International Partnership on Innovation

SAMS - Smart Apiculture Management Services

Deliverable N° 3.7

Capacity Building on Modern Beehive Construction – Achievements and Lessons Learnt

N° 3 – HIVE System

Horizon 2020 (H2020-ICT-39-2017)

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SAMS consortium partners

Logo	Partner name	Short	Country
	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (Coordinator)	GIZ	Germany
	University of Kassel	UNIKASS	Germany
	University of Graz (Institute for Biology)	UNIGRA	Austria
	Latvia University of Life Sciences and Technologies	UNILV	Latvia
	ICEADDIS – IT-Consultancy PLC	ICEADDIS	Ethiopia
	Oromia Agricultural Research Institute, Holeta Bee Research Center	HOLETA	Ethiopia
	University Padjadjaran	UNPAD	Indonesia
	Commanditaire Vennootschap (CV.) Primary Indonesia	CV.PI	Indonesia

List of Abbreviations

AI	Artificial Intelligence
CB	Capacity Building
DW	Data Warehouse
EU	European Union
ET	Ethiopia
ID	Indonesia
IoT	Internet of Things
PS	Partnership
T	Training
TT	Training of Trainers
UCD	User Centred Design

Summary of the project

SAMS is a service offer for beekeepers that allows active monitoring and remote sensing of bee colonies by an appropriate and adapted ICT solution. This system supports the beekeeper in ensuring bee health and bee productivity, since bees play a key role in the preservation of our ecosystem, the global fight against hunger and in ensuring our existence. The high potentials to foster sustainable development in different sectors of the partner regions are they are often used inefficient.

Three continents - three scenarios

- (1) In Europe, consumption and trading of honey products are increasing whereas the production is stagnating. Beside honey production, pollination services are less developed. Nevertheless, within the EU 35% of human food consumption depend directly or indirectly on pollination activities.
- (2) In Ethiopia, beekeepers have a limited access to modern beehive equipment and bee management systems. Due to these constraints, the apicultural sector is far behind his potential.
- (2) The apiculture sector in Indonesia is developing slowly and beekeeping is not a priority in the governmental program. These aspects lead to a low beekeeper rate, a low rate of professional processing of bee products, support and marketing and a lack of professional interconnection with bee products processing companies.

Based on the User Centered Design the core activities of SAMS include the development of marketable SAMS Business Services, the adaption of a hive monitoring system for local needs and usability as well as the adaption of a Decision Support System (DSS) based on an open source system. As a key factor of success SAMS uses a multi stakeholder approach on an international and national level to foster the involvement and active participation of beekeepers and all relevant stakeholders along the whole value chain of bees.

The aim of SAMS is to:

- enhance international cooperation of ICT and sustainable agriculture between EU and developing countries in pursuit of the EU commitment to the UN Sustainable Development Goal (SDG N°2) “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”
- increases production of bee products
- creates jobs (particularly youths/ women)
- triggers investments and establishes knowledge exchange through networks.

Project objectives

The overall objective of SAMS is to strengthen international cooperation of the EU with developing countries in ICT, concentrating on the field of sustainable agriculture as a vehicle for rural areas. The SAMS Project aims to develop and refine an open source remote sensing technology and user interaction interface to support small-hold beekeepers in managing and monitoring the health and productivity in their own bee colonies. Highlighted will be especially the production of bee products and the strengthening of resilience to environmental factors.

Specific objectives to achieve the aim:

- Addressing requirements of communities and stakeholder
- Adapted monitoring and support technology
- Bee related partnership and cooperation
- International and interregional knowledge and technology transfer
- Training and behavioural response
- Implementation SAMS Business cooperation

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Executive summary

As part of the User Centred Design cycles and of the SAMS project and to ensure long-term impact and dissemination of the SAMS HIVE monitoring system, and modern beekeeping techniques, a capacity building (CB) program for modern beehive construction was conducted. It was one of three CB programs performed during the SAMS project time in the SAMS target regions Ethiopia, Indonesia and Europe. The three CB programs focused on the following two main activities:

- conduction of workshops and trainings which aimed to building of capacity through theoretical and practical training, and
- establishment of partnership-networks for long-term CB after SAMS project end.

Activities and trainings within the CB program on modern beehive construction were conducted in English, German as well as in the local languages Amharic and Bahasa, depending on the context. The main target groups of the trainings were beekeepers, manufacturers of modern beehives and IT monitoring systems.

Main achievements of the trainings conducted in Ethiopia, Indonesia and Europe were:

- **Ethiopia**: conduction of 8 trainings for 125 participants from different regions in Ethiopia including beekeeping trainers, ICT companies and start-up incubators, beehive manufacturers, apiculture input suppliers, researchers and beekeeping experts. Trainings were conducted in Amharic and English language.
- **Indonesia**: conduction of 3 trainings for 26 participants including IT students and beekeepers. All trainings were conducted in Bahasa.
- **Europe**: Conduction of 8 trainings for 65 participants including students. The trainings were conducted in English and German.

In total, 216 participants were trained on modern beehive operation including implementation and feedback monitored.

As part of the UCD cycles of the SAMS project, all results of the CB activities and feedback provided by participants from CB activities were carefully monitored. This served for user-centred optimization of the SAMS system and adaptation of the CB program. Main learnings of the training include:

- LL for the optimization of the SAMS system
- LL for SAMS business development in Ethiopia
- LL for SAMS business development in Indonesia
- LL on the value of SAMS for the participants/ SAMS users
- LL for the conduction of further trainings and on provided learning materials

1. The capacity building program on modern beehive construction

The capacity building program on modern beehive construction was one of three CB programs conducted during the SAMS project time. Achievements and lessons learnt of additional CB activities are reported in the SAMSwiki and in the deliverables *D4.5 Capacity Building on Decision Support Service Implementation and Application – Achievements and Lessons Learnt* and *D5.4 Capacity Building on Bee-Management and Bee-Health – Achievements and Lessons Learnt*.

1.1 Aim of the capacity building program

The main aim of the capacity building program was to build capacity in modern beehive construction and on related IT-systems. It further aimed to adapt SAMS knowledge for similar systems and to foster optimization of the HIVE system (in compliance with the UCD principles for different regional settings). In order to gain better understanding of the needs and requirements of the SAMS users, the training served to collect feedback from participants in trainings and workshops. In the long-term, the CB aimed to strengthen local entrepreneurships and to foster cooperation within the three established SAMS partnerships (find out more in D6.1. Documentation of established Partnership Networks and Agreements) beyond the project duration. These partnership networks should further gain access to information and training material.

Main target groups for the program were beekeepers, manufacturers of modern beehives and IT monitoring systems. In order to meet the overall European Commission target of engaging female actors in H2020 projects[1], it was aimed to foster female participation in the training and education program.

1.2 Analysis of local requirements

To ensure the maximum impact of the CB program, an analysis of the status of modern beehive construction and related challenges of the target groups in the target regions Ethiopia and Indonesia, was conducted. The analysis served to gain a better understanding of the requirements and needs of the target group and to define the strategy, content and applied methodologies for specific CB activities. Furthermore, the target groups and the term modern beehive construction were defined in order to find common ground for the implementation of the activities.

1.2.1 Definition of modern beehive construction

A modern beehive is an enclosed, man-made structure in which honeybee colonies of the genus *Apis* are kept for man's economic benefit (Atkins, Grout and Dadant & Sons., 1975; Eva Crane, 1990). The design of such a hive should balance the requirements of the colony and

[1] Fact sheet: Gender Equality in Horizon 2020 (Dec. 9th, 2013), URL: h2020-grant-factsheet_en.pdf (europa.eu)

convenience for the work of beekeepers. The results from literature studies about modern beehives were used in determining the bee space, comb spacing, and other hive dimensions to develop standards and material specifications for new beehives according to the needs and nature of the two honeybee species targets by SAMS, A*. mellifera* and *A. cerana*.

A modern beehive is designed with the system to balance the requirements of the bee colony and for convenience of the work of beekeepers. For this purpose, Langstroth and its modified version of the Dadant model were chosen for the standard SAMS beehive (see appendix of D3.2 Low-fidelity HIVE prototype design as well as D3.1 Manual on beehive construction and operation). The reasons for choosing these two prototypes are several of which:

- both hive systems have several communicating hive boxes that can be stacked one above another to expand the hive volume and possibility of confining the queen to the lowest chamber (brood box) by using a queen excluder to produce a high-quality honey;
- familiarity of the hive systems in project countries and beyond is another important aspect;
- in terms of honey yield, these two main types of beehive can generate the highest honey yield, due to the option to add boxes one above the other easily;
- in terms of price, standardizing enables consistency of parts production across manufacturers in different workshops in different regions.

These adapted beehive systems also included two important parts, the inner cover to serve as feeder during the dearth period and the bottom board with a mite trap to control pests that can affect the health of bees and product quality.

During the SAMS project, different types of the SAMS HIVE monitoring system were built, including lo-fi (D3.2 Low-fidelity HIVE prototype design), hi-fi (D3.3 High-fidelity HIVE protoype design) and final versions (D3.4 Evaluation of HIVE prototype designs). The systems were constructed in two different versions:

- **SAMS Raspberry Pi system**: Monitoring system based on a Raspberry Pi single board computer combined with wittyPi energy management to read out sensor data from DS18B20 temperature sensor, from DHT22 for temperature and humidity, from HX711 analogue to digital converter module to read load cell data, and from H30A load cell to measure weight. In more detail the system is described in D3.4 Evaluation of HIVE Prototype Designs and D3.5 Manual on HIVE Construction and Operation.

- **SAMS NodeMCU system** with the NodeMCU electronic platform, is used to read sensor data and transfer it to the SAMS Data Warehouse. Besides that, the system uses the same sensor setup as described under Raspberry Pi section – DS18B20 temperature sensor, DHT22 for temperature and humidity, HX711 analogue to digital converter module to read load cell data, H30A load cell to measure weight. In more detail the system is described in D3.4 Evaluation of HIVE Prototype Designs and D3.5 Manual on HIVE Construction and Operation

Modern beehive construction was defined as the construction of the above-mentioned beehives.

1.2.2 Analysis of modern beehive construction in Ethiopia and Indonesia

An analysis of modern beehive construction in the target regions Ethiopia and Indonesia led to the following main findings. More information on beekeeping can be found in D3.1 Manual on Beehive Construction and Operation, D5.1 Bee-Management and Bee-Health indicators and in general, on SAMSwiki.

Table 1 Status of modern beehive construction and related challenges in the target regions Ethiopia and Indonesia

Ethiopia	Indonesia
• Beekeeping has a long tradition in Ethiopia • Different types of hives (traditional, transitional and modern) are used by beekeepers • Beekeepers couldn't adapt to the modern beehives because there is no standard for beehive manufacturing and the modern beehives are built with low-quality materials • Manufacturers and beekeepers lack knowledge on the requirements of bees • There are no business concepts on the construction of beehive spare parts like frames or honey super. Only complete hives are available on the market	• Different types of hives are used amongst beekeepers depending on the beekeeper's preferences and resources • Uniform internet signal coverage • Beekeepers produce beehives themselves • Business of beehive construction is perceived as not necessary since beekeepers construct their beehive themselves or manage the construction within their beekeeping community • The beekeeping ecosystem is not as developed as in Ethiopia or Europe • Immaturity of the ecosystem results from lack of integrated support from beekeeping stakeholders

Ethiopia

In Ethiopia, beekeeping has a long tradition and different types of hives are used by beekeepers, including traditional, transitional and modern beehives. Several beehive manufacturers exist. But due to the lack of standards on beehive construction, modern beehives are built in different ways and the beehives from one manufacturer do not fit with the beehives from any other manufacturer. Furthermore, beehive manufacturers lack knowledge of the requirements of bees and modern beehives are generally built with low quality materials. Beekeepers who use beehives, lack access to materials to repair the hives as spare parts are not available in the markets but only complete hives are sold.

Based on the results of the analysis, the CB program needed to focus on modern beehive construction.

Indonesia

In Indonesia, there is neither any system available to monitor bee health before the SAMS project started operating, nor any standard for modern beehives. Every beekeeper produces own beehive dimensions and builds its beehives himself/herself or within the beekeeping

community. There is no modern-beehive manufacturer or IT monitoring system manufacturer that exists yet. The SAMS project pioneered the idea of an IT monitoring system for bees in Indonesia. Through three years of SAMS project time, no modern beehive manufacturer nor IT monitoring system manufacturer were established in Indonesia.

As there were no modern beehive manufacturing before, the CB program was required to provide a smooth start for the ecosystem by creating awareness on the benefits of modern beehives and introducing standardised modern beehives to beekeepers. In the long-term, SAMS might trigger the importance of modern beehive manufacturers aside from the self-produced modern beehives by beekeepers.

1.2.3 Definition and analysis of the target group

Based on the analysis of the status of modern beehive construction in Ethiopia and Indonesia, the target groups of the CB program and their expertise (strengths and weaknesses) were defined as follows.

Beekeepers

Beekeepers were defined as established beekeepers (including new and "master" beekeepers), as well as potential beekeepers – stakeholders who are interested in starting a beekeeping business.

Ethiopia: Beekeepers in Ethiopia lack knowledge on the requirements of bees, as well as on the usability of modern beehives. Even though there are modern beehives available in Ethiopia, beekeepers lack of trust in the available systems. Concerning gender, women are well represented in the overall field beekeeping and its related activities. Nevertheless, women as beekeeping experts are rare due to the nature of the work, as beekeeping activities are night activities that require long distances traveling to inspect the apiary and because of safety issues, oftentimes women are not involving. This leads to the fact that beekeeping activities are mostly done by males, only a few women are involved in beekeeping. Main challenges of this target group concerning modern beehive construction are:

- Lack of modern beekeeping knowledge and practices as not many experts on modern beekeeping are available in Ethiopia, as traditionally other forms of beekeeping are practiced, with traditional and transitional hives
- Lack of knowledge in terms of requirement when it comes to standards and quality
- Lack of beekeepers' trust in using the modern beehives

Indonesia: Beekeepers in Indonesia are trained in building their own beehives. Nevertheless, these beehives vary in size and form as there is no standardized modern beehive. Concerning gender, in Indonesia beekeeping as a "profession" is still dominated by male actors, while female actors (wife's and daughters) usually play a non-professional supporting role in the beekeeping business. Beekeeping is still perceived as a masculine profession mainly due to their dangerous stigma which is forced by knowledge gaps. Main challenges of this target group concerning modern beehive construction are:

- There are no standardised modern beehives as beekeepers have their versions of ideal modern beehives

- More time is needed to create awareness and enrich the “modern beehive” discussion first among beekeepers before jumping into modern beehive construction

Manufacturers of modern beehives

Manufacturers of modern beehives were defined as institutions separate form beekeepers that focus on producing modern beehives to enable beekeepers in conducting their activities. Start-ups and students were considered as potential future beekeepers.

Ethiopia: Manufacturers of modern beehives in Ethiopia are established by businessmen or women for the production and marketing of modern beehives. Concerning gender, most of the beehive manufacturers are male. For example, out of 26, beehive manufacturers, only one is owned by a women cooperative association located in Nekemte, western part of Ethiopia. Main challenges of this target group concerning modern beehive construction are:

- Lack of technical expertise in interpreting the requirement of bees like the importance of bee space
- Lack of adequate material, such as quality timber in some areas
- Lack of access to working materials timber of the required size
- High cost of machineries for establishing fully furnished workshop for beehive construction
- Focus on traditions – step wise from traditional to transitional to modern beehives which requires time of adaption and awareness on benefits

Indonesia: Manufacturers of modern beehives do not exist in Indonesia. Beekeepers produce their own hives with support of the beekeeper's community, and which vary in size and form as there is no standardized modern beehive. Since most beekeepers are men constructing their own beehives, modern beehive construction is also perceived as a male activity. In addition, heavy woodwork and used machinery to produce modern beehives perceived as masculine professions. Main challenges of this target group concerning modern beehive construction are:

- There are no manufacturers of modern beehives yet as governmental structures are not focusing on supporting this field yet
- Lack of knowledge in constructing and building standardized hives and its related importance in becoming more efficient

Manufacturers of IT monitoring systems

Manufacturers of IT monitoring systems were defined as institutions that focus on producing IT-based monitoring systems for beekeepers. Since there are no Manufacturers of IT monitoring systems, IT students were further considered as part of this target group.

Ethiopia: Manufacturers of IT monitoring systems are already established in Ethiopia. Concerning gender, women rate of engineers and IT specialist are very rare and therefore most manufacturers are male. Main challenges of this target group concerning modern beehive monitoring system construction are:

- Lack of access to adequate materials like sensors or aluminium plate for constructions

Indonesia: Manufacturers of IT monitoring systems do not yet exist in Indonesia. There is one IT monitoring system start-up, but they specialize in aquaculture. Concerning gender, more women are now working in the engineering fields in Indonesia. Though the numbers are still low, female representation in this field is progressing. There is active encouragement of involvement of women in technical work through the “woman in STEM (Science, Technology, Engineer, and Mathematic)” campaign. Due to lack of this target group in Indonesia, IT students were invited in the CB program in order to raise awareness on modern beehive construction in the IT-field. Main challenges of this target group concerning modern beehive monitoring system construction are:

- There are no manufacturers of IT monitoring systems yet
- Lack of know-how and experiences when it comes to such systems
- Lack of awareness on benefits

1.3 Strategy for the conduction of the CB program

In order to achieve the above-mentioned aims, a CB program was developed by GIZ together with SAMS consortium partners HOLETA, CVPI and UNIKAS who were the main responsibilities for implementing the activities in the target regions Indonesia, Ethiopia and the EU. The program consisted of two main activities:

- conduction of workshops and trainings which aimed to increase capacity through theoretical and practical training, and
- establishment of partnership-networks for long-term CB after SAMS project end.

All results of the CB activities and feedback provided by participants from CB activities were carefully monitored for user-centred optimization of the SAMS system and adaptation of the CB program. Although activities were also conducted in Europe, the focus of the CB program were the SAMS target regions Ethiopia and Indonesia.

1.3.1 Capacity building through workshops and trainings

The implementation of workshops and trainings for CB on modern beehive construction was focused on the target regions Ethiopia, Indonesia and Europe. It started with the first pilot implementations in Europe in 2018 and in Ethiopia and Indonesia in March and April 2019 and ended in December 2020.

Topics

Based on the preconditions of local stakeholders and markets, the following overarching key questions (topics) were defined as leading questions of the trainings in each target region:

Table 2 CB Topics in Ethiopia, Indonesia and Europe

Leading question	Ethiopia	Indonesia	Europe
How to build a modern hive that is easily implemented by the HIVE monitoring system?	Yes	Yes	Yes

How to implement and adapt the HIVE Monitoring System?	Yes	Yes	Yes
How to adapt the HIVE Monitoring System?	Yes	Yes	Yes
What are the local needs which must be considered for optimization of the HIVE Monitoring System?	Yes	Yes	Yes
How to build modern hives?	Yes	No	Yes
How to locally adapt maintainability of SAMS sensor technique (also regarding minimizing the risks for false measurements)	Yes	Yes	Yes

Types of training and applied methodologies

The aim of the trainings consisted in theoretical and practical transfer of knowledge and expertise of modern beehive construction. In order to achieve this, different types of training were developed and conducted within the CB program:

- **Trainings for trainers**: aimed at ensuring long-term impact of the CB program by training future trainers in use and construction of modern beehives, SAMS beehives, and SAMS HIVE monitoring system.
- **Co-creation workshops**: aimed at co-creating and constructing SAMS HIVE monitoring systems, and modern beehives that can be easily implemented in the SAMS HIVE monitoring system with future SAMS users and businesses. It further aimed at building capacity through learning by doing.
- **Workshops with Beekeepers**: aimed at creating capacity and promoting the utilization of modern beehives amongst beekeepers (the end-users of beehives) and creating awareness of the modern beehives' benefits.
- **Workshops with scientists and bee specialists**: aimed at creating capacity and promoting the utilization of modern beehives amongst additional potential users of modern beehives, and at learning from them for the optimization of the HIVE system.

Practical exercises included assembling, implementation and adaptation of the HIVE monitoring system and other types of modern beehives. Therefore, participants of the trainings learned about the SAMS prototype.

Modern beehive construction within the CB activities

Practical training on modern beehive construction was planned to be conducted based on different types of beehives including monitoring systems.

SAMS HIVE monitoring system with Raspberry Pi: main basis to explain the SAMS HIVE hardware and software, including their lo-fi (D3.2 Low-fidelity HIVE prototype design), hi-fi (D3.3 High-fidelity HIVE protoype design) and final versions (D3.4 Evaluation of HIVE prototype designs). Exercises include building, testing and implementation of the system. As the SAMS hive system was continuously in adaption a similar hives system with a NodeMCU system was developed to identify differences in the preconditions of different settings and further adaption possibilities to create the best solution for each target region. As the introduction of the NodeMCU system happen in a later stage of the project the knowledge

gained through training with the Raspberry Pi-version were transferred to the NodeMCU based. No specific training on NodeMCU Systems was planned or conducted, also influenced by Covid 19.

Participants

In addition to the main target group of the program (beekeepers, manufacturers of modern beehives and of IT monitoring systems), further stakeholders were invited to the CB trainings. These stakeholders included IT students, start-up incubators, ICT companies, beekeeping researchers and other bee experts, to create awareness and to disseminate knowledge amongst a greater range of stakeholders. In addition, receiving more feedback from a greater variety of stakeholders for system adaption was important. Another factor was that particularly start-ups and students were considered as potential future beekeepers, thus adding to the goal of creating interest in new beekeeping technologies and awareness of their benefits amongst younger generations. Moreover, the CB activities were widely disseminated in order to attract female participants.

In addition, staff of the SAMS project partners were also included in the CB program as part of the training for trainers. This was to ensure that SAMS staff is well-trained in the construction on modern beehives and able to disseminate the knowhow through future CB trainings and activities within the SAMS partnerships.

Training materials

Part of the CB strategy was to support all trainings through a variety of learning materials. The language of the materials (English or local languages) was chosen by the implementing trainers, depending on the requirements of the training participants. Long-term availability of the materials to training participants and to the SAMS partnership networks is ensured through publication on the SAMS website and SAMSwiki after conduction of the training.

1.3.2 Long-term capacity building through SAMS partnerships

In addition to the training program, long-term partnerships between the SAMS partners were established within the three international SAMS partnerships on business development (PS1), bee colony data and knowledge exchange (PS2) and technology and services (PS3). These growing partnership networks between the SAMS beneficiaries and national and international stakeholders of the beekeeping sector and scientific society, aim to work together for the purpose of long-term dissemination of the SAMS project results and mainstreaming of the HIVE system.

2. Conducted capacity building activities

This chapter summarizes the activities conducted between 2018 and 2019 within the capacity building program on modern beehive construction. It summarizes the achievements of each activity, as well as lessons learnt from observations and participants feedback.

2.1 Activities conducted in Ethiopia

In Ethiopia, 8 trainings and workshops were conducted for 125 participants from 9 different sites involved. During the trainings 15 SAMS HIVE monitoring systems and 100 frames were constructed.

Table 3 Activities conducted in Ethiopia

Date	CB activity	Target group	Location	Hours	Participants	Language	Partner
April 8-13th, 2019	Training of Trainers on IT Adaptation and Prototyping (No. 1)	Trainers from HOLETA and ICEADDIS and future SAMS providers (ICT companies, and start-up incubators)	Holeta Research Centre, Holeta	60 hours (7 days)	11 participants (0 female)	English	HOLETA ICEADDIS UNIKAS
May 13-17th, 2019	Workshop on SAMS Beehive Construction (No.1)	Beehive manufacturers, apiculture input supplier	Holeta Research Centre, Holeta	30 hours (5 days)	15 participants (0 Female)	English	HOLETA ICEADDIS
April 19th, 2019	Workshop on the SAMS technology and business applications	SMEs, Start-ups	Holeta Research Centre, Holeta	1,5 hours (1 day)	3 participants (0 female)	Amharic	ICEADDIS UNIKAS
July 25th - August 2nd, 2019	Training of trainers on IT Adaptation and Prototyping (No. 2)	Trainers from HOLETA and ICEADDIS and future SAMS providers (ICT companies, and start-up incubators)	Gedo, Ethiopia	35 hours (4 days)	11 participants (0 female)	English	HOLETA ICEADDIS UNIKAS

October 7-11, 2019	Workshop on SAMS Beehive Construction (No. 2)	Beehive producer and apiculture input supplier	Holeta Research Centre, Holeta	30 hours (5 days)	7 participants (0 female)	English	HOLETA
January 18th, 2020	Workshop on SAMS Beehive Prototyping and Awareness Creation (No. 1)	Researchers (Ethiopia-wide centres)	Holeta Research Centre, Holeta	3 hours (1 day)	33 participants (4 female)	English	HOLETA
February 6th, 2020	Workshop on SAMS Beehive Prototyping and Awareness Creation (No. 2)	Beekeeping experts	Holeta Research Centre, Holeta	3 hours (1 day)	33 participants (2 female)	English	HOLETA
August 24-27th, 2020	Workshop on SAMS Beehive Construction (No. 3)	Beehive manufacturers, apiculture input supplier	Bako, Ethiopia	24 hours (4 days)	12 participants (0 female)	English	HOLETA
December 15 to 22 2020	Assembling SAMS System Capacity Building Workshop	Holeta Stafe members	Holeta Research Centre, Holeta	59 hours (7 days)	9 participants (3 female)	Amharic English	Iceaddis Holeta

2.1.1 Training of Trainers: IT adaptation and prototyping

In April and July 2019, two trainings of trainers in IT adaptation and prototyping were conducted including knowledge transfer on the SAMS monitoring system, hardware and software aspects, and practical training in the construction of the SAMS monitoring system. Participants were trainers from the SAMS project partners HOLETA and ICEADDIS, and future SAMS providers (ICT start-ups, ICT consultancy).

Achievements

Theoretical and practical training of 11 trainers and future SAMS providers:

- Knowledge transfer on the SAMS monitoring system: functionality, sensors, what data can be used for what
- Knowledge transfer on SAMS hardware aspects: devices and parts, sensors, the soldering and connections, work that should be done in the wood-workshop

Knowledge transfer on SAMS software aspects:

- Training No. 1 raspberry Pi operating systems (raspbian), algorithms/ spectral analysis (FFT)/ median averaging
- Training No. 2: preparing a SD-card, locking RaspberryPi to a Wi-Fi, how to calibrate the scale, configuring scheduling scripts, setting time zone and obtaining data in case of network failure

Practical training in the construction of the SAMS monitoring system prototype and construction of 15 functional SAMS system prototypes

- Training No. 1: Construction and installation of 5 SAMS system prototypes for testing and data collection (all systems were installed in Holeta)
- Training No. 2: Construction of 10 SAMS system prototypes *in the field* out of which eight systems were installed (three in Bako and five in Gedo); the two unimplemented systems were found to have non-functional parts that were replaced during the next prototype implementation in January

Successful awareness creation on the usefulness of the SAMS technology and networking as many participants were interested in adapting the SAMS monitoring system do develop own businesses and to work with the SAMS consortium to establish a business partnership (e.g. Anabi).

Lessons Learnt

LL for the optimization of the SAMS system

- Need for adaptation of some parts: this system can be more effective if it is based on locally available materials instead of depending on imported parts (e.g. aluminium plate, solar modules and cables). Parts like wires, solar modules and wooden materials can be obtained from local markets in Ethiopia (no need for import) – all sensor parts and scale units are not available at the local market and must be imported from foreign nations (e.g. Germany) (Training 1)
- Weak 3G network in Ethiopia: connection of the systems to the SAMS Data Warehouse was difficult (Training 1)

- The position of RaspberryPi in relation to the SD Card Slot created discomfort and should be corrected – it was difficult to access the SD card to remove and insert it from its slot (Training 2)
- The placement of the Wi-Fi-router within one of the beehive monitoring systems, led to reduced internet connectivity with growing distance between the monitoring systems and caused problems for data uploads (Training 2)
- Materials were regarded as expensive and the replacement of car battery through a cheaper system was proposed (Training 2)

LL for SAMS business development

- Import of parts can be an obstacle for new businesses
- Many participants were interested in adapting the SAMS monitoring system and to make business out of it, many were interested in the SAMS business partnership
- Need to install the systems during night-time as the bees in Ethiopia (*Apis mellifera*) are particularly aggressive during daytime
- Lack of 3G-network in Gedo location is a challenge for installation in some regions in ET

LL on the value of SAMS for the participants/ SAMS users

- Participants saw high value in the remote monitoring system as Ethiopian honeybees are very aggressive and frequently abscond
- The construction is still complicated, and users require trainings to understand how to build working prototypes by themselves and to be able to write the codes, as these are very critical for producing stable operational monitoring system under local context

LL for the conduction of further trainings and on provided learning materials

- The first training showed the need to conduct additional training on the installation of prototypes under field conditions. This was implemented in the second training which was conducted in the field.
- Need to develop a rough guide for prototype installation procedures like preparing a SD-card, locking RaspberryPi to a Wi-Fi, calibrating scale and configure scheduling scripts are among the points that should be considered in the training

Figure 1 Trainees preparing wood for modern beehive construction (left) and finished beehive constructed by the trainees (right)

2.1.2 Workshops on beehive construction

In May and October 2019, and in August 2020, three trainings on beehive construction were conducted in Holeta and Bako. Participants were introduced to the SAMS technology, SAMS beehive construction and business development and built capacity on beehive construction. Participants were beehive manufacturers and apiculture input suppliers (suppliers of beehive materials) from beehive manufacturing workshops with woodwork background.

Achievements

Theoretical and practical training for 34 beehive producers and apiculture input suppliers to promote the capacity of beehive manufacturers for future CB of their own hive manufacturers:

- Knowledge transfer on the SAMS technology (tools, materials and specifications for modern and effective beehive construction)
- Knowledge transfer on types, defects (quality problems) of and solutions for modern beehives in Ethiopia
- Knowledge transfer on and introduction to SAMS business development
- Knowledge transfer and practical training on hive operation without bees
- Practical training in the construction of the SAMS beehive and manufacturing of quality beehives (including frame dimensions, requirements of brood and honey chambers, hive entrance and bottom board dimensions, inner cover dimensions and its use)

Construction of 20 modern beehives and preparation of 100 beehive frames:

- Training No. 1: Construction of 5 modern beehives
- Training No. 2: construction of 10 complete beehives (bottom board, frames, hive chambers outer covers)
- Training No. 3: Construction of 5 complete beehives (bottom board, frames, hive chambers, outer covers) and preparation of 100 additional beehive frames

The participating beehive manufacturers expressed the intention to construct beehives based on the SAMS-Design.

Successful networking, all participants (of training No. 2 and 3) are interested in partnership with HOLETA for better market access and additional training on the beehive construction for different zones of Ethiopia. They are also interested in the international partnership of SAMS business development.

Lessons Learnt

LL for the optimization of the SAMS system

- Parts like hive chambers and handles should be constructed as groove to save storage space and make transportation easy (Training 1)
- Some measurements should be readjusted as some materials are difficult to obtain (Training 1)
- Lack of proper overlapping between the sides with length 505 and 365 mm. In order to correct the problem, the side of 365 mm was increased to 390 mm and a new hive was constructed, tested and checked for the required quality (Training 2)
- Participants suggested to replace construction materials for example the use of wood in place of plywood for inner cover construction as these materials are not readily available in local markets (Training 2)
- Participants suggested that the use of mite trip board should be revised, as mite is not a problem in many areas. Its use only should be based on request and should not be included as mandatory part to reduce the price of construction (Training 3)

LL for SAMS business development

- Participants gave feedback on market linkages and on registration procedures of the SAMS beehive as Ethiopian standard (dependence on customer orders)
- All participants are potential partners for future SAMS businesses

LL on the value of SAMS for the participants/ SAMS users

- The approach and gained knowledge were rated as “excellent” by participants, the participants appreciated that the SAMS system is useful for beekeepers and that the concept learned in this training was helpful for their activities of beehive construction

LL for the conduction of further trainings and on provided learning materials

- The provided manual should be shortened and translated to local language
- Need for more awareness creation on SAMS beehive and SAMS system in Ethiopia
- Need to conduct trainings for teachers for greater impact (HOLETA alone cannot cover all Ethiopia)

Figure 2 CB participants attending the workshop

2.1.3 Workshops on the SAMS technology and business applications

The training was conducted on April 19th, 2019 at the Holeta Research Centre in Ethiopia in Amharic. An introduction to the SAMS technology and possible use of the system for business application was given. Participants were local SME like KEKROS, a mobile and satellite communication technology consultant, and the local start-up Anabi, an agritech company that integrates emerging and advanced technologies, namely IoT and AI to transform beekeeping and food production. Furthermore, iceaddis and UNIKAS provided training on how to assemble and implement the SAMS system for HOLETA colleagues. The training covered the following categories.

1. Assemble the monitoring system and flashing SAMS image
2. How to use BerryLan app and putty software
3. Preparing and connecting the power supply system (solar system)

Achievements

Training of one local SME and one start-up:

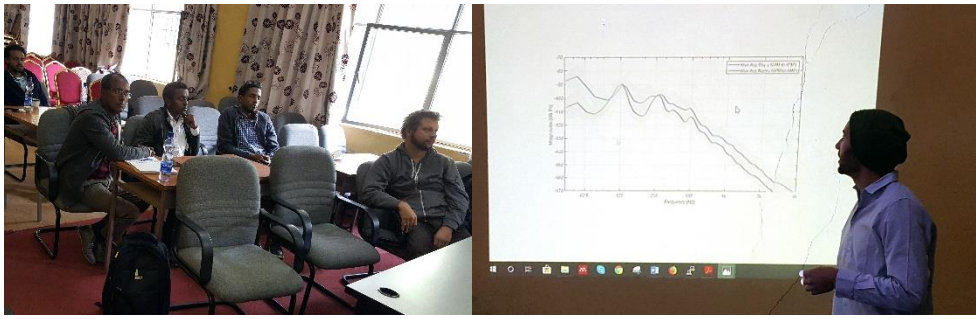
- hands-on knowledge exchange on the SAMS technology and hive assembly
- Two of the participants later joined the business development follow-up activities and continue to develop their beehive monitoring system by integrating SAMS technology into their products

The participants showed interest to follow up on the SAMS's progress and to engage in further SAMS activities and partnership opportunities. They planned to participate in another half-day workshop at HOLETA.

Lessons Learnt

Both participants were interested in creating a variation pf SAMS system because of not easily available SAMS system parts in the country.

One of the variation systems was focusing to improv beekeeping through IoT devises without out remote communication technology, instead it uses locally placed alarm systems that will give signals for the beekeepers. They chose this option because beekeepers usually don't use high tech mobile phones and prefer to work with familiar methods.



2.1.4 Workshop on SAMS beehive prototyping and awareness creation

Two trainings were conducted in HOLETA on beehive prototyping and awareness creation including knowledge transfer on the SAMS prototype components and precision beekeeping, as well as practical field experience with the SAMS monitoring system. Participants were researchers form different research centres located in different regional states of Ethiopia and for beekeeping experts from Oromia National Regional State of Ethiopia. Based on feedback provided by participants from previous CB workshops, an additional focus laid on awareness creation on the advantages of smart beehive monitoring systems.

Achievements

Training of 33 researchers (4 female) and 33 beekeeping experts (2 female):

- Knowledge transfer on the SAMS prototype components as well as on the hardware and software solutions developed within the SAMS project
- Practical field experience with the SAMS monitoring system and bee colony monitoring methods
- Knowledge transfer on precision beekeeping, bee colony monitoring and usefulness of the SAMS system for research purposes

Successful awareness creation on the SAMS system and development of wide-spread interest in different regions amongst researchers (Training 1) and beekeeping experts, including experts from the development sector (Training 2). It further served for as networking platform and the introduction of the SAMS partnerships.

Lessons Learnt

LL on the value of SAMS for the participants/ SAMS users

- Researchers understood that the SAMS system would be very helpful to work with the highly aggressive honeybees in Ethiopia (remote real-time monitoring) (Training 1)
- Researchers found that the SAMS technology can further enable beekeepers to be more efficient and reduce disturbances of colonies (Training 1)

- Beekeeping experts understood that the SAMS technology will not only monitor the colony, but also enable the beekeepers to be more efficient and reduce inspections (Training 2)

LL for the conduction of further trainings and on provided learning materials

- Need for additional CB with the same participants for more practical, hands-on training
- Better understanding of what should is required to changed/ improved the transfer of knowledge on the SAMS monitoring system in ET to enable stakeholders to assemble and use such systems easier and to create a better understanding

Figure 3 Building beehive monitoring systems

2.2 Activities conducted in Indonesia

In Indonesia, 3 trainings were conducted for 26 participants. During the trainings 20 modern beehives were co-created with potential SAMS users.

Table 4 Activities conducted in Indonesia

Date	CB activity	Target group	Location	Hours	Participants	Language	Partner
January 13- February 29th, 2020	Workshop of SAMS beehive adaptation and prototyping	Bandung Polytechnic students	Labtek Indie Head Quarter, Bandung	55 hours (11 days)	5 participants (4 female)	Bahasa	CV.PI
October 24th, 2020	Modern Beehive Co-Creation	Beekeepers	Madu Maribaya	4 hours (1 day)	4 Participants (2 female)	Bahasa	CV.PI
October 30th-31st, 2020	Workshop on Apis Cerana Beekeeping & Modern Beehive Usability	Beekeepers	Banjaranyar	7 hours (2 days)	17 participants (0 female)	Bahasa	CVPI

2.2.1 Workshop on SAMS modern beehive adaptation and prototyping

In February 2020, a training on modern beehive adaptation and prototyping was conducted by CV.PI in Bandung. The training focused on including knowledge transfer on the SAMS monitoring system and the product development framework (UCD) as well as practical training in SAMS system construction, hardware and software. It was designed as a 11-day continuous training and was aimed to expose the SAMS technology to broader audiences, particularly to people who are interested in or have a background in IoT development. Participants were intern students from the State Polytechnic of Bandung, majoring in telecommunication engineering.

Achievements

Theoretical and practical training for 5 intern students:

- Knowledge transfer and introduction to the SAMS technology and product development framework, including User Centered Design and agile methodology
- Practical training and knowledge transfer on tinkering a NodeMCU and RasPi firmware, Phyton programming language, as well as designing user interface using Figma
- Practical training in the construction of SAMS monitoring systems (assistance in assembling and finalization of the systems)

Encouragement of the participants to re-create their own bee monitoring system, adapting or modifying the existing SAMS monitoring system: successful introduction to the benefits of the monitoring technology.

Construction of 2 NodeMCU systems. The students afterwards owned the systems for their study. Implementation of the systems failed due to colony absconding in the dry season.

Lessons Learnt

LL for the optimization of the SAMS system

- Suggestions from students were considered in the development of the SAMS system. The suggestions included: adding a camera into the system, so the monitoring activity would be more visually intact, and adding a new output in the system, so the SAMS technology in the future will not only be able to monitor the colony, but also detecting forage availability in the ecosystem

LL on the value of SAMS for the participants/ SAMS users

- The students discovered that the SAMS system is useful for beekeepers in West Java – pointing out the benefits of real-time monitoring of bee colonies by local beekeepers

LL for the conduction of further training and on provided learning materials

- Feedback showed that they learned valuable skills in IoT engineering

Some students expressed interest in learning Design Thinking, Scrum and agile methodology which was used in the teamwork. They see this framework as innovative and efficient for product development and working management.

Figure 4 Assembling of hive systems (left) and visiting Tani Kota apiary and encountering colony absconding (right)

2.2.2 Modern beehive co-creation

Co-creation workshop with beekeepers, scientists and engineers. The one-day workshop was conducted in Madu Maribaya and aimed to co-create modern beehives for the adoption of the SAMS system. Participants developed capacity in the construction of modern beehives through a learning-by-doing approach.

Achievements

Practical training of and knowledge exchange between participants from different disciplines through co-creation of a modern beehive prototype that can be easily used for the implementation of the SAMS HIVE monitoring system:

- Knowledge transfer on modern bee monitoring technologies to the beekeeper
- Knowledge transfer of beekeeping modern beehive knowledge to the engineer, design researcher, and designer
- Fostering knowledge exchange and UCD-methodologies amongst stakeholders from different disciplines (beekeeper, engineer, designer)

In total, 20 modern beehives were built with the new design and are used for the SAMS HIVE monitoring system implementation.

Development of technical drawings of modified modern hives which later can be easily implemented. No cables will be visible and dangling outside beehives with this newly adapted modern beehive.

In a further step, the newly designed beehive prototypes are built, tested, and implemented together with the SAMS HIVE monitoring system.

Lessons Learnt

LL on the value of SAMS for the participants/ SAMS users

- The participating beekeepers found that the technology could be very useful for more effective bee monitoring. Beekeepers will be more courageous to open a new apiary if this technology can be practically used.

LL for the conduction of further training and on provided learning materials

- Co-creation ("two-way communication") was well-accepted by the beekeeper, although it was a new experience for him – the beekeeper was satisfied and open to share his knowledge to the engineer and designer
- Research and development on beekeeping was also well-accepted by the beekeeper and it is perceived as a useful tool to foster the digitalization of beekeeping

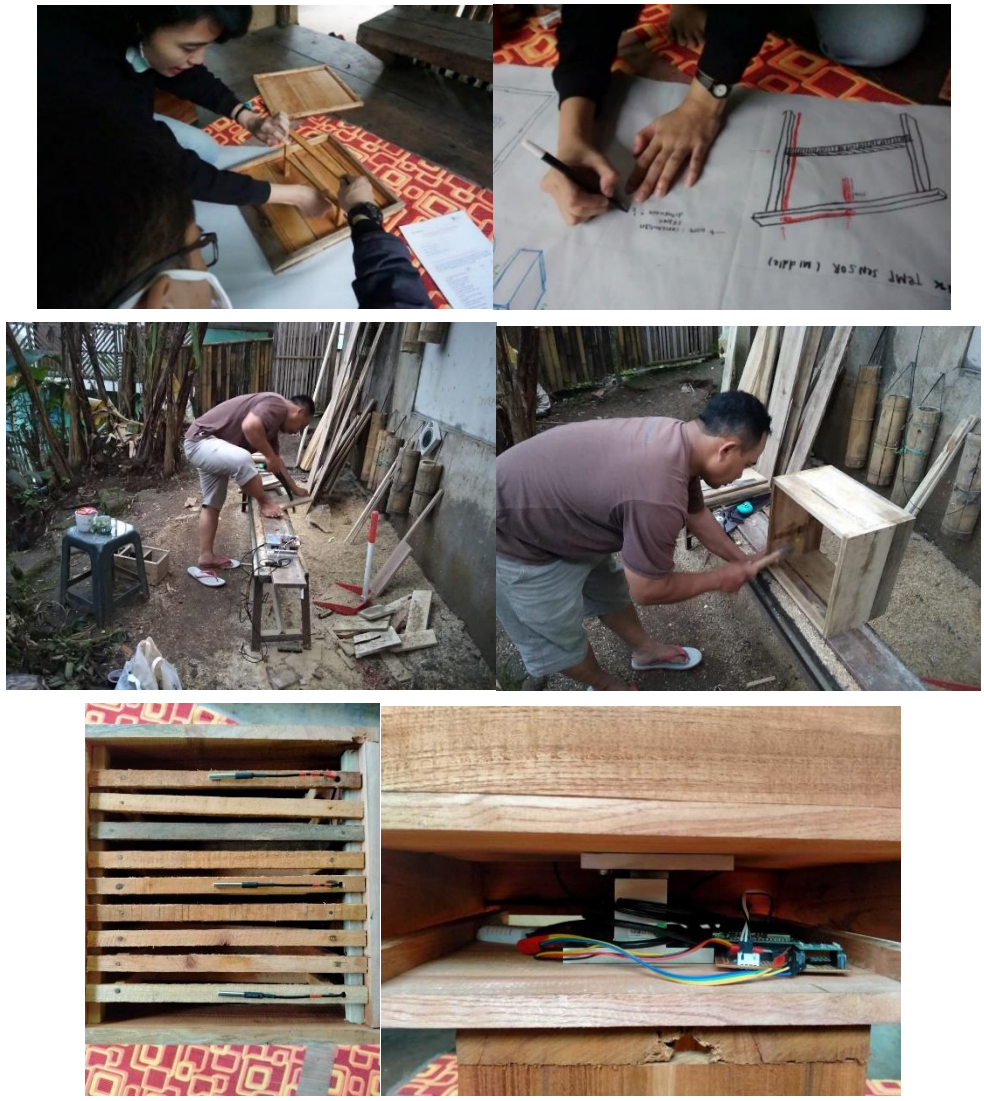


Figure 5 Modern beehives co-creation porocess with Koswara (beekeeper)

2.2.3 Workshop on *Apis Cerena* beekeeping and modern beehive usability

In October 2020, a training on *Apis cerana* beekeeping and modern beehive usability was conducted. Participants were grassroot beekeepers from rural areas.

Achievements

Theoretical and practical training of 17 beekeepers:

- Training in the usability of modern beehives and the SAMS monitoring system
- Field trip to the apiary site on KTH Bina Lestari in Village Banjaranyar, Ciamis regency area: demonstration how to maximize beekeeping potential by using modern beehives
- Knowledge exchange on A. cerana beekeeping methods and maximizing the potential of modern beehives usability

Lessons Learnt

LL for the optimization of the SAMS system

- SAMS can help grassroot beekeepers to monitor their deep-in-the-forest “beehive trap” and make beekeeping activity more effective, e.g. reduce transportation for beekeepers to check their beehive. But right now, SAMS is unable to fulfil this purpose concerning battery life/ electricity availability, telecommunication network signal strength and the complex/ big dimension of the system (makes it hard to travel on foot while carrying those around). Part of the reasons are out of the scope of SAMS, at it cannot influence local infrastructural aspects. Other reason was continuously in the focus of the system adaption.

LL for SAMS business development

- KTH Bina Lestari are potential partners for SAMS business

LL on bee-management and bee-health

- Beekeepers must to be able to place the system deep in the forest, as it is mainly common to place them there

LL on the value of SAMS for the participants/ SAMS users

- The participating beekeepers found that the technology could be very useful for more effective bee monitoring

LL for the conduction of further training and on provided learning materials

- According to participants’ feedback, one of the most valuable learnings from the training was the raised awareness for bee forage and its planting possibilities

- Physical meetings are valued as very important and required for this type of workshop and physical presence in the workshop is considered as respect towards the participants

Figure 6 Discussion on optimizing modern beehives (above) and demonstrating SAMS HIVE monitoring system implemented in the modern beehive (below)

2.3 Activities conducted in Europe

In Europa, trainings, lectures and workshops were conducted for 65 participants from different countries like Germany, Romania and Latvia. In two lectures for international students at the University of Kassel, project content as well as hardware and software of the SAMS HIVE system were taught based on the topics of digitalisation in agriculture and precision beekeeping. Information material on the construction of modern beehives in the EU was provided. 20 new modern beehives were acquired and 24 equipped during trainings with monitoring systems at UNIKAS.

Table 5 Activities conducted in Europe

Date	CB activity	Target group	Location	Duration	Participants	Language	Partner
November 15th, 2019	SAMS hardware system development	IT Students	Latvia University of Life Sciences and Technologies, LATVIA	8 hours (1 day)	23 participants (4 female)	English	UNIKAS UNILV
January 1st, 2019	Lecture Digitalization in agriculture (SAMS)	Students	University of Kassel, GER	2 hours	7 participants (4 female)	English, German	UNIKAS
Mai 13th, 2019	Training for Students	Students	University of Kassel, GER	2 hours	4 participants (1 female)	English	UNIKAS
November 25th, 2019	Training for Students	Students	University of Kassel, GER	2 hours	5 participants (2 female)	English	UNIKAS
February 10th, 2020	Training for Students	Students	University of Kassel, GER	2 hours	3 participants (0 female)	English	UNIKAS
May 27th, 2020	Training for Students	Students	University of Kassel, GER	2 hours	6 participants (2 female)	English	UNIKAS

August 10th, 2020	Training for Students	Students	University of Kassel, GER	2 hours	4 participants (0 female)	English	UNIKAS
December 9th, 2020	Lecture Digitalisation in agriculture: Precision beekeeping (SAMS)	Students	University of Kassel, GER	3 hours	13 participants (6 female)	English German	UNIKAS

2.3.1 Training on SAMS hardware system development

In the training conducted at Latvia University of Life Sciences and Technologies, IT students from the Faculty of Information Technologies and Erasmus students participated. The objective of the workshop was to introduce the SAMS project to the IT students, demonstrate different hardware and software solutions developed within the project, and to give hands-on exercises on SAMS hardware development and connection to the SAMS Data Warehouse.

Achievements

Practical and theoretical training of 23 IT students:

- The training allowed the participants to gain experience in system debugging to identify errors in hardware and software side, as it is an integral part in every system's design and development process. This also allowed to evaluate what should be changed/ improved to better detect and back trace possible errors during SAMS system setup
- Knowledge transfer on the SAMS project, precision beekeeping, bee colony monitoring and the SAMS hardware
- Knowledge transfer on the SAMS DW its specifics (authentication and authorization, objects and their mapping, logical structure and hierarchy etc.) and enabling participants to connect their prototypes to the DW using specific credential file and authorization procedure
- Practical exercise for the installation of SAMS Raspberry Pi image and connection of Raspberry Pi to the wireless network
- Assembling of the prototype for the SAMS monitoring system: based on provided schematic and instructions, participants connected different sensors to the breadboard

When prototypes were successfully connected, participants calibrated the scales and made several test measurements.

Introduction to Witty Pi for the Raspberry Pi power management and practical exercise to connect those two devices and test the power management options (schedule power on/ off times).

Lessons Learnt

LL for further development of the DSS

- The configuration of additional devices involved, such as Wi-Fi router, should also be considered: there were some issues with a network DNS (Domain Name Server) therefore additional router configuration was needed to grant the access to the SAMS DW
- The human factor is very important to develop working prototypes: it is needed to be very attentive while wiring the sensors and writing the code, as any mistake can cause system instability and even stop the operation

LL for the conduction of further trainings and on provided learning materials

- Based on the feedback it is suggested to decrease the time for the workshop and split it into two days as the topics requires high concentration of participants

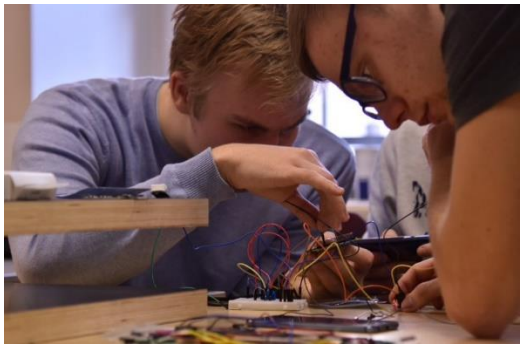


Figure 7 Assembling of SAMS HIVE monitoring system at LLU

2.3.2 Training for students – SAMS HIVE system implementation

In the respective training sessions, which were conducted by the University of Kassel at the test site and seminar room of the apiary in Witzenhausen, the students were taught the essential project contents and the construction and operation of the SAMS HIVE systems.

Achievements

Practical and theoretical training of students:

- The training allowed the participants to gain experience in system debugging to identify errors in hardware and software, as an integral part in every system's design and development process. This allowed to evaluate what should be changed/ improved to better detect and back trace possible errors during SAMS system setup
- Knowledge transfer on the SAMS project, precision beekeeping, bee colony monitoring and the SAMS hardware
- Knowledge transfer on the SAMS DW as part of the overall SAMS system
- Practical exercise for the installation of SAMS Raspberry Pi image and connection of Raspberry Pi to the wireless network
- Assembling of the prototype for the SAMS monitoring system: based on provided schematic and instructions, participants connected different sensors to the breadboard

When prototypes were successfully connected, participants calibrated the scales and made several test measurements. Introduction to Witty Pi for the Raspberry Pi power management and practical exercise to connect those two devices and test the power management options (schedule power on/ off times).

Lessons Learnt

LL for further development of the SAMS HIVE system

- The configuration was iteratively simplified based on the experience from the workshop, so that barely any specific technical know-how is required to configure the systems via a web interface

- Status LEDs were developed based on the hints and questions for quick recognition of the system status for unskilled users
- The cable routing from the computer case to the sensor frame could be significantly improved by observing students to be trained during the installation of the systems, thus simplifying the installation

LL for the conduction of further trainings and on provided learning materials

- The training material was adapted to the needs of the students and thus also for the end user. Answers to frequently asked questions, such as the configuration of the data warehouse, were recorded in the manual
- From the experience gained in the training with the students, the basis was created for a lecture on the topic of digitalisation in agriculture and precision beekeeping. Here, the practical knowledge is to be built upon

Figure 8 Assembling of SAMS HIVE monitoring system at UNIKAS

3. Main Achievements and Lessons Learnt

This chapter summarizes the achievements and lessons learnt from the capacity building program on modern beehive construction.

3.1 Main achievements of the CB activities

Table 6 Overview of CB activities and main achievements

Country / Region	No. of trainings	Hours of training	Total No. of participants	Participants	Languages
Ethiopia	8	187 hours (28 days)	125 participants (6 female)	Trainers (SAMS staff) IT companies apiculture start-ups start-up incubators beehive manufacturers apiculture input suppliers researchers	English Amharic

				beekeeping experts	
Indonesia	3	66 hours (14 days)	26 participants (6 female)	IT students beekeepers	Bahasa Indonesia
Europe	8	23 hours (8 days)	65 participants (19 female)	students, lecturers, beekeepers	English; German

In total, 19 trainings with 216 (31 females) took place in English and local languages.

Capacity building and knowledge transfer

Capacities and knowledge which were transferred through the training included:

- Practical and theoretical training on the HIVE monitoring system construction, installation and operation (inside and on the field): hardware and software adaptation, materials, components/ parts and their assembly
- Knowledge transfer on the SAMS HIVE monitoring functionality and benefits: SAMS data, hardware and software aspects
- Knowledge transfer on SAMS business development in the local context of Ethiopia and Indonesia
- Knowledge transfer on modern beekeeping and ICT solutions for apiculture in the local context of Ethiopia and Indonesia
- Knowledge transfer on the SAMS product development framework, including User Centered Design and Agile Methodology

Awareness creation and dissemination

Additional focus was put on awareness creation on the benefits of ICT for apiculture. First CB activities showed that most beekeepers in Ethiopia and Indonesia did not know about modern beekeeping technologies and modern beehive and that there was a great knowledge gap on the application and benefits of remote beekeeping technologies for beekeepers. Therefore, one main achievement of the trainings was successful awareness creation on ICT for apiculture and the SAMS HIVE monitoring system.

Building of HIVE systems for implementation and testing

In total, 41 SAMS HIVE monitoring systems were developed and 60 beehives constructed within the described CB activities in Ethiopia, Indonesia and EU.

- 15 SAMS HIVE systems were created within the trainings and most of them were implemented for testing and mainstreaming of the SAMS technology in Ethiopia. Additionally, 20 beehives and 100 frames were constructed.
- In Indonesia, 2 SAMS HIVE systems (NodeMCU based) were developed, and in addition 20 modern beehives were built in total and most of them were used for the implementation of the SAMS HIVE monitoring system.

- In EU, 24 SAMS HIVE monitoring systems were developed and 20 beehives were acquired.

In most CB trainings, Raspberry Pi based monitoring systems were used to explain SAMS HIVE hardware and software. In order to actively involve the participants in the development and to achieve the greatest possible learning effects on both sides, prototypes were presented in their different development phases and built, tested and implemented together. This applies to the system prototypes in their lo-fi (D3.2 Low-fidelity HIVE prototype design), hi-fi (D3.3 High-fidelity HIVE protoype design) and final versions (D3.4 Evaluation of HIVE prototype designs). Even though the training sessions took place with the Raspberry Pi based system, with the manual in D3.5 Manual on Hive Construction and Operation, the knowledge gained in the workshops can be transferred from the Rasberry Pi based system to the NodeMCU based system.

Optimization of the HIVE system

The program served to gain better understanding of the needs and requirements of SAMS users (including beekeepers, researchers, beehive manufacturers, input suppliers and trainers in the field of apiculture). The program served to gain better understanding of the needs and requirements of SAMS users (including beekeepers, researchers, beehive manufacturers, input suppliers and trainers in the field of apiculture). The feedback provided by participants of the trainings was used within the UCD-cycle and for mainstreaming of the SAMS HIVE monitoring system. By doing so, the training served to co-create and construct SAMS HIVE monitoring systems with future SAMS users and businesses and to learn from these experiences. The conduction of a co-creation workshop and observation made during practical beehive construction activities allowed to gain valuable knowledge for the optimization of HIVE system – and these lessons learnt were directly used for HIVE development and optimization during SAMS project time. In addition, all results of the conducted work and elaborated information were integrated into the transferability studies of the deliverables D6.2 Cross-Regional Transfer Study, D6.3 Transfer Study on Data Management and Utilization, and D6.4 Transfer Study on Technology and Services. Specific lessons learnt for the optimization of the HIVE system are listed in Chapter 2.2.

Development of learning materials

Throughout the SAMS project time, a variety of learning materials were developed to pass on knowledge on modern beehive construction, the HIVE system, and particularities of the local markets in Ethiopia and Indonesia. These training materials were developed in English language as well as in local language, depending on the language of the training. All materials were published on the SAMS website and SAMSwiki where they are publicly available. Furthermore, they were provided to the partnership network of the SAMS partnerships.

In addition, introductory videos on the SAMS technology were created and published: SAMS Hive system by Sascha Fiedler UNIKAS and The SAMS Hive System. The videos were shared and discussed during the SAMS Final Conference.

Fostering long-term capacity building

Through networking and partnership activities, three partnerships were developed to foster long-term CB in the target regions and beyond, and to ensure further development and mainstreaming of the SAMS technology and results. Capacity building within the partnerships is based on supporting knowledge transfer, mutual learning between different stakeholders of the apiculture sector and scientific society. It further aims at creating capacity through dissemination of the SAMS technology and SAMS knowledge, as well as through testing of the SAMS HIVE system with beekeepers and beekeeping related start-ups. The three partnerships are described in depth in the project deliverable D6.1 Documentation of established Partnership Networks and Agreements. Main contact persons for the partnership can be found on the SAMSwebsite:

- **International Partnership on SAMS Business Development (PS1):** CB of beekeepers, beekeeping-related start-ups and beehive manufacturers in the application and marketing of the SAMS technology and through support in business development.
- **International Partnership on Bee Colony Data and Knowledge Exchange (PS2):** CB of beekeepers and start-ups through involvement in testing of the SAMS Data Warehouse. In addition, the partnership aims at fostering knowledge exchange on modern beekeeping through further development and dissemination of the SAMSwiki platform. The SAMSwiki is a free open source wiki which was developed within the SAMS project and aims to collect beekeeping knowledge from around the globe.
- **International Partnership on Apiculture Technology and Services (PS3):** CB through the involvement of beekeepers and bee breeders in testing of the SAMS HIVE monitoring system.

After learning about the SAMS technology and project, several CB participants expressed interest in adapting the SAMS technology for their own businesses and in partnering with the “International Partnership of SAMS Business Development”. With this, the CB trainings were further used to foster the development of local and international apiculture networks and to sustain the SAMS results in its target regions in the long term.

3.2 Main lessons learnt from the CB activities

CB trainings were used as a form of continuous user-centred evaluation of the SAMS system. The SAMS HIVE monitoring system construction together with beekeepers, scientists, input suppliers and other beekeeping experts led to insights into technological strengths and weaknesses of the device as well as to needed adaptions in terms for easier and more user-friendly construction of the system. Moreover, insights from the participants served to gain new input in the needs and requirements of potential SAMS users and local conditions in which the system will be used (e.g. internet coverages, locally available materials, market structures).

LL for the optimization of the SAMS system

- Need for adaptation of some parts through cheaper parts (e.g. car battery)

- Need to replace imported parts through locally available materials (wires, solar modules and wooden materials can be obtained from local markets)
- Weak 3G network in Ethiopia can affect data transmission to the SAMS Data Warehouse
- Need to adapt the construction of the system prototype for easier construction, reparation and transport, and for better connectivity (accessibility of the SD Card Slot, placement of the Wi-Fi-router, construction of chambers and handles)
- Need to adapt measurements of the prototype (frame dimensions
- In Indonesia, during the system implementation phase, one of the feedbacks given by the beekeepers is concerning the ability of how the existing modern beehive can adapt the system monitoring augmentation. With existing modern beehives, when the SAMS HIVE monitoring system was implemented there were cables coming out from the beehives, this is visually attracting people's curiosity, which is avoided by beekeepers. Beekeepers in Indonesia are often struggling not only with pests but theft as well. Based on this feedback, a co-creation workshop is then initiated to create modern beehives that can be seamlessly augmented by the SAMS HIVE monitoring systems.

Figure 9 Modern beehives implemented (left) and modern beehives from the co-creation result (right)

LL for SAMS business development in Ethiopia

- Import of parts can be an obstacle for new businesses (e.g. sensor parts and scale units must be imported, e.g. from Germany)
- Many participants were interested in adapting the SAMS monitoring system and to partner with the SAMS business partnership (PS1)
- Need to install the systems during night-time as the bees in Ethiopia re particularly aggressive during daytime
- Participants gave feedback on market linkages and on registration procedures of the SAMS beehive as Ethiopian standard (dependence on customer orders)

LL for SAMS business development in Indonesia

- The students discovered that the SAMS system is useful for beekeepers in West Java – pointing out the benefits of real-time monitoring of bee colonies by local beekeepers

LL on the value of SAMS for the participants/ SAMS users

- High value of the system in Ethiopia as Ethiopian honeybees are very aggressive and frequently abscond

- The construction of the system is still complicated, and users require trainings to understand how to build working prototypes by themselves
- Participating researchers and beekeeping experts found that the SAMS technology can further enable the beekeepers to harvest more honey by solving disturbances of bees and solving colony follow-ups

LL for the conduction of further trainings and on provided learning materials

- Need to develop a rough guide for prototype installation procedures & for continuous training
- Participants in the ID training expressed interest in learning Design Thinking, Scrum and Agile Methodology which was used in the teamwork

3.3 Challenges for the implementation of CB activities

Despite carefully planning and organizing the CB activities, not all aims could be achieved as not all trainings could be implemented as planned and particularly female participation within the trainings was very low. This was due to unexpected challenges due to the COVID-19 pandemic, unrests in Ethiopia and other factors.

Effects of COVID-19 pandemic

The pandemic COVID-19 situation required rescheduling and adaptation of all Capacity Building (CB) activities in all target regions conducted after February 2020, as gatherings and event organizing were not allowed (or partially allowed but with rules that made it difficult to conduct such activities). Some activities had to be cancelled due to restrictions on physical contact and travel. Virtual conduction was considered in the EU but not as effective. In addition, partnership activities were restricted due to continuing restrictions on physical contact and travel. This affected the establishment of international partnerships, as well as the presence of partners during the final signature ceremony.

Ethiopia: As in the rest of the world, COVID-19 was also affected the capacity building activities in Ethiopia. Based on the original capacity building plan, CB on beehive construction was planned for 78 individuals. Also 5 CB training for 40 were individuals planned on beehive monitoring system construction. But due to COVID-19 pandemic, only 38 beehive manufacturers and 18 IT expert participants received the training.

Indonesia: Based on the assumption that the situation would improve after three to four months, capacity building activities planned in Indonesia were temporarily postponed in March 2020. After realising that the pandemic situation would prevail until SAMS project end in December 2020, the conduction of online trainings was considered. Nevertheless, training for system implementation and modern beehive construction were not possible to be conducted as virtual training. With not much time left on the project, the Indonesian partner carried any capacity building activities that were still possible and corresponding with any related COVID-19 local restrictions and regulations. Once the pandemic situation improved around June-July and citizens were well informed about hygiene measures (physical distance, mask wearing, etc.), a workshop could be realized with limited participants - in an open-air room and restricted

time. Nevertheless, the limitations which came with COVID-19 led to reduced numbers of participants.

Europe: Due to COVID-19, UNIKAS was not able to travel to Ethiopia and Indonesia and provide face to face workshops as planned. As a result, no further hardware implementation workshops were held abroad. Lectures were held virtually, and workshops and video production were conducted as CB material with distance rules. Due to COVID-19, the final phase of the system implementation in Indonesia and Ethiopia could unfortunately not be carried out as planned, so that local problems could be identified late or insufficiently and adapted or fixed. In addition to the reduction in the availability of personnel to build the systems, the lack of limited presence of UNIKAS played a significant role in the result of the implementation.

Unrests in Ethiopia

Five capacity building trainings were cancelled due to the recurring unrest in Ethiopia. As a result, the numbers of participants in the trainings were reduced.

Reduced female participation

Although it was aimed to foster female participation in the trainings, female participation in the CB program on modern beehive construction was relatively low. In total, 31 out of 216 participants were female, which is caused by several factors:

- In Ethiopia, the beekeeping sector is dominated by men. Only few women are involved in beekeeping activities. In addition, activities which were planned to be conducted with female participants had to be cancelled due to Covid-19 and unrest in ET. Thus, the female participation in CB activities was low.
- In Indonesia, beekeeping is still dominated by male actors and actually the wife and daughters usually only support the beekeeping activity. The reason why beekeeping is still perceived as “masculine” profession is mainly because bees have a dangerous stigma, and many beekeeping practices in Indonesia involving bee hunting in jungles, high trees, and death rate by non-domesticated bee stung are still occurring. Therefore, it was very difficult to include female beekeepers in the trainings. On the other hand, it was much easier to involve female technology students in the trainings in Indonesia. Although technology-related students are primarily male, nowadays this paradigm is shifting due to active movement and encouragement through the “woman in STEM (Science, Technology, Engineer, and Mathematic)” campaign. As proof, the involvement of female participants in the system monitoring capacity building in February 2020 was four out of five participants.
- In Europe, female participation was relatively low as the trainings were conducted in universities where the overall rate of female students in technical study programs is not very high. For example, at the Faculty of Information Technologies at Latvian University for Life Sciences and Technologies it is for example less than 10%.

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