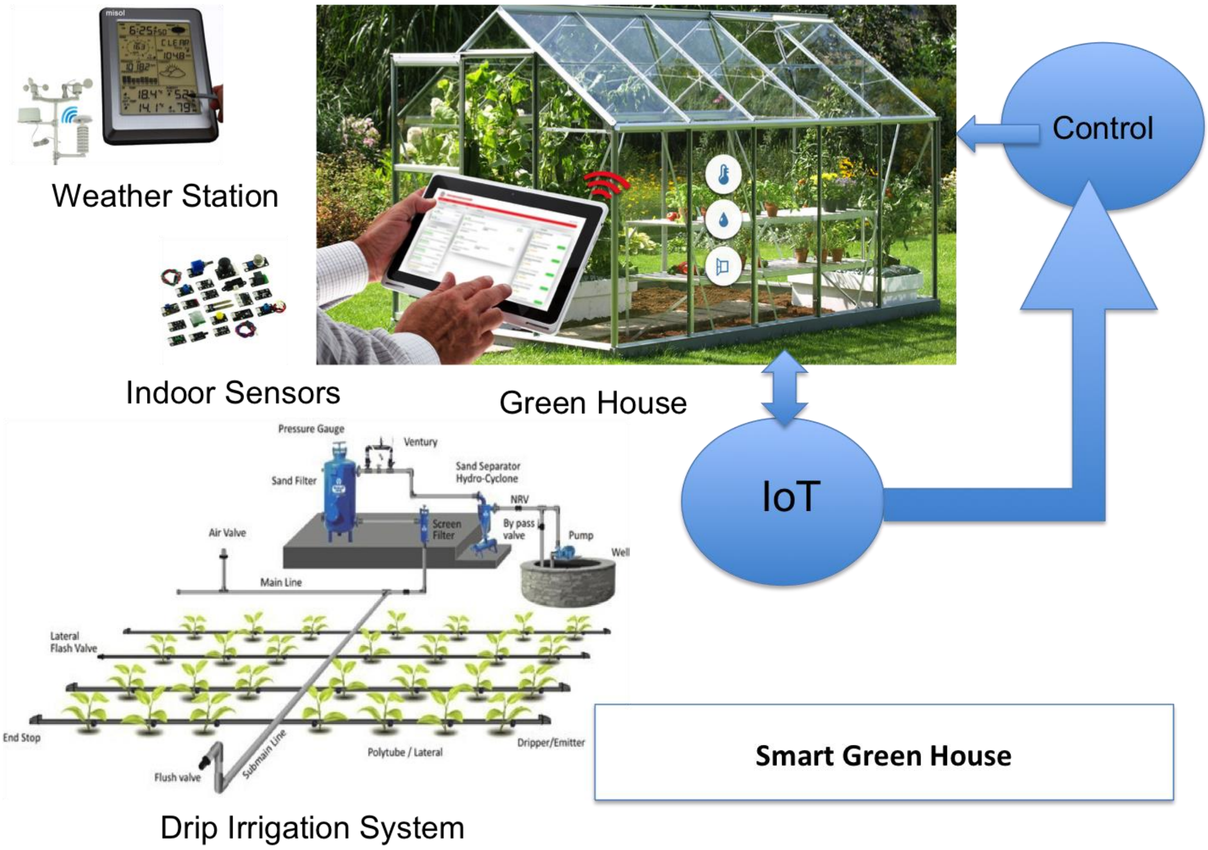


Figure 2: Overall architecture of system implementation in Green House

Figure 3: Weather Station and its Display

A. Greenhouse Automation System

Technologies have almost reached everywhere, be it in the technical fields or the agricultural fields. One of the specified sectors where this technology has created great impact is Greenhouse, as we call it. Modern technologies are used to monitor certain environmental conditions which is a must to ensure optimum growth of plants in the greenhouse, enhanced crop productivity along with proper utilization of water and other resources.

These conditions variables must be well defined and the data regarding soil conditions, and climatic condition parameters that affect the plant development, must be carefully collected through automated processes. Doing so makes it possible to obtain a large number of data at high frequency with a smaller number of human assistances involved. Though the Display and Cloud based systems (Internet and mobile app) are proven suitable to keep the user updates with the greenhouse status, multiple factors make it not worth of investments we make. These factors include high prices, bulky size, maintenance issues and useless to unskilled workers.

The only focus of this project is to develop such a system/device which is structure-wise much simpler yet easy to install and cheaper. Thus, this project has employed easily available component like microcontroller and microprocessor as its chief element that is used to monitor and collect the varying greenhouse details such as: temperature and humidity recordings, measure of soil moisture, temperature, humidity and electrical conductivity, reading pressure, CO_2 and pressure etc., at different instants of time. Doing so will obviously assist in maintaining the green house and promote the productivity.

The reason why the use of microcontroller in this project is much appreciated is also because of its low power consumption and reasonable cost besides easy availability. The fact that microcontroller works through a real-time phenomenon adds extra pile to its benefit. It interacts with multiple sensors associated with the project in a real-time basis and keeps control of lighting, aeration and drainage functions accordingly as per the requirement of the crops by triggering corresponding devices which can be: a cooler, fogger, dripper and lights etc. Since this project keeps track of real-time data, use of an integrated Liquid Crystal Display (LCD) is not an exception. LCD displays those collected data and forwards the data to a cloud over internet process. There, a complete process of data logging maintenance occurs. Software can be updated in regular time interval which further extends the flexibility of this project to meet the user requirements.

All this feature combined as a whole produces an easy, cost effective, portable and easy maintenance alternative for greenhouse applications, beneficial for small scale agriculture sectors in remote areas.

i. Working of Greenhouse Automation System

We are using a basic embedded system that keeps record of certain parameters of the greenhouse, mostly climatic parameters and continuously monitors those specifications at regular intervals. The idea not only enhances the greenhouse cultivation process and productivity, but it also reduces the human effort invested and prevailing issues to a greater extent. In this project, simple components like sensors, microcontroller, ADC (Analog to Digital Converter), actuators are employed which makes it more cost-effective.

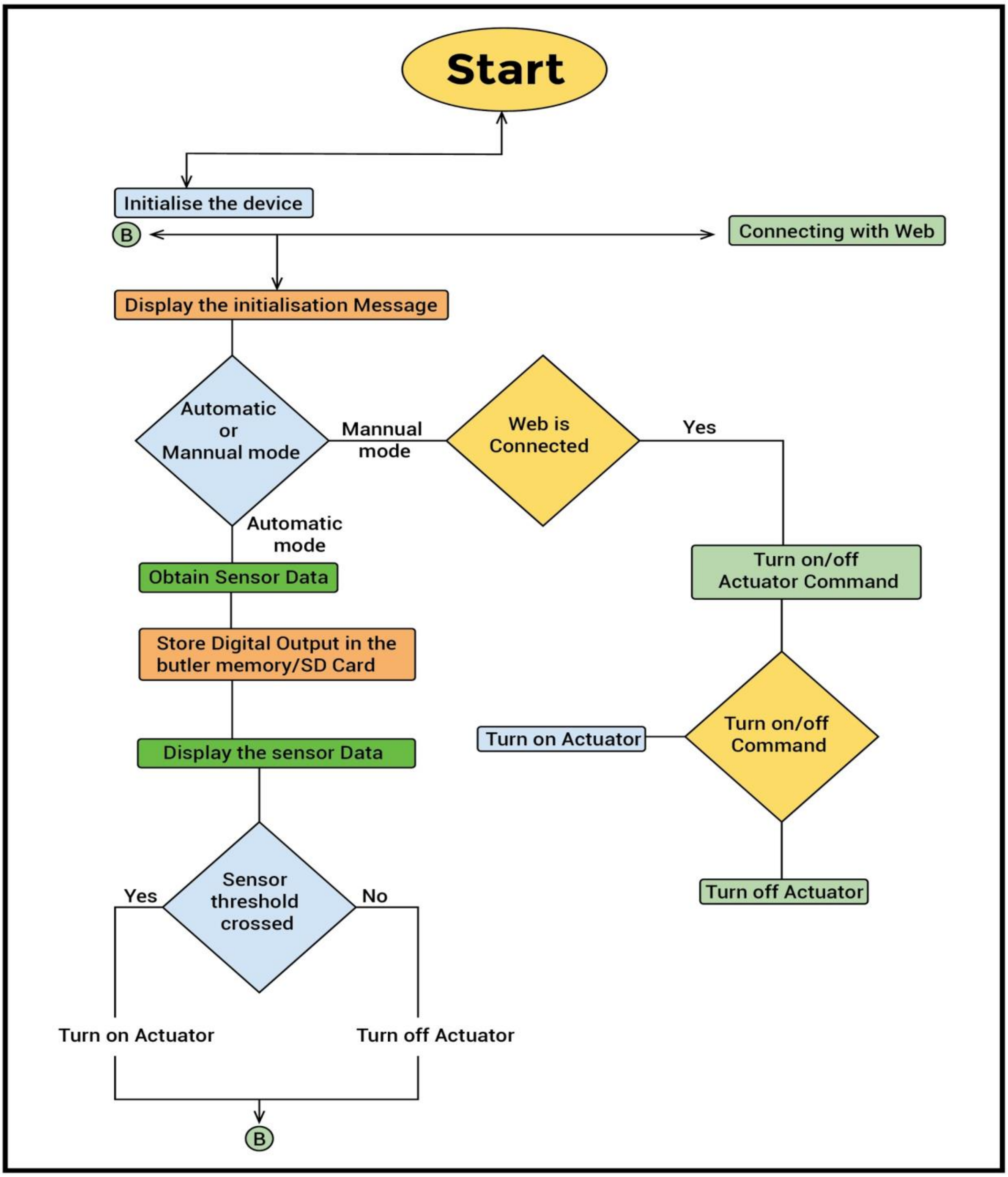


Figure 4: Flow diagram of Greenhouse

At ordinary conditions, the system remains active monitoring the climatic and soil condition, as soon as the sensor fitted at several spots start detecting variation in the continuously monitored factors like changes in temperature, the project compares it with the threshold value set in the program and takes necessary actions. In technical words, when sensor detects changes, the microcontroller gets activated and it reads data collected from sensor at its input terminal. By then, the ADC already converts the analog data into presentable digital form. As per the requirement, microcontroller triggers corresponding relays to settle the environmental conditions and those parameters reach the best possible state.

The use of microcontroller, LCD display and continuous data logging process makes this project more cost-effective and user-friendly at the same time. Hence, this project completely eradicates the necessity of setting-up the environmental conditions through effort and offers flexible system.

Circuit Description of Greenhouse Automation System

The Circuit diagram of control unit of automated green House is shown in figure 1. Here we described each section separately as given below.

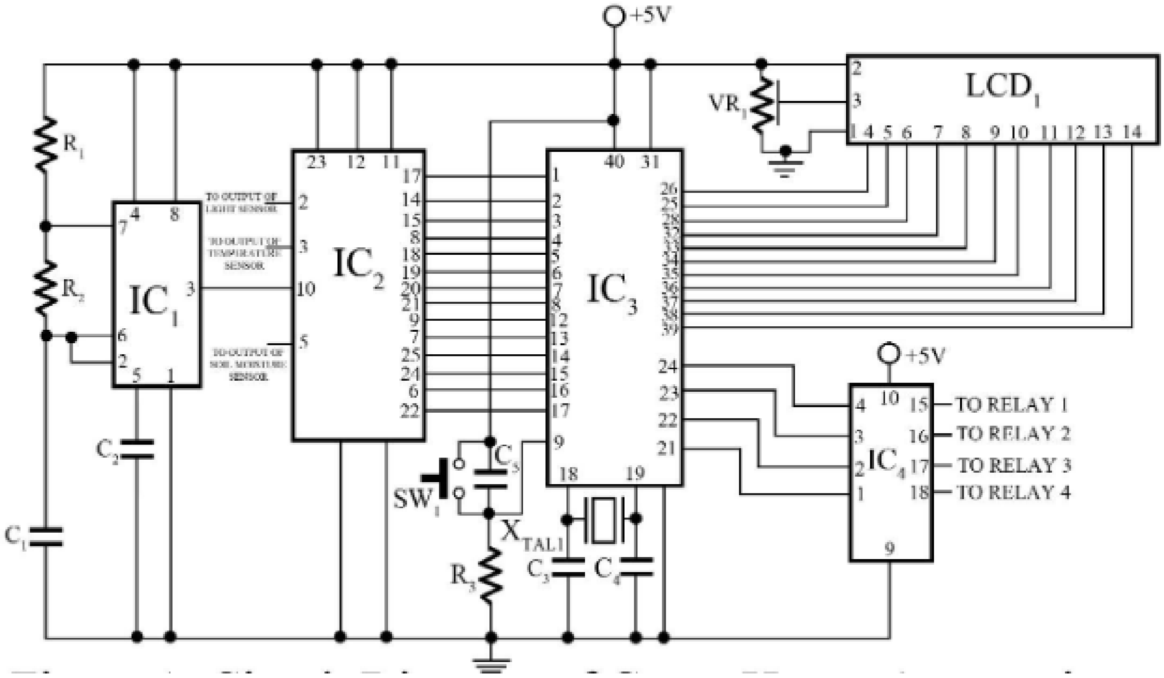


Figure 5: Circuit Diagram of Greenhouse Automation

ii. Transducers (Data acquisition system)

In this section, different sensors are used to measure the soil moisture, humidity, temperature and light intensity. And, then the sensed data is transferred to ADC for conversion.

a. Functional description of Soil temperature, humidity and EC sensor:

EC10 soil conductivity sensor performance stability and high sensitivity, is to observe and study the occurrence of salt soil, evolution, improvement and water and salt dynamic important tool. It is suitable for soil moisture monitoring, scientific experiment, and water saving irrigation, greenhouse, flower and vegetable, grassland pasture, soil speed measurement, plant culture, sewage treatment, fine agriculture and so on. The sensor has the following characteristics:

1. can directly measure soil, water and fertilizer solution, as well as other nutrients and substrate conductivity.
2. electrode with special treatment of alloy materials, can withstand a strong external impact, easy to damage.
3. completely sealed, acid and alkali corrosion, can be buried in the soil or directly into the water for long-term dynamic detection.
4. high precision, fast response, good interchangeability, probe plug-in design to ensure accurate measurement, reliable performance.
5. perfect protection circuit with a variety of signal output interface optional.

Case 1: Dry condition- In this case, two copper probes are dipped into the dry soil up to a fair depth. In absence of path for conduction in between the copper leads, the sensor circuit is not complete and hence 0 to 0.5 V is obtained as output.
Case 2: Optimum condition- In this case, soil is wet to some extent. As soil absorbs the water, it penetrates into the successive layers of the soil and due to the existing capillary force; it gradually spreads across the soil layer. As a result, the soil moisture increases and increases the conductivity strength of soil that establishes the conductive path between the probes. And, thus current starts flowing in between supply and transistor through the path just constructed. In such a case, the voltage detected at the emitter output of transistor is found to be in the range of 1.9V to 3.4V nearly.
Case 3: Excess water condition- it is that situation when water content in the soil exceeds the optimum level. In that case, there is an extreme increment in the conductivity property due to excess water. Because of which, a steady conduction path is formed in between the probes of sensors and after a certain limit, output voltage is saturated to a constant value. The maximum output is found to be 4.2V.
Temperature Functional description:
For accuracy and precision, we measure temperature and humidity using one dedicated industrial grade temperature and humidity sensor and two other secondary sensors (SCD30 and BMP280). SCD30 is 3-in-1 sensor that can measure CO2, temperature, and humidity. Similarly, BMP280 is also 3-in-1 sensor that can measure environment pressure, temperature and humidity.
Grove - AHT20 I2C Industrial Grade Temperature and Humidity Sensor
Grove AHT20 Temperature and Humidity sensor is based on AHT20, compared with Grove - Temperature & Humidity Sensor Pro (AM2302/DHT22), AHT20 is a new generation of temperature and humidity sensor embedded with a dual-row flat and no-lead SMD package, suitable for the reflow soldering. AHT20 is equipped with a newly designed ASIC chip: an improved MEMS semiconductor capacitive humidity sensor, and a standard on-chip temperature sensor. The output is I2C protocol with the Grove interface. The performance of AHT20 is more stable in harsh environments compared with the previous generation of temperature and humidity sensor, as a matter of fact, AHT20 is fit able in most industrial scenarios.
Specification
Operating Voltage: DC: 2.0-5.5V
Measuring Range (humidity) 0 ~ 100% RH
Temperature Range: -40 ~ + 85 ℃
Humidity Accuracy: ± 2% RH (25 ℃)
Temperature Accuracy ± 0.3 ℃
Resolution: Temperature: 0.01 ℃,
Humidity: 0.024% RH
Output Interface: Grove I^2C Interface
I2C address: 0x38
Digital Light Sensor (TSL2561 Grove)
This module is based on the I2C light-to-digital converter TSL2561 to transform light intensity to a digital signal and can be used to measure the change in light intensity for various applications. The TSL2561 is controlled and monitored by sixteen registers (three are reserved) and a command register accessed through the serial interface. These registers provide for a

variety of control functions and can be read to determine the results of the ADC conversions. Different from the traditional analog light sensor, as Grove - Light Sensor, this digital module features a selectable light spectrum range due to its dual light-sensitive diodes: infrared and full spectrum.

It can switch between three detection modes to take readings. They are infrared mode, full-spectrum, and human visible mode. With its high-resolution and wide operating temperature range, it can be used to measure the change in light intensity in various light situations with many popular microcontrollers.

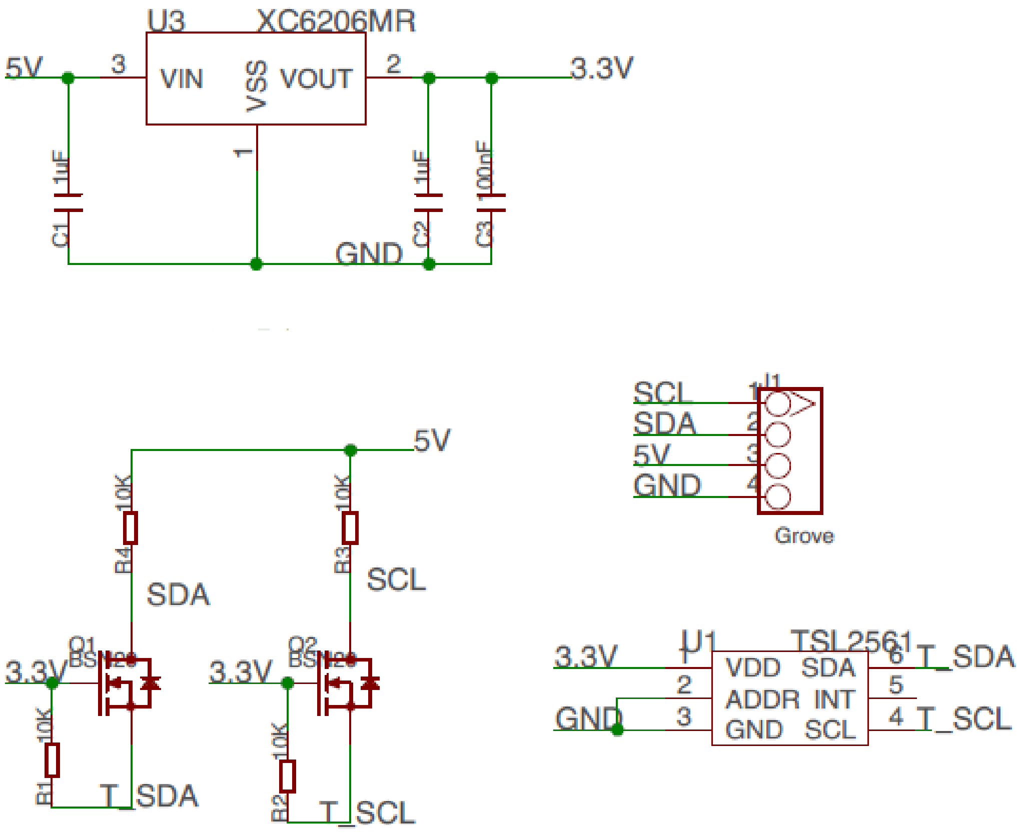


Figure 6: Principle of Light Sensor Functioning

Features:

Selectable detection modes: infrared mode, full-spectrum mode, and human visible mode

High-resolution: 16-Bit digital output at 400 kHz

I2C Fast-Mode Wide dynamic range: 0.1 - 40,000 LUX

Wide operating temperature range: -40°C to 85°C

UV Sensors (Grove Based on GUVA-S12SD)

The Grove – UV Sensor is used for detecting the intensity of incident ultraviolet (UV) radiation. This form of electromagnetic radiation has shorter wavelengths than visible radiation. It is based on the sensor GUVA-S12SD.It has a wide spectral range of 200nm-400nm. The module will output electrical signal which is varied with the change of the UV intensity. UV sensors are used for determining exposure to ultraviolet radiation in laboratory or environmental settings.

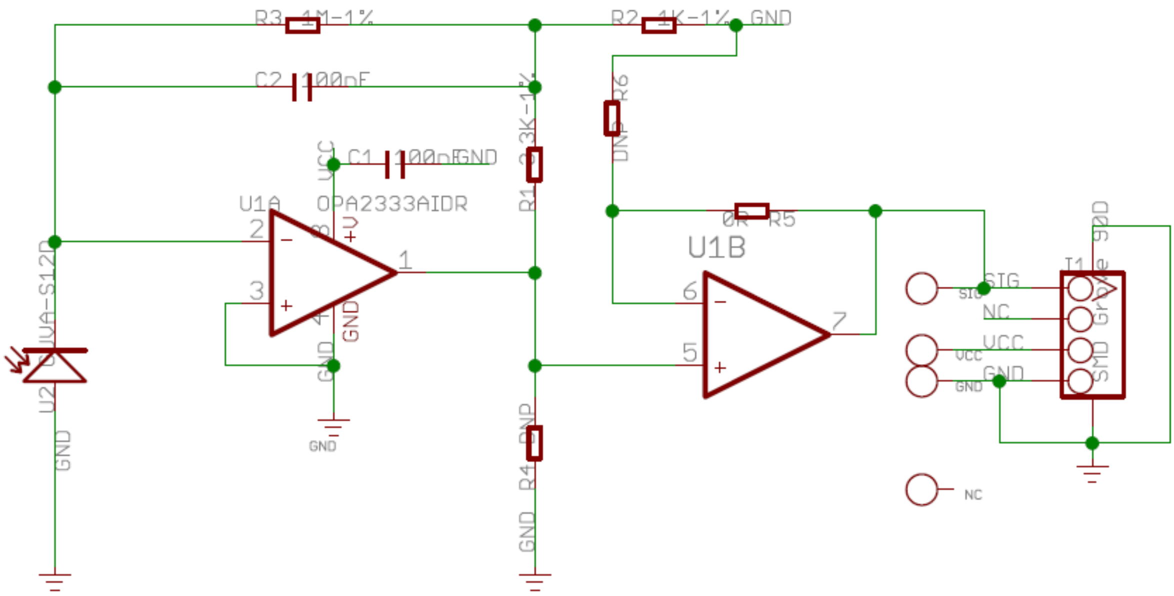
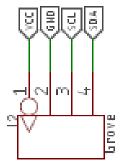


Figure 7: Working of the UV Sensor

CO_2 Sensor (SCD30)

The Grove - SCD30 is a 3-in-1 sensor that can measure CO2, temperature, and humidity. Based on Sensirion SCD30, it is a Non-Dispersive Infrared (NDIR) carbon dioxide sensor with high precision and wide measurement accuracy which can reach ± (30 ppm + 3%) between 400ppm to 10'000ppm. It would be a perfect choice for a multifunctional sensor for weather station or other environmental projects.

Embedded with Sensirion SCD30, The Grove - SCD30 integrates Non-Dispersive Infrared (NDIR) measurement technology for CO2 detection. It also has Sensirion humidity and temperature sensors on the same sensor module. You can see that there is a monkey face graphic on the module, actually, this is a carbon dioxide molecular model. As you can see, the 4 valence electrons on each oxygen atom and also the covalent bonds between the carbon and oxygen atoms are clearly shown.



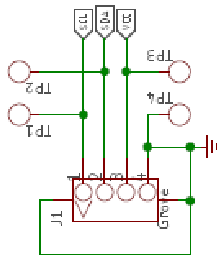


Figure 8: Working of the CO2 Sensor

pH Sensors

This is a professional Arduino pH Sensor Meter Kit with industrial electrode. It has built-in simple, convenient, practical connection and long life (up to 1 year), which makes it very suitable for long term online monitoring. It has an LED which works as the Power Indicator, a BNC connector and PH2.0 sensor interface. To use it, just connect the pH sensor with BND connector, then plug the PH2.0 interface into the analog input port. If programmed, you will get the pH value easily. You, may also check Liquid Sensor Selection Guide to get better familiar with our liquid sensor series. This industrial pH electrode is made of sensitive glass membrane with low impedance. It can be used in a variety of PH measurements with fast response and excellent thermal stability. It has good reproducibility, is difficult to hydrolysis, and can eliminate basic alkali error. In 0pH to 14pH range, the output voltage is linear. The, reference system which consist of the Ag/AgCl gel electrolyte salt bridge has a stable half-cell potential and excellent anti-pollution performance. The ring PTFE membrane is not easy to be clogged, so the electrode is suitable for long-term online detection.

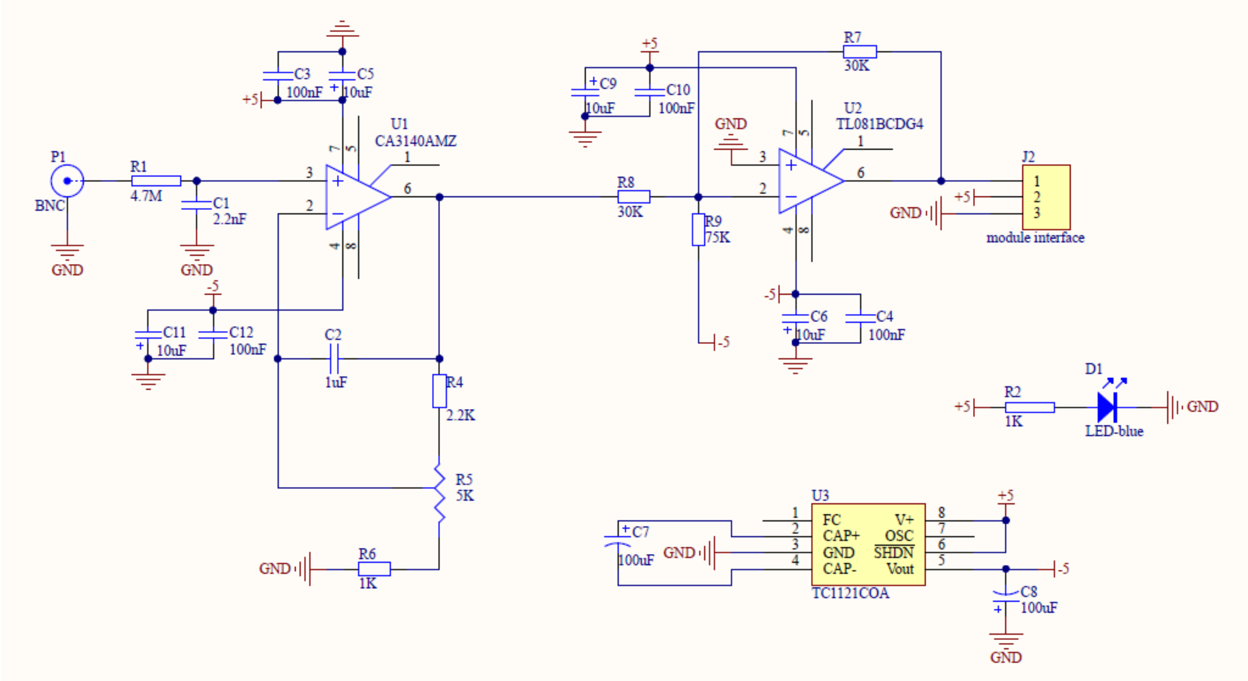


Figure 9: Working of the pH sensor

Specification:

- Module Power: 5.00V
- Module Size: 43mm × 32mm
- Measuring Range: 0-14PH
- Measuring Temperature: 0-60 ℃
- Accuracy: ± 0.1pH (25 ℃)
- Response Time: ≤ 1min
- pH Sensor with BNC Connector
- PH2.0 Interface (3-foot patch)
- Gain Adjustment Potentiometer
- Power Indicator LED
- Cable Length from sensor to BNC connector: 660mm

Pressure Sensor (BME280)

Grove BME280 provides a precise measurement of not only barometric pressure and temperature, but also the humidity in the environment. The air pressure can be measured in a range from 300 hPa to 1100hPa with ±1.0 hPa accuracy, while the sensor works perfectly for temperatures between - 40°C and 85°C with an accuracy of ±1°C. As for the humidity, you can get a humidity value with an error of less than 3%.

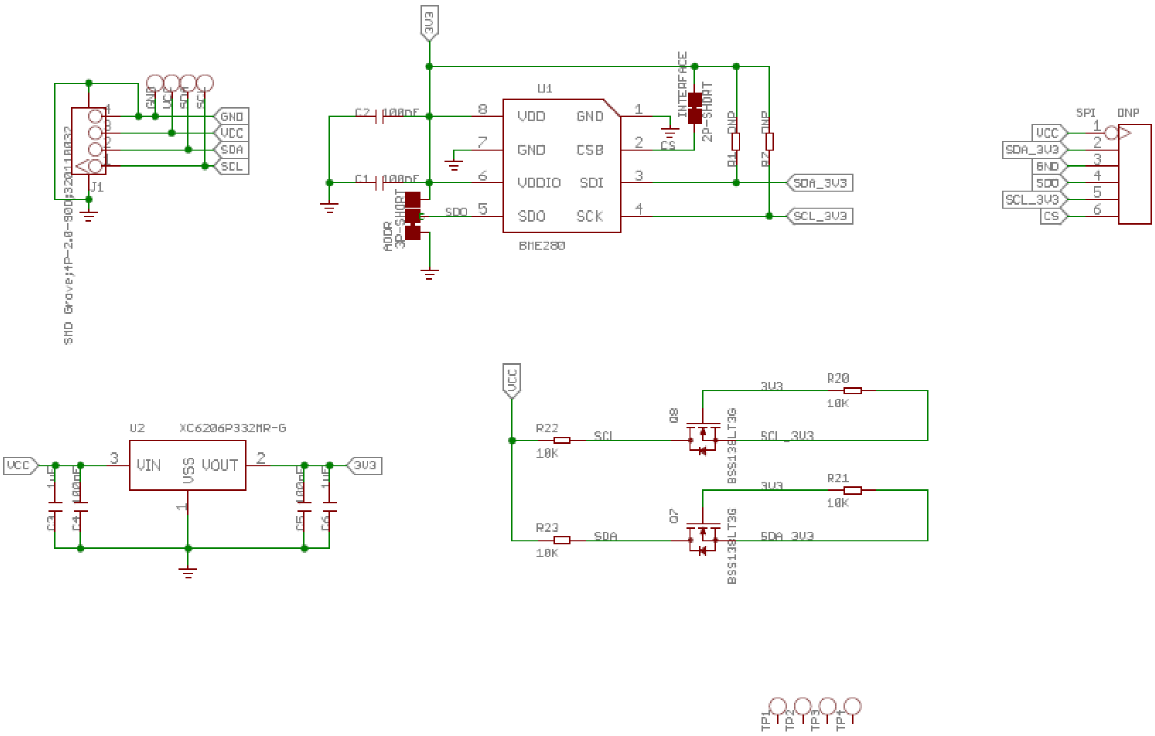


Figure 10: Working of the Soil Humidity Senor

Owing to its high accuracy on measuring the pressure, and the pressure changes with altitude, we can calculate the altitude with ±1-meter accuracy, which makes it a precise altimeter as well.

b. Microcontroller Microprocesor

It receives the analog data sent by the sensors and then performs necessary actions to convert it into the presentable digital format for further processing. The digitized data from sensor is received through configured input pins. Then, those sensed values are compared with the preset threshold value from the program. The microcontroller initiates actions if required based on the comparison. To do so, it triggers the actuators to carry out necessary operations. Microcontrollers are the base components in most of the electronics project around which entire circuit is fabricated. Especially the ATmega328 family of microcontrollers which are based on architecture are best fitted for embedded control system project like this. These microcontrollers cover a wide range of applications, be it in military equipment, automobiles or keyboard. These microcontrollers are available in market from ATmega company. To meet requirements, further modifications have been made to the microcontroller which include as I2C interfaces, analog to digital converters, watchdog timers, and pulse width modulated outputs.

Hence, we see multiple ranges of parts used to fabricate a single microcontroller makes the ATmega family best match for the base architecture of a company's entire line of products. Also, the microcontroller is a multi-functional device and developers only require to learn this platform. In this project, another device; ESP32 which is a low-power, high performance on a chip microcontroller with integrated Wi-Fi and dual mode Bluetooth. It is dual core 32-bit microcontroller with 520KiB SRAM LX6 microprocessor @ 240 MHz, is used. The fact that it is manufactured using Espressif System's high-density non-volatile memory technology and is compatible with the industry standard C++/Python instruction set and pin out, makes it more efficient for use.

The use of on-chip Flash in the microcontroller allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer.

Not only this, the ESP32 is designed with static logic for operation down to zero frequency and therefore, it supports two software selectable power saving modes. Under the normal conditions, the Idle Mode stops the CPU. And, it allows the operation of RAM, timer/counters, serial port, and interrupt system to continue functioning.

ACTUATORS

Actuators like relays, contactors, and change over switches etc. are employed in the project which performs triggering operations. Actuators perform the function of triggering AC devices; Motors, Exhaust Fan, Heater, Mist Generator, Light etc. in the project. We can say actuators work like an automatic on switch to turn on the devices. The use of relays to drive AC bulbs to simulate actuators and AC devices elaborates the statement. Just by replacing all the simulation devices by actual devices, working of entire circuit can be interpreted.

Temperature sensor detect the temperature and generate signal according to temperature it senses. Processor compare output voltage of temperature sensor and operate the fan. As we are using PWM pin, the speed of fan is variable according to temperature. According to the software code fan start to rotate at 30^0C and at 60^0C speed of fan become 100%. LCD shows the value of temperature and fan speed.

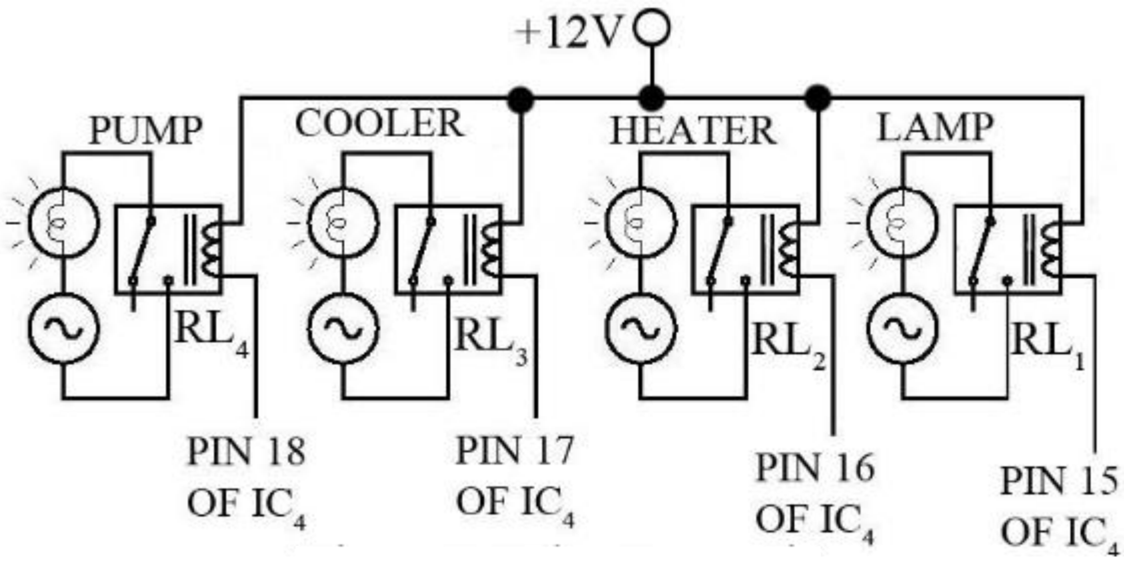


Figure 11: Relay Connection

c. Display Unit

The information is displayed on different display platforms:

LCD (Liquid Crystal Display)

Acts like a mirror that reflects the status of environmental parameters under consideration in a presentable digital form. Since LCD provides real-time information which is continuously monitored and updated corresponding to the changes in the parameters, the reliability of the project is highly reliable.

PC- Besides, LCD that displays information around the vicinity of the greenhouse, information is displayed over internet, it allows remote display of data and makes the project more flexible and friendly at the same time.

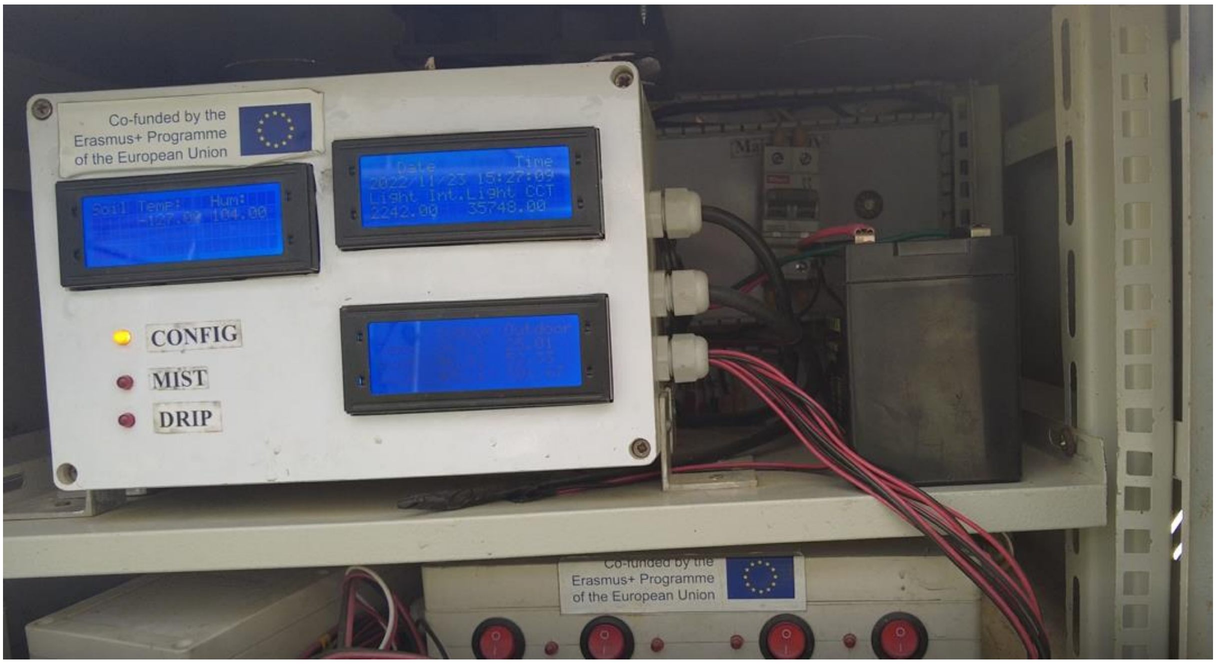


Figure 12: Display Unit

Data logger

To generate data logs for the future reference, data is stored over cloud.

Result of Greenhouse Automation System | Automated Greenhouse

Soil Moisture Sensor	Soil Condition	Optimum Range
	Dry Soil	0V – 1.9V
	Optimum Level of Soil Moisture	1.9V - 3.2V
	Slurry Soil	>3.2V
Light Sensor	Illumination Status	Optimum Range
	Optimum Illumination	0V - 0.69V
	Dim Light	0.7V - 2.5V
	Dark	2.5V - 3V
	Night	3V - 3.4V
	Temperature in ^{0}C	Output in Volt
	10^{0}C	0.5V
	15^{0}C – 20^{0}C	0.75V – 1V
	20^{0}C – 25^{0}C	1V – 1.25V
	25^{0}C – 30^{0}C	1.25V – 1.5V
	30^{0}C – 35^{0}C	1.5V – 1.75V
	35^{0}C – 40^{0}C	1.75V – 2V
	40^{0}C – 45^{0}C	2V – 2.25V
	45^{0}C – 50^{0}C	2.25V – 2.5V

Temperature Sensor	50^{0}C – 55^{0}C	2.5V – 2.75V
	55^{0}C – 60^{0}C	2.75V – 3V
	60^{0}C – 65^{0}C	3V – 3.25V
	65^{0}C – 70^{0}C	3.25V – 3.5V
	70^{0}C – 75^{0}C	3.5V – 3.75V
	75^{0}C – 80^{0}C	3.75V – 4V
	80^{0}C – 85^{0}C	4V – 4.25V
	85^{0}C – 90^{0}C	4.25V – 4.5V
	90^{0}C – 95^{0}C	4.5V – 4.75V
	95^{0}C – 100^{0}C	4.75V – 5V

Mode of operation:
MANUAL SET-UP: This set-up involves visual inspection of the plant growth, manual irrigation of plants, turning ON and OFF the temperature and humidity controllers, manual irrigation etc. over internet.
FULLY- AUTOMATED: This is a sophisticated set-up which is well equipped to react to most of the climatic changes occurring inside the greenhouse. It works on a feedback system which helps it to respond to the external stimuli efficiently. This set-up overcomes the problems caused due to human errors; it is not completely automated.

d. Green House Mobile Application

Nowadays, billions of IoT devices, e.g., sensors and RFIDs, arise around us providing not only computing intensive, but also delay-sensitive services, ranging from augmented/virtual realities to distributed data analysis and artificial intelligence. Internet of things is a concept where each device is assigned an IP address and through that address, anyone makes that device identifiable on the internet. Nowadays the internet is an evolving entity which started as the internet of computers. This removes human interaction with machines and makes it technically possible and desirable in various domestic processes by replacing it with programmed electronic systems. Ultimately it is a system that aims to increase the quality of life with the automation of appliances that may be controlled over the internet.
Web and Mobile application has two features mainly focusing on Monitoring and Controlling of various devices. All the data from sensors gets stored in the database and from the database we can easily access the devices data.

Figure 13: Mobile Application for Green House Automation

e. Monitoring Devices

With the help of an inbuilt Wi-Fi module, the data collected are uploaded to the database. We can visualize the data in the form of beautiful charts which feature real-time updates. Using our web and mobile application, we can continuously monitor real-time data.

We will use a web application using PHP, HTML and CSS, and mobile application using flutter. Both the mobile and web application will have similar features. To monitor the data, we have the option of creating a dashboard for the data of our need. When logged in, we can see all the data produced by our devices in our dashboard with aggregate reports and graphs.

The whole setup is divided into two main segments first is the server side and the other is client or user side. The server can be created with the help of LAMP (Linux, Apache, MySQL, and PHP). HTML is used to create a web page and CSS is used to enhance the look of the webpage. Two HTML files are created in the local host as Server. To make it available on the internet these two HTML files are uploaded to VPS (Virtual Private Server). One is Index.php which is used to design the main page. The first page of the webpage is entitled to the system name and images. Other page is made available to the end-user for which after navigating, opens up another new page where the sensor values are displayed in the graphical format. In that, various graph represent the values. GUI shows the present status of the system in terms of soil moisture content, air humidity, temperature. From these parameters, the environmental conditions within the greenhouse are continuously monitored and maintained, enabling the necessary climatic conditions are always maintained in the Greenhouse.

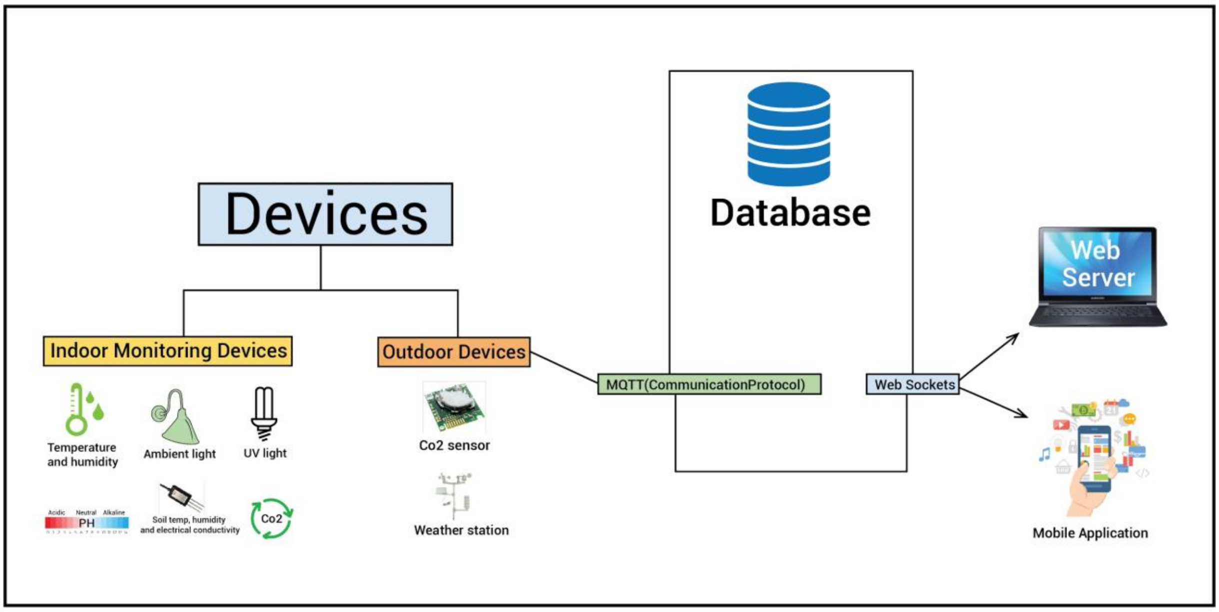


Figure 14: Monitoring Greenhouse over Internet

f. Controlling Devices

Same as monitoring devices with the help of an inbuilt Wi-Fi module, the devices will be controlled using the internet in manual mode. We can control the devices with the help of web and mobile applications. Using our web and mobile application, if we need to trigger any devices to manipulate parameters we can do it forcefully by controlling the Loads.

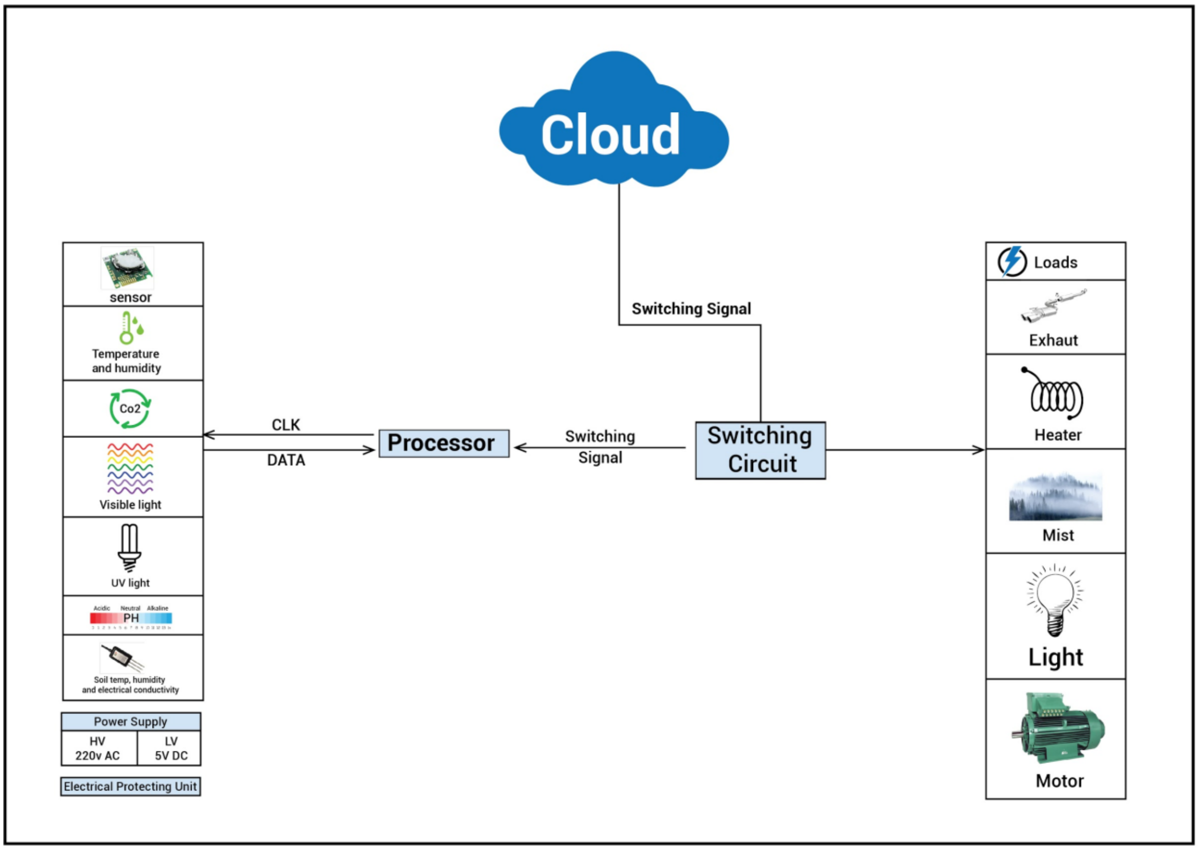


Figure 15: Controlling Greenhouse over Internet

B. Fish Pond Automation

Functioning of Fish Pond is not much different than functioning of green house, we monitor sensor data (Oxygen level, Temperature) over internet and control the load (motor).

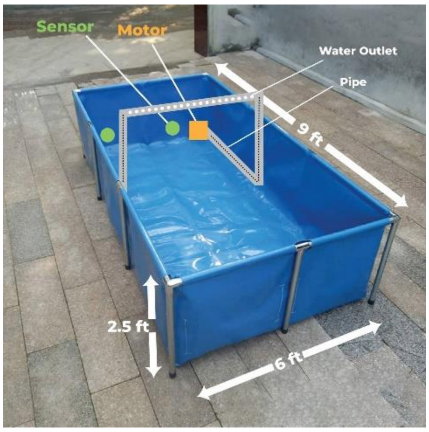


Figure 16: Model Fish Pond

Dimension: 6 ft (length) x 9 ft (width) x 2.5 ft (height)

Material used = Fiber

Sensor used: Dissolved Oxygen Sensor, Temperature Sensor

Oxygen maintaining method: Fountain (Pascal's law)

Figure 17: Installed Automated Fish Pond

C. Drip Irrigation Automation

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface.

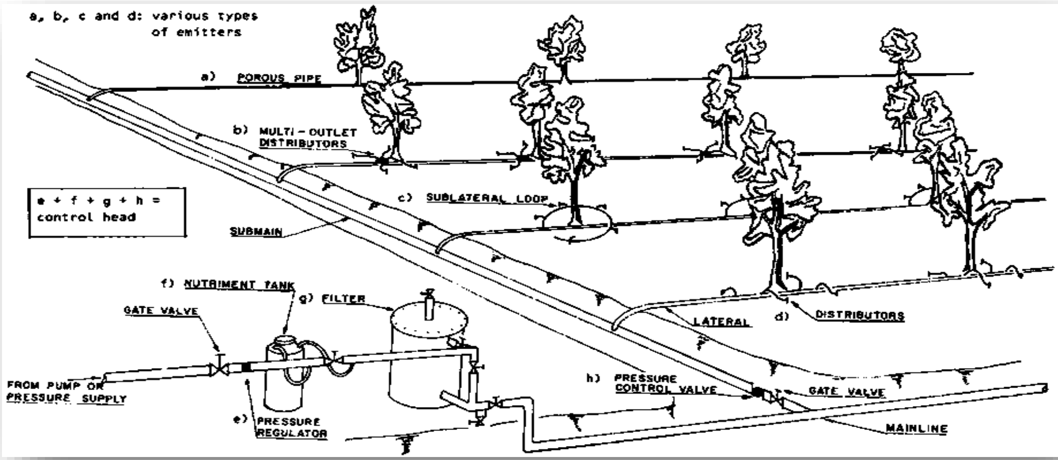


Figure 18: Drip Irrigation Automation

D. Agro-Health Lab

The Agro-Health Laboratory will be equipped with Double beam UV/Vis spectrophotometer for measuring UV/Visible light active pesticides and chemical residue in vegetables in fruits. The lab will have digital Refractometer for brix measurement (sugar content) of honey and fruits which determines the quality of honey and fruits. Fruit Durometer will be installed to measure the pulp hardness of fruits and vegetables. Fruit Durometer gives good information regarding the right time to harvest fruits and vegetables. The lab will also be equipped with soil nutrient measuring instrument which measures the 14 different nutrients parameter (N, K, P, NO_3-, etc.,) of the soil. The soil nutrient information is vital for the healthy growth of plant with good quality of fruits and vegetables.

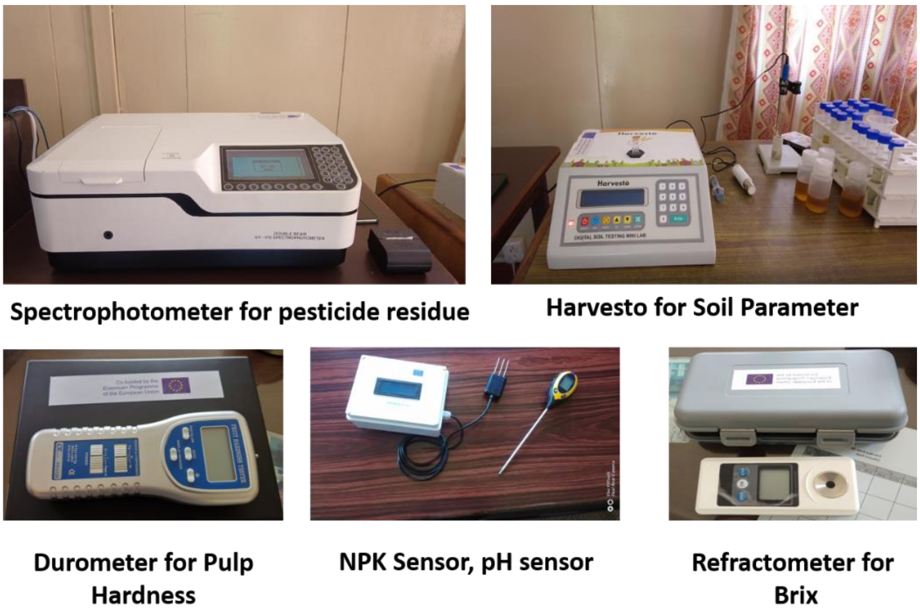


Figure 19: Equipment in Agro Health Lab

The Agro-Health functions for following purpose:

- Digital Soil NPK Nutrient Tester Meters: Gives the amount of Nitrogen, Phosphorus and Potassium; key nutrients of the soil
- Digital Harvesto Agriculture Soil Testing Kit: Determines soil nutrients with 11 more parameters besides Nitrogen, Phosphorus and Potassium.
- Double Beam UV/Vis Spectrophotometer: Determines Pesticide Residue in fruits and vegetables. Can be used to find the decay of residue with time.
- Digital Refractometer: Determines Brix Measurement (sugar content) in fruits and honey.
- Fruit Durometer: Measuring Pulp Hardness of vegetables and fruits and determines the quality of vegetables and fruits

1.7 Teaching and Learning Scenerios

1.7.1 Training Groups

Three levels of smart farmer characteristics were identified and defined based on the occupational standards of Thailand Professional Qualification Institute. The Three levels are as follows:

- G1A (Practitioner farmer) are the farmers' who follow traditional agriculture practices. They uses ICT (mobile) but for non-agriculture purposes. They have basic digital literacy skills.
- G1B (trained farmer) are the farmers' who follow traditional agriculture practices. They uses ICT (Mobile) but for non-agriculture purposes. They have intermediate digital literacy skills
- G2 (Non-standard farmers) with those who do the modern farming practices

1.7.2 Key indicators

Three groups of trainee will comprise of farmers (50 persons), smart farmers (20 persons) and academicians and researchers (12 persons).

- Group 3 (G3): Academicians involving faculty members of Kantipur Engineering College and Acme Engineering College, Researchers from Vegetable Crop Development Center and Agriculture Knowledge Center. The group will make up to 12 persons.
- Group 2 (G2): Smart farmers (20 persons) are the agriculture extension agents, educated farmers returned from abroad. They are familiar with some technology and have the potential to bring changes to the existing farming practices.
- Group 1 (G1A and G1B): Ordinary farmers (100 persons) are the less advanced farmers. They do not have Internet access in their farm, and sometimes also have difficulties to write and read. Farmers who are willing to learn can be included in this group. Due to the diversity of profiles, two subgroups are foreseen. Group 1B (Trained farmers) with the intermediate level in terms of digital literacy, Group 1A (Practitioner farmers) with those who have some basic understanding.

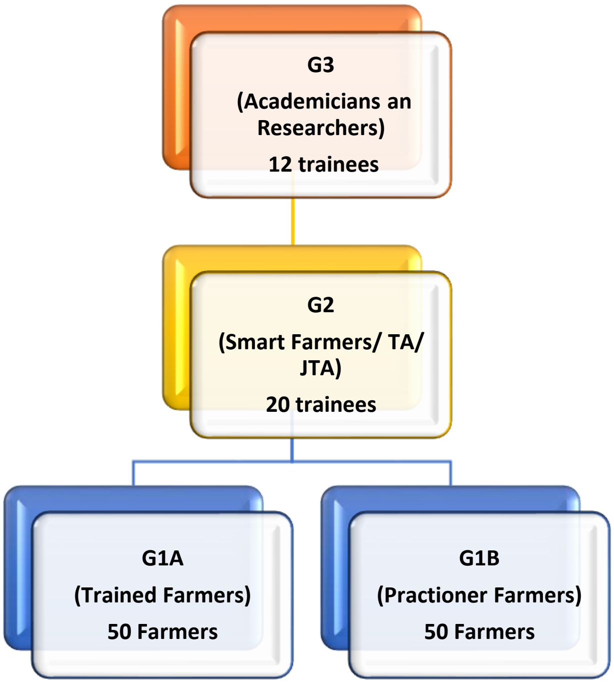


Figure 20. Expected participants for the training by KEC and AEC

1.7.3 Implementation of training process

The training process for KEC comprised of following steps:
Step 1: The academicians, researchers and smart farmers of G3 and G2 were identified to participate in the training of trainers
Step 2: The identified participants attended physical training on the concepts of IoT in agriculture, smart monitoring and controlling, business modelling, and occupational health and demonstration on the equipment in smart lab. After the training, assessment will be done to assess the learning during the training.
Step 3: Farmers from G1A and G1B identified participated in the training of the farmers. They will have an introduction to the concepts of digital agriculture, smart irrigation, smart monitoring, and controlling. Skills of farmers along with hands-on practice in the smart lab. Assessment to understand the knowledge and skills gained by the trainees will be conducted.
Step 4: After the completion of training, interested participants of the physical trainings were enrolled into online platform. They will undergo 4 weeks of learning. Interaction with the trainers will be via the online platform to answer questions raised by the trainees.
Step 5: At the end of the online learning, an assessment in the form of written exam was conducted and feedback collected by the trainers. The trainees were awarded a certificate on completion of the training.

- **Training of trainers (First Phase)**
  - Training duration – 5 days
  - Participants – 37 academicians (G3), researchers (G3), and smart farmers (G2)
  - Mode – Face to face and field trip to farmers field and research centre
  - Modules covered – IoT in agriculture, smart monitoring and controlling, business modelling, occupational health, demonstration in smart lab.
- **Training of farmers (Second and Third Phase)**

- Training duration – 5days each
- Participants – 66 farmers (G2, G1A and G1B)
- Mode – face to face and virtual
- Contents - IoT in agriculture, smart monitoring and controlling, business modelling, occupational health, demonstration in smart lab.

- **Cross Pilot Training**
  - Training duration – 2 days
  - Participants – 11 G3 and G2 Category
  - Criteria for farmers – Already taken first or second phase training
  - Mode – face to face and virtual
  - Contents- Use of sensors of soil parameters; sensors for cattle temperature, humidity and motion; oxygen sensor in fish pond, experience sharing.

- **MOOC (Online teaching and learning platform)**
  - Training duration – 4 weeks
  - Participants – Interested farmers from G2, G3, G1A, and G1B
  - Mode – Online
  - Modules – Digital agriculture, Agro-business, standardization and smart farm

- **Demonstration**

The list of activities that will be demonstrated through videos or face to face interaction during the smart lab visit by the trainee are as following:

1. Installation of greenhouse (video)
2. Drip irrigation and automation (video and lab demonstration)
3. Installation and uses of weather station (video and lab demonstration)
4. Installation and uses sensors like pH, light intensity, temperature, CO_2, EC, humidity (video and lab demonstration)
5. How to use measure soil nutrients? (lab demonstration)
6. How to use UV/Vis spectrophotometer for measuring chemical residue? (video and lab demonstration)
7. How to measure brix content of fruits and honey? (video and lab demonstration)
8. How to measure pulp hardness of vegetables and fruits? (video and lab demonstration)

1.7.4 KPIs

- Train 37 smart farmers and 100 farmers to use smart technologies in agriculture,
- MOU with Khon Kaen University, Thailand and Thoplo Machines Pvt. Ltd, Nepal.
- Develop Startup Training Center with Thoplo Machine.

1.7.5 Collaborations

- Vegetable Crop Development Center, Lalitpur, Nepal
- Agriculture Knowledge Center, Lalitpur, Nepal

- Extension Agents (trained during ToT)
- Progressive and Educated farmers
- Department of Agriculture and Livestock

1.7.6 Sustainability of Smart Lab

Strategy to sustain Smart Lab after completion of the project for Kantipur Engineering College and Acme Engineering College:

- The farm will continue as demonstration/practical site for the farmers and related students.
- After the completion of the project, the maintenance of equipment will be done by the college.
- Faculty and students of Computer and Electronics & Communication Engineering will continue to use the smart lab for the development and use of equipment for smart and safe farming.
- Researchers from different sectors of Nepal can use these data for research in environmental, agricultural, disease and pests control in Nepal.
- The facility of Agro-Health Lab will be continuously serving to measure the soil nutrients and chemical residues in foods and vegetables.