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SUstainabledevelopmeNT Smart Agriculture Capacity

« SUNSpace »

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Document Description	The purpose of this document is to develop the WP2/T2.4 “Guideline (meta-model) for Quality Pilot”. This document presents the background on the off-season vegetable production pilot and on the process of Smart Lab implementation. The process of installation of the equipment, types of farmers for training, implementation of trainings, Key Performance Indicators, collaboraters with RUB in the implementation of project and Sustainability of smart lab are included in this document.

Document history

Date	Name	Description
2020.07.08	Ugyen Yangchen (RUB)	Initialization of the document
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2022.10.30	Ugyen Yangchen (RUB)	Added summary of the write up
2022.12.04	Sylvain TOUCHARD (ULL)	Last Reviewed and closed

Contents

1. Off-Season Vegetable Production Pilot (RUB)

The quality pilot has been focused on off-season vegetable productions using smart technologies in protected environment. With the Royal Government of Bhutan's policy to venture for 100% organic agriculture and in view of the import of vegetables containing heavy pesticide residues, the demand for domestically produced and organic vegetables was growing in the country. While farmers in the Punakha-Wangdue valley, who are predominantly rice producers, are now beginning to cultivate and sell vegetables, there is a shortage of vegetables during the off-season and consumers have to depend on the imported vegetable. In view of this, there is a huge opportunity to produce off-season vegetables. However, farmers lack the technology (IoT and smart irrigation) and resources such as water, labor for off-season vegetable production. As vegetables are more suited to cultivation in greenhouses that are amicable to the use of technologies, the pilot promoted off-season vegetable cultivation in the pilot areas in Punakha and Wangduephodrang Districts.

1.1. Situation Analysis in Bhutan

Farmers in Bhutan practice subsistence and integrated agriculture (Katwal, 2013). To maintain soil nutrients, synthetic fertilizers, cow dungs, and forest plant litters are mixed and semi-decomposed. Rough geographical terrain and small land that farmers possess (3 acres for a farmer on average) limits the use of machinery and large-scale cultivation. The agriculture inputs of labor shortage aggravated by rural-urban migration, aging population (Pivoto et al., 2018), inadequate irrigation, production damage from pest and diseases outbreak. Irrigation of crops is largely dependent on rain and few kitchen gardens are irrigated with drinking water.

Inadequate inputs and inferior management in crop cultivation have reduced crop production. The average yields of vegetables, for example, chilli (1769kg/ac), tomato (793kg/ac), broccoli (1083kg/ac) and cauliflower (1189kg/ac) in 2018 (RNR statistics, 2019) seem to lower than the expectation. Therefore, cultivation of vegetables in a protected environment (greenhouse) with efficient use of resources (drip irrigation) as well as automation with sensors and weather equipment would contribute in reducing labour shortage, inadequate irrigation as well as reducing incidences of pest and diseases in greenhouse. Adoption of smart technologies is expected to increase the vegetable productivities.

1.2 Use Case Building

For the use cases, two field visits were made at Ap Tenzin, Laphuna village (individual farmer), and Ap Gyeltshen, Sopsokha village (individual farmer) of Baap gewog, Punakha District. They are small-scale farmers with landholding of 2.5 to 4 acres of land growing paddy and vegetables yet the progressive farmers in the community. Ap Tenzin focus on off-season vegetables especially cauliflower, broccoli, while Ap Gyeltshen grows vegetable (Chilli, tomatoes) and crops (paddy, maize) during the season. Both of them practice mixed farming (grow crops as well as raise cattle). They are interested to enhance their vegetable production using technologies as well as are in need to protect their crops from pest and diseases.

There are two aspects for the pilot. The first one is developing the capacity of farmers, academicians, researchers in smart farming. The second one is demonstrating smart farming technologies (off-season vegetable production) to farmers, academicians, extension agents, agriculture students, researchers, increasing productivity of chili, tomato, and cole crops and to control resource usage (water, fertilizer, pesticide). Farmers are gaining the capacity of using smart technologies through training in monitoring and analysing the temperature, water, and the nutrient requirement for vegetable production, growing off-season vegetables in a controlled environment (greenhouse) and using the forecast information for the prediction (weather, pest, and disease).

1.3 Objective of the Off-season vegetable pilot

- To build the capacity of academicians, researchers, and farmers in the Punakha – Wangdue valley in smart farming technologies to increase off-season vegetable production.
- To create awareness on the use of IoT in crop production and farm management.
- To adopt, for farmers, smart farming practices in vegetable cultivation, resource management and marketing of agriculture products.

1.4 Expected outcome of the pilot:

- To develop the capacity of 20 smart farmers and 12 academicians and researchers, in the usage of smart technologies in agriculture, and train 40 farmers in Punakha and Wangduephodrang Districts.
- To conduct three trainings (two face to face and one online) on digital agriculture, smart technologies, standardization, and agro-business .
- To enhance 60% of the farmers skills relevant to digitial agriculture in growing vegetables.

1.5 Expected impact of the pilot:

- To increase productivity of identified vegetables (chilli, tomato and colecrops).
- To control resource usage (water, fertilizer and labour) using smart irrigation control system (sensors for drip and sprinkler irrigation) and proper management of nutrients in the soil using pH and EC sensors.

2. Description of Smart Lab

2.1. Process of installation of smart lab

In the Smart Lab, greenhouses have been constructed for vegetable production. Sensors have been installed for smart monitoring and controlling system. Drip irrigation and sprinkler irrigation have been installed for the irrigation of vegetables. The evaporative cooling pad have been installed inside the greenhouse to reduce the indoor temperature and make it suitable to grow cole crops (Off-season). The sensors are listed in the Table 1.

Table 1: Lists of Sensor Equipment

Equipment	Description
Outdoor weather station and sensors	To monitor - Air Temperature - Relative humidity - Rainfall - Wind speed and direction - UV radiation - CO_2 sensor to monitor CO_2 concentration in the air
Air indoor sensors	To monitor - Temperature - Relative Humidity - CO_2 sensor to monitor CO_2 concentration inside the greenhouse
Soil sensors	To measure - Soil electrical conductivity (EC) - Soil pH

The data collected from the installed sensors in the farm top are stored in the cloud. Then, the users can access the data through the website (platform yet to be installed in the local server). The data are analysed to control temperature and humidity inside the greenhouse. Users can monitor data collected from sensors and the working status of sensors and controller via the platform (website to be installed in a local server).

2.2. Implementation of Smart Lab

The fixed greenhouses (GH) have been constructed to grow crops in protected environment to maintain suitable growing conditions. There are four green houses to grow cole crops, tomato, chilli. In one of the GH cooling pad have been installed to reduce temperature during summer. Drip irrigation has been installed for irrigation of vegetable. Plastic is covering the roof of the GH and green nets have been used below the plastic cover to provide partial shading to crops. Insect nets at the base of the greenhouse to repell the insects. The insect net has also provided ventilation inside the greenhouse.

- **Dimension of greenhouse:** 2.5 m (height) x 5 m (width) x 20 m (length).
- **Greenhouse Equipment:**
  - Aluminium arch frame – 42 pieces that makes the dome shape at the roof fixed into ground
  - Beats – 40 pieces, to hold and support the arch frame
  - Clip – 100 numbers, to hold beats to arch frame
  - Wiggle wire – 40 numbers, to hold together plastic and frame (Figure 1a)
  - Connecting angle – 21 numbers, connect arch frame
  - Pole – 4 numbers with 5 meter length, to connect arch frame
  - Pressing clamp – 40 numbers to clamp plastic with arch frame (all sides of greenhouse as shown in Figure 1a)
  - Belt – 1 bundle, runs through the arch frame to the hold plastic
  - Helix peg – 2 numbers to hold belt to the ground
  - Door – 20 screw to fix the door frame
- **How to set up?**
  - The aluminum arch frame is fixed into the ground and the angle connects arch frame and the pole connects the arch frame horizontally (Figure 1b). Belts run through the arch frame to hold plastic-covered over the arch frames. The belt is used to hold plastic and arch frame together. Pegs instead are used to keep the belt fixed to the ground as shown in Figure 1c. The shade net is fixed below the plastic roof and the insect net at the bottom of the greenhouse at ½ meter height.

Figure 1a. Front view of poly house

Inside view of Poly house

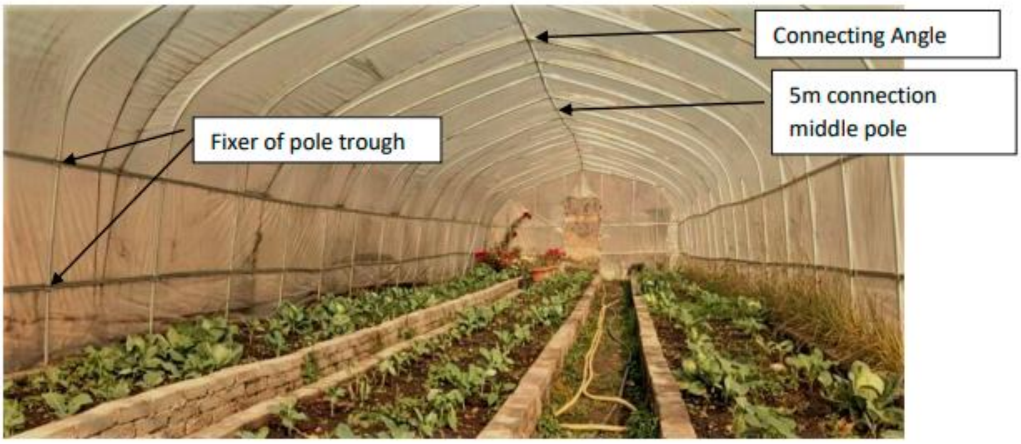

Figure 1b. Inside view of poly house

Outer view of Poly house

Figure 1c. Outer view of poly house

- **Dimension of modified greenhouse:** 4 m (height) x 5 m (width) x 20 m (length).
- **Greenhouse Equipment:**
    - Aluminium arch frame – 42 pieces that makes the dome shape at the roof fixed into ground
    - Beats – 40 pieces, to hold and support the arch frame
    - Clip – 100 numbers, to hold beats to arch frame
    - Wiggle wire – 40 numbers, to hold together plastic and frame
    - Angle – 21 numbers, connect arch frame
    - Pole – 4 numbers with 5 meter length, to connect arch frame
    - Clip – 40 numbers to clamp plastic with arch frame (all sides of greenhouse)
    - Belt – 1 bundle, runs through the arch frame to the hold plastic
    - Peg – 2 numbers to hold belt to the ground
    - GI pipe – 42 numbers of 1 meter long GI pipe to hold the arch frame and the concrete
    - Screw – 84 numbers of screw to fix the GI pipe and Arch frame

- **How to set up?**
  - The double line wall of ½ meters is raised from four sides of the greenhouse. The GI pipes are fixed with the wall. The arch frame is fixed with the GI pipe and 2 screws each are used to hold the GI pipe and arch frame (Figure 2). Rest of the construction is the same as a normal greenhouse.

Figure 2. Fixing of screw on the arch frame and GI pipe

- Evaporative Cooling pad system

The hot summer months from June to September are not suitable for growing broccoli, cauliflower. Cole crops (cauliflower and broccoli) require cool temperature for their growth and development. During the lean seaseon, these vegetables are imported into the country. Evaporative cooling system (ECS) reduces air temperature by evaporation of water into the airstream. As water evaporates, energy is lost from the air causing the temperature drop. ECS reduces internal temperature of the greenhouse. Using ECS, cole crops can be grown during off-season (March –September). The illustration is in Figure 3.

  - Cooling pad – 1 set
  - Water tank – 500 litres
  - Wall – 1 metre to keep the cooling pad
  - Electric point – to supply electricity to pump the water into the pads

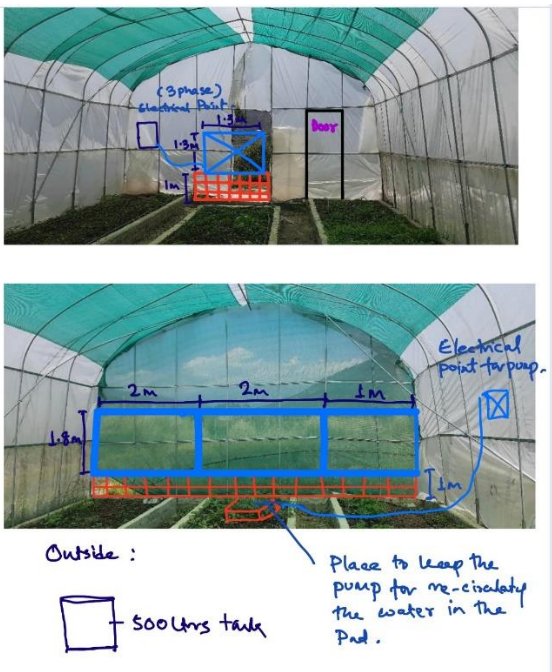

Figure 3. Illustration of an installation map of evaporative cooling pad system inside greenhouse

Figure 4. a) Installed exhaust fan and electrical point inside greenhouse b) cooling pad c) tank containing 500 litres of water connected to cooling pad through pipes.

- Agro-meteriology station
  The real time data on outdoor temperature, rainfall, relative humidity, UV radiation, CO_2 recorded in the farm top via a console. Data on the outdoor have been connected with the web page that is yet to be installed. The meteorology station gives the overall weather data of the smart lab area. The Figure 5 shows the agro-meteorology station, console, and farm top.

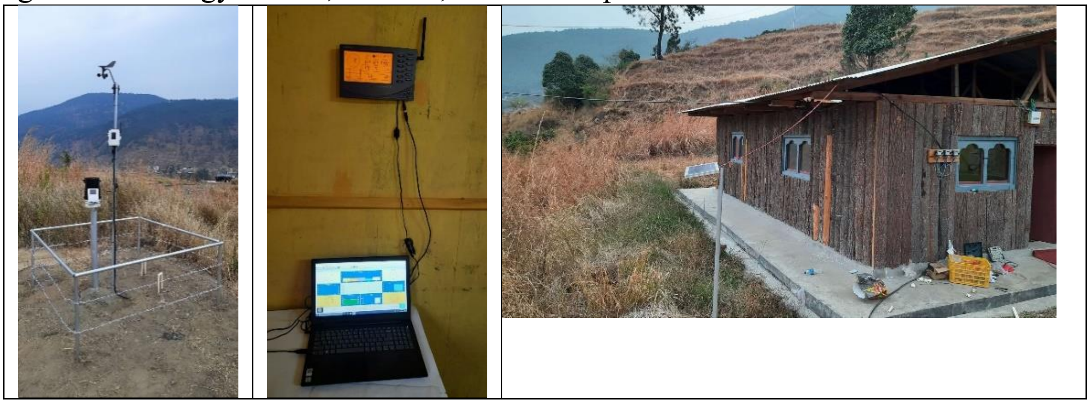

Figure 5. Installation of automated agro-meteorology station, console receiver, farm top, and solar panel

- Smart irrigation controller system:

The smart irrigation controller system consists of drips, sprinklers, pumps, tanks and solar panels to pump water for distribution into the system. The release of water is controlled using mobile app named Opensprinkler (Figure 7). The app has options for scheduled and manual operation of system.

- Drip irrigation : for efficient irrigation of vegetable crops through drip system
- Overhead Sprinkler irrigation : for efficient irrigation of vegetable crops through sprinkler system.
- Pump and accessories : 30 HP pump are pumping water from the river to the reservoir tank. Two HP pump for the distribution of water through the smart irrigation systems into drip and sprinkler irrigation. All pipes and related accessories are used for connection from the irrigation control system to the greenhouses (Figure 6).

Figure 6. Installation of 2 HP pump and 100 watts solar panel for distribution of water into smart irrigation system.

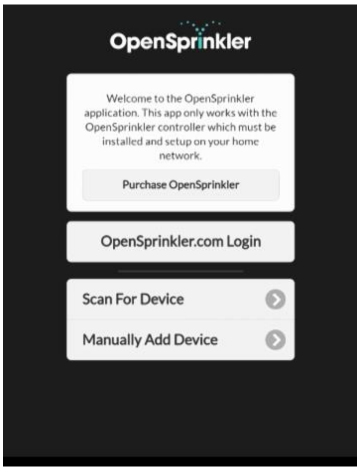

Figure 7: Opensprinkler app to control release of water

- Soil EC and soil pH sensor (portable) : these are portable devices to measure soil EC (electrical conductivity) and soil pH. The Figure 8 shows the two equipments.

Figure 8. Soil pH and EC measuring sensor

The below Figure 9 shows the system architecture of the smartlab build in the pilot site using the above equipment.

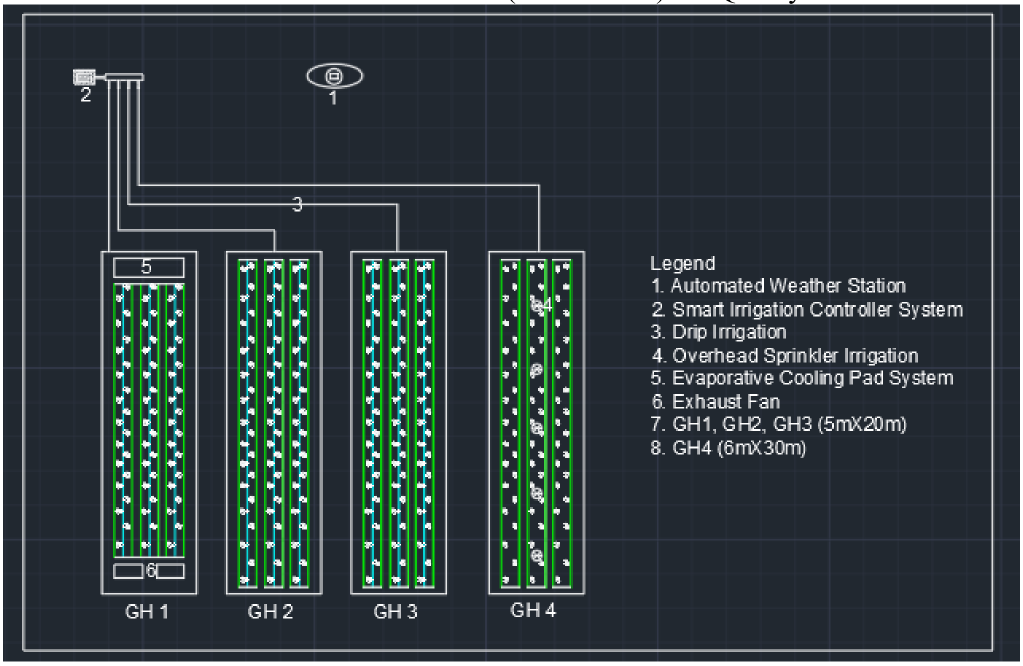

Figure 9. System architecture of Smart Lab in the farm, College of Natural Resources

3. Teaching and Learning

3.1. Training Groups

Three levels of smart farmer characteristics have been 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

3.2. Key indicators

Three groups of trainee have been composed of farmers (40 persons), smart farmers (20 persons), academicians and researchers (12 persons) (Figure 10).

- Group 3 (G3): Academicians involving faculty members of Department of Agriculture from Royal University of Bhutan. Researchers from the research and development centres of Ministry of Agriculture and Forest. The group has been made up to 12 persons.
- Group 2 (G2): Smart farmers (20 persons) are the agriculture extension agents/officers who work closely with the farmers in the blocks of districts in Punakha and Wangdue Districts in Bhutan. 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 (40 persons) are the less advanced farmers. They do not have Internet access in their farm, and, sometimes, 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.

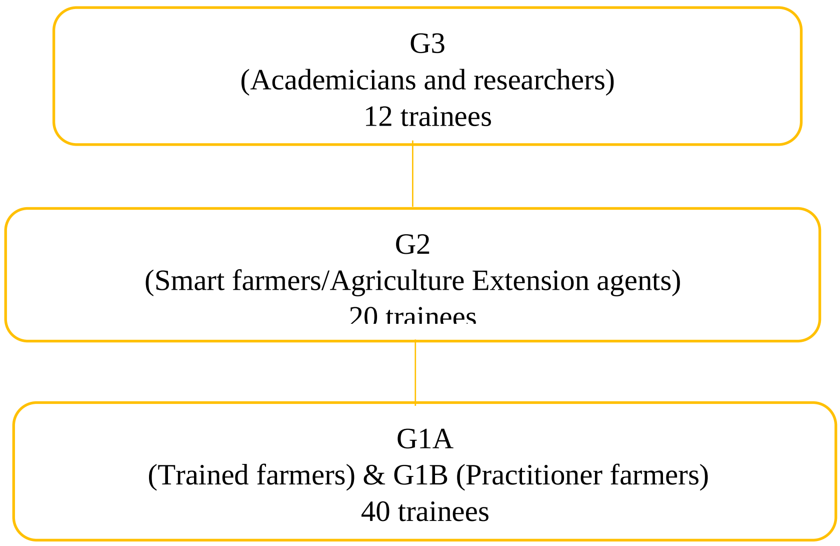

Figure 10. Expected participants for the training by RUB

3.3. Implementation of training process

The training process for RUB included the following steps:

Step 1: The academicians, researchers and smart farmers of G3 and G2 have been 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 safety demonstration on the equipments in smart lab. After the training, assessment has been done to assess the learning during the training.

Step 3: Farmers from G1A and G1B have been identified to participate in the train the farmers. They have followed an introduction to the concepts of digital agriculture, smart irrigation, smart monitoring, and controlling. Skills of farmers along with handson practice in the smart lab. Assessment to understand the knowledge and skills gained by the trainees has been conducted.

Step 4: After the completion of training, interested participants of the physical trainings have be enrolled into online platform. They have undergone 4 weeks of learning. Interaction with the trainers was 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 has been conducted and feedback has been collected by the trainers. The trainees have been awareded a certificate on completion of the training.

- **Training of trainers**
  - Training duration – 5 days
  - Participants – 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 trainers on the installation of Smart Farming Technologies**
  - Training duration – 7 days
  - Participants –7 academicians (G3)
  - Mode – face to face and hands on practice
  - Contents - hands-on installation of an agro-meteorology station and smart irrigation system.
- **Train the farmers**
  - Training duration – 2 days
  - Participants – G1A and G1B (40 farmers),
  - Criteria for farmers - Qualification: Class 10 and above, practising farming, understand and interested in smart farming technology
  - Mode – face to face
  - Contents - Introduction to Smart monitoring, control, and automation, Agro-Business: Business modelling, Digital agriculture, data capture, storage, and transfer; Installation of an automated weather station, Smart irrigation, Evaporative cooling pad, Smart farming in Bhutan: experiences and challenges in Nahi gewog, Hands-on practice of smart irrigation, cooling pad,

and soil and EC sensors, Standardization, Agro-health and safety: Diseases, pest, and fertilizer management, food safety and traceability

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

- **Demonstration**

During the training, learners (academicians, researchers, and smart farmers) were demonstrated with the following activities:

1. Off-season vegetable cultivation practices in greenhouse
2. Demonstration of smart irrigation control system (drip, sprinkler) in greenhouse
3. Evaporative Cooling pad system operation and function
4. Operation and functions of automated agrometeorological station
5. Data interpretation and visualization
6. Installation of greenhouse

The participants of the training have been finally awarded with a certificate on completion of the training as well as completion of assessments.

3.4. KPIs

- Train 20 smart farmers, 7 academicians and 5 researchers in smart technologies in agriculture,
- Upscale 40 farmers in Punakha and Wangduephodrang Districts to adopt digital technologies in agriculture.

3.5. Collaborations

- Research and Development Centre, Bajo
- Chimipang Royal Project
- Extension Agents (trained during ToT)
- Progressive and Educated farmers
- Department of Agriculture, Ministry of Agriculture and Forest

3.6. Sustainability of Smart Lab

Strategy to sustain Smart Lab after completion of the project for Royal University of Bhutan:

- The farm will continue as a demonstration/practical ground for teaching and learning to students of agriculture-based programmes
- Faculty, Master and undergraduate students of Natural Resource Management, Agriculture, Organic agriculture, and Environment Science can continue using the smart lab for research in smart agriculture, environmental studies, and related areas.
- Use for capacity development of young farmers through Entrepreneurship Incubation Centre based at the college.

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