Smart apiculture management services for developing countries - the case of SAMS project in Ethiopia and Indonesia

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The European Union funded project SAMS enhances international cooperation of ICT (Information and Communication Technologies) and sustainable agriculture between EU and developing countries in pursuit of the EU commitment to the UN Sustainable Development Goal “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”. The project consortium comprises four partners from Europe (two from Germany, Austria and Latvia) and two partners each from Ethiopia and Indonesia. Beekeeping with small-scale operations provides perfect innovation labs for demonstration and dissemination of cheap and easy-to-use open source ICT applications in developing countries. SAMS allows active monitoring and remote sensing of bee colonies and beekeeping by developing appropriate ICT solutions supporting the management of bee health and bee productivity as well as a role model for effective international cooperation. SAMS addresses requirements of end-user communities on beekeeping in developing countries by following the User Centred Design (UCD) approach. It includes technological improvements and adaptation as well as innovative services creation in apiculture based on advanced ICT and remote sensing technologies. SAMS increases the production of bee products, creates jobs (particularly youths/women), triggers investments, and establishes knowledge exchange through networks.

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Abstract

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Introduction

Pollination through insects is basic to agricultural and horticultural plants. It has been estimated that 66% of the worlds crop species are pollinated by a diverse spectrum of bees, including the polylectic honey bee (Kremen, Williams and Thorp, 2002; Partap, 2011). The symbiosis of pollinated species and pollinators is in a sensitive balance and the reduction and/or loss of either will affect the survival of both (Abrol, 2011; Panday, 2015). Thus, the conservation of honey bees and other pollinators is of great interest to maintain biodiversity, to provide the world's food security and in a broader sense to ensure our existence (Potter et al., 2019). Honey bees do not only play a key role in preserving our ecosystems, beekeeping also positively contributes to income gain (Bradbear, 2009). The pollination process is crucial for the reproduction of cross-pollinated plant species, increases the yields and enhances their quality (Fichtl and Adi, 1994; Eilers et al., 2011; Admasu et al., 2014; Klatt et al., 2014). Besides the important aspect of pollination, honey bees also produce a variety of bee products, including honey, beeswax, pollen, royal jelly or propolis which also leads to an economic benefit for the beekeeper (E Crane, 1990). During the last decade, honey bees got further into the center of the world's attention due to higher colony losses than usual (Oldroyd, 2007; Van Der Zee et al., 2012; Brodschneider et al., 2016; Gray et al., 2019). In 2007, the term colony collapse disorder (CCD) was coined for the depopulation of a honey bee colony (Oldroyd, 2007; van Engelsdorp et al., 2008; Dainat, VanEngelsdorp and Neumann, 2012). The reasons for this phenomenon are not yet well understood, but it is suggested that proper hive management lowers the risk of CCD and colony losses in general. Meanwhile, the role of bees for the world's economy and food security is undoubted and therefore not only scientists, but also farmers, ecologists and policy makers join together to make efforts in preserving them (EFSA, 2013).

Proper hive management and monitoring for pests, parasites and diseases, as well as for colony strength were identified to be crucial factors for honey bee health and productivity and therefore are regarded as vital elements of successful beekeeping (EFSA, 2013). To assess those parameters, beekeepers must open the hive and visually inspect it regularly (Van Der Zee et al., 2012; Delaplane, Van Der Steen and Guzman-Novoa, 2013; Brodschneider et al., 2016, 2018; Gray et al., 2019). However, manual monitoring of beehives is a time-consuming process for beekeepers and stressful to the bee colonies. Time-consumption even increases with the distance of the beekeeping sites to the homesteads, so every inspection also incurs travel costs to beekeepers (Meikle and Holst, 2015; Zetterman, 2018). Further, honey bee species and races differ in their behavior (Gupta et al., 2014). While the Asian honey bee Apis cerana is known for their gentle temperament and easy handling, African Apis mellifera is very aggressive, causing safety issues for the beekeepers during hive operation. To facilitate the hive management

procedure, the implementation of smart apiary management services is believed to be the future (Bencsik et al., 2011; Edwards-Murphy et al., 2015; Meikle and Holst, 2015; Zacepins et al., 2016). For this approach, information communication and technology (ICT) based on remote sensing tools to monitor the bee colony's health and productivity are used (Zacepins et al., 2015). So far, several multi-dimensional monitoring information systems have been developed and applied in "Precision Beekeeping" (Kviesis et al., 2015; Zacepins et al., 2015; Rodriguez et al., 2017; Komasilovs et al., 2019; Kontogiannis, 2019), but only a few implemented solutions for honey bee data collection offer basic functionality for data analysis and decision making and hence still need to be improved (Kviesis, Zacepins and Riders, 2015).
A combined biological, sociological and technical approach is made within the SAMS (Smart Apiculture Management Services) project. It enhances international cooperation of ICT and sustainable agriculture between EU and developing countries in pursuit of the EU commitment to the UN Sustainable Development Goal "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". Main objectives of SAMS are to develop, refine and implement an open source remote sensing technology for monitoring the health and productivity of bee colonies and to foster the regional added benefit and gender equality in employment. Precision beekeeping is increasingly implemented in Europe, but lags behind in Africa and Asia. The SAMS project focuses on beekeeping in Ethiopia (Demisew, 2016; Negash and Greiling, 2017; Wakjira and Alemayehu, 2019) and Indonesia (Gratzer et al., 2019) as in those countries there is a huge beekeeping potential that is not fully discovered yet. An important asset is the co-creation of local systems, to avoid falling in the trap of other beekeeping programs in developing countries (Nat Schouten and John Lloyd, 2019). As mentioned before, maintaining honey bees has a high potential to foster sustainable development in different economic sectors, such as the beekeeping sector itself, the forestry, agricultural or the beauty (cosmetics) sectors of developed and developing countries (Bradbear, 2009; Gupta et al., 2014). It also creates jobs, income and contributes to the global fight against hunger (Panday, 2015; Roffet-Salque et al., 2015). SAMS and its cooperation on international and national level comprises of mutual learning and research on best-suitable open source ICT technology and best-practice bee management.
Aim of this paper is to give overview of the SAMS project and present ideas and concepts that have been or will be developed including beekeepers, business facilitators, researchers and others. This article presents main ideas and achievements within the project from different points of view and includes basic principles of User Centred Design, the SAMS developed bee colony monitoring device and proposed data warehouse. Api management and development of beehives for Ethiopia and Indonesia are included as well. Possibilities for smart apiary management and possible SAMS business models are described too.

Concept of the SAMS project

Advanced ICT and remote sensing technologies enhance precision apiculture and help to increase the role of bees in pollination services as well as the production of hive products while maintaining a healthy environment. Precision apiculture is an apiary management strategy based on the monitoring of individual colonies without hive inspection to maximize the productivity of bees (Zacepins et al., 2015). Driven and based on the User Centred Design approach, SAMS is an apiary management service based on three pillars:

1. Development of modern and modular hives, adapted to the local context, equipped with a remote measurement system for bee colony behaviour, productivity and health status monitoring,
2. Development of a cloud-based Decision Support System (DSS) to implement a management Advisory Support Service (ASS) for the beekeepers,
3. Development of adapted bee management guidelines about seasonal changes, available forage plants, needed beekeeping actions based on ICT concepts.

User Centred Design (UCD)

It is worth to underline that the whole process within SAMS follows a user centred design approach - a more holistic term is human centred design (HCD). All actions and developments within the project are performed in close cooperation and collaboration with the end-users (especially with the focus user group: beekeepers).

"Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, usability knowledge, and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance" (BS EN ISO 9241-210:2010(E), 2010). Human centred design is a multi-step iterative process (see Fig. 1) and includes analysing the context of use, specifying the user requirements, producing design solutions and evaluating them against those user requirements, if possible, with user participation.

Within the SAMS project, a thorough user research and context of use analysis has been conducted to understand the preconditions of local potentials and challenges for a successful technology supported apiculture. In order to include beekeepers as the SAMS focus users, empirical methods like contextual interviews, observations, surveys, workshops, focus group discussions and field studies have been undertaken. Results have been documented and presented to all SAMS team members and beekeepers for review. Based on the results, the SAMS team together with beekeepers started a collaborative design thinking process and produced concepts and low-level prototypes for key products around the decision support system (DSS) and the advisory support service (ASS) for beekeepers.

With the diverse contexts of implementation in Indonesia, Ethiopia and EU countries, SAMS meets the challenge of including culture specific variations in the prototyping process. These culture specific variations consider different beekeeping traditions, different bee types and climate conditions as well as different languages, different social and political contexts. Multidisciplinary exchange of information and collaboration between local culture experts, beekeeping experts, hardware specialists, database architects and software engineering specialists are absolutely essential. The collaboration is motivated by a goal-oriented strategy following the main idea to develop technically robust, reliable, easy to use, easy to maintain (under the specific conditions) and affordable services that provide added (economical) value to the beekeepers.

SAMS Service Design

Besides an open source remote sensing technology for monitoring the health and productivity of bee colonies, SAMS fosters the regional added benefit by identifying business models and creating jobs. Incomes for the different target groups can originate from purchasing and subscription fees from the actual end-users, from selling data and expertise as consultancy services to larger agricultural players, from selling detailed ecological/climate/flora information as input for precision apiculture, or from honey exporters relying on quality and traceability indicators for their technological solution, continuously refined based on the actual requirements of the users and their context of use.

SAMS designs concepts for a locally feasible and sustainable assembly of the SAMS hardware, as well as adapted distribution and maintenance strategies. Funding models for start-ups or dependencies to upscale the SAMS monitoring system implementation locally and regionally will be suggested.

Development and standard of SAMS beehive

One of the aspects of SAMS is related to development and standardisation of the beekeeping practice in Ethiopia and Indonesia. To achieve this the first stage is generalisation of the beehive construction and development of a standard SAMS beehive, which can be used in future beekeeping and enables sensor placement and information technology implementation.

A modern beehive is an enclosed, man-made structure in which honey bee 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 convenience for the work of beekeepers. In traditional hives, honey bees build their natural nest by constructing a group of parallel combs vertically downwards from the roof of the nest cavity almost the same way as they do in wild nests. During comb construction, the space - called “bee space” - they leave between the combs and comb spacing (midrib to midrib distances), and lots of striking features and variabilities are found varying from species to species and among the different races of a species (Seeley, 1977; Jensen, 2007). To gain insight into details of the requirements of honey bees, preliminary studies on bee space measurements from different agro ecologies of Ethiopia and assessment of dimensions of different beehive components manufactured in different workshops have been conducted for A. mellifera colonies (https://sams-project.eu/). For A. cerana requirements, different literatures were assessed and consulted, needs and requirements were analysed

(Florida, n.d.; http://ecoursesonline.iasri.res.in/mod/page/view.php?id=16210, 2020; Mogens Jensen, 2007; Schouten, Lloyd, & Lloyd, 2019). The results from studies have then been used in determining the bee space, comb spacing and other hive dimensions to develop standards and material specifications for new beehive according to the need and nature of the two honey bee species.

To select the prototype to design and develop the standard beehive for SAMS, various available prototypes have been considered. Improved modern beehive such as Langstroth, Dadant, Foam, Zander, and modified Zander have been assessed for their advantage and ease of construction. All of these considered prototypes are designed and have been optimized for A. mellifera and A. cerana. From the preliminary study and literature analysis results, dimensions of different parts and procedures required for hive construction have been carefully organized for the standard SAMS beehive in such a way that a complete hive system can easily be produced locally and beyond the project for use in the beekeeping industry. For this purpose and the required criteria, Langstroth and its modified version the Dadant model were chosen for the standard SAMS beehive. The reasons for choosing these two prototypes are several: 1) 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; 2) familiarity of the hive systems in project countries and beyond is another important aspect. Almost all-commercial beekeeping throughout Europe, North America, Australia, and parts of South America and Asia, as well as in some African countries operate based on the Langstroth and Dadant pattern (Atkins, Grout and Dadant & Sons., 1975; Segeren and Mulder, 1997). This universality can help easy adaption of the new SAMS beehive system among the beekeeping community assuring sustainability of the project; 3) 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; 4) in terms of price, standardizing enables consistency of parts production across manufacturers in different workshops in different regions. This will bring prices of hive parts down to very reasonable levels and opens the opportunity to make business out of beehive production. Therefore, this can assure sustainability and create impact on productivity and bee health, as this innovation can transform beekeeping activity into a full-scale industry.

The proposed beehive system sketch is shown in Figure 2. The complete system consists of a loose bottom board, bottomless brood chamber, supers above brood chamber, inner cover and outer cover. The bottom or lower chamber is used for the queen to lay eggs, and the above boxes (supers) to serve as honey storing room for the bees. The volume of each chamber is based on the assumption of 10 vertically hanging frames that can be placed for the bees to build their honeycombs. Between the frames, other parts and each frame - a 10 mm bee space for A. mellifera and 9 mm for A. cerana - to allow movement of individual worker bee for comb construction, brood rearing, and storing foods are considered. However, the major difference in this development compared to the previous prototypes is that the bottom board and inner cover are designed to serve additional multiple roles or purposes.

Proposed dimensions and detail views of a beehive bottom board is described in manual on beehive construction and operation (https://sams-project.eu/wp-content/uploads/2018/10/D.3.1_SAMS_Manual-on-Beehive-construction-and-operation.pdf).

SAMS Hive monitoring system

In modern beekeeping in Europe, precision beekeeping is well established with many commercial systems available for remote bee colony monitoring, mainly recording and transmitting weight measurements (Lecocq et al., 2015).

Some of these commercial solutions are expensive and Ethiopian or Indonesian beekeepers cannot afford them. Some systems do not provide data transfer capabilities using the mobile networks, others do not work without standard power supply. Thus, within the project the SAMS hive monitoring system, considering peculiarities of the two target countries and based on the local beekeepers needs have been developed.

The system contains several functional groups:

1. A power supply with router to run up to 10 monitoring units;
2. A central computer unit where the sensors are connected;
3. A sensor frame with temperature sensor and microphone placed in the beehive;
4. A scale unit placed beneath the beehive with outdoor temperature and humidity sensor.

The power supply for the monitoring units is provided by a photovoltaic system (power unit) via cables. It consists of the standard components: solar module, charging controller and battery. The power unit also supplies a mobile GSM Wi-Fi router which is used as a hotspot for the monitoring units to transfer data to a web server (SAMS Data Warehouse). The flow chart of the SAMS HIVE system is shown in Figure 3.

The monitoring unit consists of a printed circuit board (PCB) with Raspberry Pi single board computer, a step-down converter to change the voltage of the power unit to 5V, and a 24-bit analog-to-digital converter (ADC) that converts the Wheatstone bridge signals of the load cell to a digital format. The load cell measures the weight of the colony. The sensor frame with temperature sensor and microphone are also connected to the computer. This allows acoustic signals and colony temperature to be recorded. The acoustics are recorded over a certain timespan and uploaded as Fast Fourier Transformed (FFT) spectrum. It is recorded with 16 kHz sampling frequency, covering a frequency range from 0 kHz to 8 kHz. The FFT is made with 4096 points resulting in a frequency resolution of approx. 3.9 Hz.

The computer can easily be extended with additional sensors. For example, it is possible to connect a small weather station to collect region-specific climate data. It is also possible to connect additional temperature sensors to be placed in different hive locations (top, bottom, in frames). A deep sleep mode can be used in between the measuring intervals by means of a power control unit (WittyPi) in order to reduce energy consumption considerably. As soon as the computer receives power from the power unit, it starts the measuring routine. The measuring routine and the interval can be adjusted as required.

After successful recording, the data is transferred via Wi-Fi to the mobile GSM router and sent to the web server (Figure 3 and Figure 4). If the upload is not possible, the data remains on the SD card until a successful upload has been performed. In this case, a new upload attempt starts after 30 seconds. Each device has its own ID so that it can be uniquely assigned on the web server. Individual sensors can also be added to users, locations or groups on the web server. Successful recording, data storage, uploads or errors are logged and transferred to the web server. Events for troubleshooting can be viewed there by administrators. On the device, 2 LEDs indicate working or deep sleep mode. Plug connections ensure easy installation. The sensor frame is connected via a 9-pin D-Sub connector and a standard DC power plug was selected for the power supply.

A software was developed to operate the Raspberry Pi and its components as a monitoring system. In order to ensure the simple and long-term availability of the code, a separate SAMS page was created on the Github developer platform. The code can be found open source at https://github.com/sams-project. The Github page contains the code to operate the monitoring system and a web application to calibrate the functions.

The recommended installation is to use a sensor frame above the brood chamber (Figure 5). The sensor frame contains microphone and temperature sensor. The sensors are installed centrally in the frame so that they are located above the brood nest. The frame is placed horizontally on the brood chamber and the sensors are connected via cable to the PCB with the computer unit.

The current price of SAMS monitoring system hi-fi prototype is about 170 €. In addition there are the expenses for power supply and GSM. The dimensioning of the photovoltaic system for power supply depends on the location, the number of monitoring units and the measuring intervals but is about 200 € for up to ten monitoring units. Qualitative electronic components were used to ensure the sustainability of the monitoring system. The components are robust, durable and can also be used for other purposes. The design is suitable for a simple deconstruction of the components. A recycling plan should support this if necessary. In addition to its expandability, the system can also be used for other academic and research applications as well as for bee institutes to collect sensor data.

SAMS data warehouse

All the measured data about the behaviour of the bee colonies should be stored for further analysis and decision support. Aim of the Decision Support System (DSS) is to analyse data and compile it into useful information readable by end-users. To extract valuable information for the beekeepers in Ethiopia or Indonesia the data must be analysed, interpreted and translated into understandable instructions that consider the operational ability of the users. The main aim of the DSS is to detect and recognize various bee colony states and inform the beekeeper. Still it needs to be noted that beekeepers remain as the final decision maker and can choose when to take action.

For the SAMS project each country context and environmental factors will be thoroughly analysed to develop specific algorithms that allow safe interpretation. The SAMS DSS is expected to have a modular design, consisting of a comprehensive expert interface, which

apiculture experts can use, e.g. in a service centre, to analyse and monitor data, as well as easy to use and understand views on smartphones or SMS services, that alert beekeepers about hives that need attention. The user centred design approach makes sure that technical layout and user interfaces will be developed in parallel, based on shared research results. With the decentral approach of response, local beekeeping experts can assist the beekeepers if needed.
For the bee colony data storage a data warehouse (DW) was developed (Komasilovs et al., 2019), which can be considered as a universal system, which is able to operate with different data inputs and have flexible data processing algorithms (Kviesis et al., 2020). Architecture of the planned DW is demonstrated in Figure 6. DW is capable to analyse data in real-time or store it for future analysis.

Api-management within SAMS

Api-management is also part of the SAMS project, including the contextualizing of local systems focusing on the two target countries Ethiopia and Indonesia, the development of an open source and agile database and a honey bee health and management related capacity building strategy.
In Europe, the beekeeping sector is comparably strong and Europe is the second most important honey producer in the world. However, the EU is a net importer of honey from third countries as the production is not sufficient to saturate the market (García, 2018). Governmental involvement and subsidized national programs aim to strengthen the stagnated European bee product market.
In Europe, beekeeping has a long tradition and knowledge is accessible by numerous books and journals. Bee health is affected by a diverse spectrum of organisms (Protozoa, fungi, bacteria, insects, mites, etc.) (Bailey and Ball, 1991; Genersch, 2010), but the parasitic mite Varroa destructor, introduced to Europe, is the major threat to European honey bees (Rosenkranz, Aumeier and Ziegelmann, 2010). Without proper control mechanisms by the beekeepers, the affected honey bee colonies die within 2-3 years. The varroa mite seems to be no big issue for Ethiopian nor for Indonesian honey bees but this is not well documented. Besides mites, several other organisms affect Ethiopia's bees, including Protozoa, fungi, insects, birds and mammals, but with the exception of ants or wax moths, mostly no treatment methods are applied (Ellis and Munn, 2005; Awraris Getachew Shenkute et al., 2012; Tesfay, 2014; Pirk et al., 2015).
In Ethiopia, beekeeping dates back ~5000 years (Tekle and Ababor, 2018), and more than 1 million households maintain around 10 million honey bee (Apis mellifera) colonies producing 53000 tons of honey per year, making Ethiopia to Africa’s leading honey and beeswax producer (FAOSTAT, http://faostat.fao.org). However, the apicultural sector is far behind its potential of 500000 tons of honey per year. The reasons include limited access to modern beekeeping practices and equipment, a shortage of trained work forces, the usage of agriculture chemicals, drought seasons, and the lack of infrastructure and market facilities (Yirga et al., 2012; Legesse, 2014; Fikru and Gebresilassie, 2015). 95% of Ethiopian beekeepers use traditional hive-systems that are often non-sustainable (clay, straw, bamboo, logs, ...) and have a low productivity (Yirga and Teferi, 2010; Beyene et al., 2015). Beekeeping training centers in Ethiopia are rare and in general, local beekeepers gain their traditional knowledge from further generations of the family

or village (Fichtl and Adi, 1994). Among others, Holeta, the largest bee research institution in the country, is also involved in educating beekeepers and connecting them by offering training and hard copies of training manuals for beginners and advanced beekeepers including beekeeping equipment production manuals. Through national and international partnerships and development programs, the Ethiopian beekeeping sector is on its way to align with global honey market players.

The beekeeping situation in Indonesia further differs from that in Europe or Ethiopia. In relation to the large Indonesian population size, beekeeping is no widespread activity and beekeeping-related literature is sparsely available (Gratzer et al., 2019). Honey hunting has tradition in parts of the country, but managing of honey bees in hives is a comparably young activity in Indonesia. Most beekeepers keep the native Asian honey bee Apis cerana, followed by the introduced A. mellifera which is mainly used for migratory beekeeping. While A. cerana is regarded less productive than A. mellifera, it is known for its easy handling and gentle behavior. One major problem identified is the absconding behavior of Indonesian bees. During unfavorable conditions, the colonies leave their hives, which leads to financial losses of the beekeepers. Other reasons for the underdeveloped beekeeping sector partly overlap with those of Ethiopia, others are specific for Indonesia such as the missing quality standards for bee products (E Crane, 1990; Masterpole et al., 2019). Due to the limited access and availability of literature, little information is given on bee health issues, treatment methods or management of honey bees in Indonesia (Gratzer et al., 2019). Within the last few years, minds are about to change. More and more people become aware of the importance and potential of the honey bee and the prerequisites Indonesia, which is rich in flora and fauna, offers for beekeeping.

As contextualizing is an ongoing process, a growing digital knowledge database was created - the “SAMSwiki” (https://wiki.sams-project.eu). The SAMSwiki is open to everyone and has a wiki like approach that offers the opportunity for every interested person to contribute its knowledge. The SAMSwiki is based on a literature research and so far, was fed with over 130 literature sources. Topics include the current beekeeping situation in Ethiopia and Indonesia, bee management options, and SAMS-system related content.

Possibilities for smart bee management

Managed bee colonies need regular monitoring actions. Especially during the active foraging season, external or internal hive inspection is a necessary task for each beekeeper. Those actions are time-consuming and especially the regular opening of the beehive is a stress factor for the colony. With smart management, or precision beekeeping, those mandatory interferences are reduced to a minimum (Bencsik et al., 2011; Meikle and Holst, 2015; Zacepins et al., 2015). Smart bee management possibilities can be manifold and some of them, including the most relevant ones for the SAMS-project, are represented in Table 1. For example, the start of a mass nectar flow indicates honey yield in the near future and so far, beekeepers either estimated this event by knowing the vegetation in the surrounding, by observing the flight entrance or by checking the inside of the hive, but a technical solution would make the beekeeper’s work more efficient. The beekeeper gets informed as soon as an increase in weight of the monitored beehive by a certain, prior defined, percentage-value occurs and based on the identification of this event, further actions can be planned without even being present at the apiary (migrating bee colonies, management options, planning of honey harvest, etc.). A typical event occurring only in African or Asian colonies is absconding, which has not been studied before using precision beekeeping. Within the project some easy to understand illustrations have been developed for each important bee colony state, including basic recommendations for the beekeepers. One example can be seen in Figure 7.

Business models within SAMS

One of the SAMS goals is to provide a platform, concepts and ideas for local business developments. Figure 8 illustrates the overall concept of the SAMS business model that involves various stakeholders in the process.

SAMS technology produced from the University's research process aims to make beekeeping activities more effective and efficient. In addition, to the production of the appropriate SAMS technology, the university implements the technology in the beekeeper's community and conduct training for technical maintenance. In making this technology, it is high cost to produce this technology so it is quite difficult for its marketing to beekeepers. In this case, beekeepers are beneficiaries whom implement technology, so the University needs funding. The funding could be fulfilled by collaboration with Government and business people as Funder. SAMS Technology can produce data (SAMS Data, Research & Theory Cloud) that can be utilized by the wider community both by the government, researchers, and universities themselves.

SAMS data can be combined with NGOs data that can be utilized by the government (described as institution mountain) to help policies making in the fields of forestry, animal husbandry, agriculture, and the environment. The policy is then derived as an intake of community empowerment, leaders and other driving nodes. SAMS Research and theory cloud data produced and processed into useful information for beekeeping management and then distribute open source to provide benefits to beekeepers and other stakeholders who need it. By this sharing activity, there will be engagement between University and Community. This concept is also expected to provide valuable benefits for the stakeholders involved. For beekeepers, bee colony management technology (SAMS) developed is obtained free of charge, as well as raising awareness in protecting the environment and government policies that support beekeepers and environmental communities. For governments, universities and businesses as funders, getting data from the technology applied to the colonies maintained by beekeepers for research and policymaking.

There are three directions that still need to be improved:

Practice - The role that individuals play in driving institutional change is key in building the SAMS ecosystem. Much remains to be identified as a potential for development involving many stakeholders. There is, therefore, a need to recognize the importance of key individuals in driving the SAMS ecosystem, and empowering them to further expand (and more importantly to facilitate others to expand).

Institutional - There remains a lack of institutional support within to support the SAMS ecosystem but it is the potential to be developed in Indonesia. Furthermore, SAMS Technology will also establish a social innovation to engage more socially aspirational younger generations (i.e. their customers) to be more involved in the honey & Bee Industry.

Systemic - The key social problems facing the SAMS Technology application in Indonesia. The market survey will also map the research through participant survey responses include all respondent-identified potential in supporting the future business model of SAMS application in Indonesia. Wealth was also identified in the interviews as a key determinant of all these other issues, how to develop SAMS Business and maintain its sustainability showing the interrelated nature of technology and also social problems, reinforcing the need for a collaborative, multi-agency approach to solving these future challenges in implementing the SAMS technology. Finally, there remains a lack of clarity around the concept and definition of the SAMS Business (which is still in the research process) makes it a challenge to be solved among strategic leaders to understand and implement the SAMS.

Conclusions

The SAMS project developed an open source information and communication technology that allows active monitoring and managing of bee colonies to ensure bee health and bee productivity. Continuous monitoring of variables associated with honey bee colonies, including weight changes, temperature, humidity, acoustics, activity at entrance for detection of different bee colony states like swarming, broodless stage, and others is becoming feasible for most practical applications. Established European or North American systems do not sufficiently take notice of peculiarities that can be expected when monitoring colonies in Africa or Asia. Application of SAMS can give answers to the requirements of beekeeping in different countries and settings, for sustainable agriculture worldwide. However, to develop SAMS to the local context, the project targeted to collect data from different user groups (individual beekeepers, beekeeping cooperatives, private and public input supplier like beehive producers, beekeeping experts and researchers and others) for UCD analysis. Through this approach, SAMS wants to overcome country-specific challenges of beekeeping and simplify the management. At the end of the project, there will be the possibility to understand the behaviour of bees and the environmental aspect better to ensure food production and bee farming activities. In addition, the production of bee products increase, jobs are created (particularly youths/ women), investments are triggered and knowledge exchange networks established. Final outcomes of the project are: a) a physical low-cost beehive model, that is locally produced and adapted to local conditions, including integrated open source sensor and information transition technology, as well as energy-supply solution; b) a decision support system that combines the sensor-based data-outputs with other information sources and predictive models to measure, analyse and describe different states of the bee colony such as health, vitality, production, etc. c) an automatic advisory support tool, which will alert the beekeeper in an easily understandable way if any aberrations from normal states are metered and will provide advice on appropriate countermeasures and d) a bee management business concept for the local production and up-scaled implementation of the developed beehives with integrated beehive monitoring system.

References

Abrol, D. P. (2011) Pollination Biology: Biodiversity conservation and agricultural production, Pollination Biology: Biodiversity Conservation and Agricultural Production. doi: 10.1007/978-94-007-1942-2.

Admasu, A. et al. (2014) Honey bee forages of Ethiopia.

Atkins, E. L., Grout, R. A. and Dadant & Sons. (1975) The Hive and the honey bee : a new book on beekeeping which continues the tradition of ‘Langstroth on the hive and the honeybee’.

Awraris Getachew Shenkute et al. (2012) ‘Honey production systems (Apis mellifera L .) in Kaffa , Sheka and Bench-Maji zones of Ethiopia’, Journal of Agricultural Extension and Rural Development, 4(19), pp. 528–541. doi: 10.5897/JAERD12.088.

Bailey, L. and Ball, B. V. (1991) Honey bee pathology. Academic press.

Bencsik, M. et al. (2011) ‘Identification of the honey bee swarming process by analysing the time course of hive vibrations’, Computers and Electronics in Agriculture. Elsevier B.V., 76(1), pp. 44–50. doi: 10.1016/j.compag.2011.01.004.

Beyene, T. et al. (2015) ‘Evaluation of transitional and modern hives for honey production in Mid Rift Valley of Ethiopia’, Global Journal of Animal Scientific Research, pp. 48–56.

Bradbear, N. (2009) ‘“Bees and their role in forest livelihoods” A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products’, Food and Agricultural Organization of the United Nations, 19, p. 194. doi: 10.1017/CBO9781107415324.004.

Brodschneider, R. et al. (2016) ‘Preliminary analysis of loss rates of honey bee colonies during winter 2015/16 from the COLOSS survey’, Journal of Apicultural Research, 55(5), pp. 375–378. doi: 10.1080/00218839.2016.1260240.

Brodschneider, R. et al. (2018) ‘Multi-country loss rates of honey bee colonies during winter 2016/2017 from the COLOSS survey’, Journal of Apicultural Research, 57(3), pp. 452–457. doi: 10.1080/00218839.2018.1460911.

BS EN ISO 9241-210:2010(E) (2010).

Crane, Eva (1990) Bees and beekeeping: science, practice and world resources.Heinemann, Newness, London, Bees and beekeeping: science, practice and world resources.

Crane, E (1990) Bees and beekeeping: science, practice and world resources. Heinemann Newnes.

Dainat, B., VanEngelsdorp, D. and Neumann, P. (2012) ‘Colony collapse disorder in Europe’, Environmental Microbiology Reports, 4(1), pp. 123–125. doi: 10.1111/j.1758-2229.2011.00312.x.

Delaplane, K. S., Van Der Steen, J. and Guzman-Novoa, E. (2013) ‘Standard methods for estimating strength parameters of Apis mellifera colonies’, Journal of Apicultural Research. doi: 10.3896/IBRA.1.52.1.03.

Demisew, W. A. (2016) ‘Beekeeping in Ethiopia: Country situation’, in ApiExpo Africa, pp. 1–32.

Edwards-Murphy, F. et al. (2015) ‘Development of an heterogeneous wireless sensor network for instrumentation and analysis of beehives’, in Conference Record - IEEE Instrumentation and Measurement Technology Conference, pp. 346–351. doi: 10.1109/I2MTC.2015.7151292.

EFSA (2013) Towards holistic approaches to the risk assessment of multpiple stressors in bees, EFSA Scientific Colloquium XVIII Summary Report. doi: 10.2805/53269.

Eilers, E. J. et al. (2011) ‘Contribution of Pollinator-Mediated Crops to Nutrients in the Human Food Supply’, PLoS ONE. Edited by G. Smagghe, 6(6), p. e21363. doi: 10.1371/journal.pone.0021363.

Ellis, J. D. and Munn, P. A. (2005) ‘The worldwide health status of honey bees’, Bee World, 86(4), pp. 88–101. doi: 10.1080/0005772X.2005.11417323.

van Engelsdorp, D. et al. (2008) ‘A survey of honey bee colony losses in the U.S., fall 2007 to spring 2008.’, PloS one, 3(12), p. e4071. doi: 10.1371/journal.pone.0004071.

Fichtl, R. and Adi, A. (1994) Honey Bee Flora of Ethiopia, Book.

Fikru, S. and Gebresilassie, G. (2015) ‘Assessment of Beekeeping Practices (Absconding, Bee Forage and Bee Diseases and Pests) in Jigjiga Zone, Somali Regional State of Ethiopia’, Poultry, Fisheries & Wildlife Sciences, 03(02), pp. 1–8. doi: 10.4172/2375-446x.1000135.

Florida, U. of (no date) ‘Asian honey bee (suggested common name) scientific name : Apis cerana Fabricius (Insecta : Hymenoptera : Apidae)’, http://entnemdept.ufl.edu/creatures/misc/bees/Apis_cerana.htm.

García, N. L. (2018) ‘The Current Situation on the International Honey Market’, Bee World, 95(3), pp. 89–94. doi: 10.1080/0005772x.2018.1483814.

Genersch, E. (2010) ‘Honey bee pathology: Current threats to honey bees and beekeeping’, Applied Microbiology and Biotechnology, pp. 87–97. doi: 10.1007/s00253-010-2573-8.

Gratzer, K. et al. (2019) ‘Challenges for Beekeeping in Indonesia with Autochthonous and Introduced Bees’, Bee World, 96(2), pp. 40–44. doi: 10.1080/0005772x.2019.1571211.

Gray, A. et al. (2019) ‘Loss rates of honey bee colonies during winter 2017/18 in 36 countries participating in the COLOSS survey, including effects of forage sources’, Journal of Apicultural Research. doi: 10.1080/00218839.2019.1615661.

Gupta, R. K. et al. (2014) Beekeeping for Poverty Alleviation and Livelihood Security, Beekeeping for Poverty Alleviation and Livelihood Security. Springer Science+Business Media. doi: 10.1007/978-94-017-9199-1.

Http://ecoursesonline.iasri.res.in/mod/page/view.php?id=16210 (2020) Apiculture (0+1), Bee Hive.

Jensen, M (2007) Beekeeping with Apis ceran indica. First edit. Danish Beekeepers Association.

Jensen, Mogens (2007) Beekeeping with Apis cerana indica.

Klatt, B. K. et al. (2014) 'Bee pollination improves crop quality, shelf life and commercial value', Proceedings of the Royal Society B: Biological Sciences, 281(1775), p. 20132440. doi: 10.1098/rspb.2013.2440.

Komasilovs, V. et al. (2019) 'Modular sensory hardware and data processing solution for implementation of the precision beekeeping', Agronomy Research, 17(2), pp. 509–517. doi: 10.15159/AR.19.038.

Kontogiannis, S. (2019) 'An Internet of Things-Based Low-Power Integrated Beekeeping Safety and Conditions Monitoring System', Inventions, 4(3), p. 52. doi: 10.3390/inventions4030052.

Kremen, C., Williams, N. M. and Thorp, R. W. (2002) 'Crop pollination from native bees at risk from agricultural intensification', Proceedings of the National Academy of Sciences of the United States of America, 99(26), pp. 16812–16816. doi: 10.1073/pnas.262413599.

Kviesis, A. et al. (2015) 'Future development perspectives of the precision apiculture (precision beekeeping)', in NJF Congress: Nordic view to sustainable rural development, 25, Riga (Latvia), 16-18 Jun 2015.

Kviesis, A. et al. (2020) 'Application of fuzzy logic for honey bee colony state detection based on temperature data', Biosystems Engineering, 193, pp. 90–100. doi: 10.1016/j.biosystemseng.2020.02.010.

Kviesis, A., Zacepins, A. and Riders, G. (2015) 'Honey bee colony monitoring with implemented decision support system', in Engineering for Rural Development, pp. 446–451.

Lecocq, A. et al. (2015) 'Weight Watching and the Effect of Landscape on Honeybee Colony Productivity: Investigating the Value of Colony Weight Monitoring for the Beekeeping Industry', PLOS ONE. Edited by G. Smagghe, 10(7), p. e0132473. doi: 10.1371/journal.pone.0132473.

Legesse, G. Y. (2014) 'Review of progress in Ethiopian honey production and marketing', Livestock Research for Rural Development, 26(1), pp. 1–6.

Masterpole, Z. C. et al. (2019) 'Value Chain Analysis in Lampung Province, Indonesia'.

Meikle, W. G. and Holst, N. (2015) 'Application of continuous monitoring of honeybee colonies', Apidologie, 46(1), pp. 10–22. doi: 10.1007/s13592-014-0298-x.

Nat Schouten, C. and John Lloyd, D. (2019) 'Considerations and Factors Influencing the Success of Beekeeping Programs in Developing Countries', Bee World, 96(3), pp. 75–80. doi: 10.1080/0005772X.2019.1607805.

Negash, B. and Greiling, J. (2017) 'Quality Focused Apiculture Sector Value Chain Development in Ethiopia', Journal of Agricultural Science and Technology A, 7(2). doi: 10.17265/2161-6256/2017.02.005.

Oldroyd, B. P. (2007) 'What's killing American honey bees?', PLoS Biology, pp. 1195–1199. doi: 10.1371/journal.pbio.0050168.

Panday, D. (2015) 'Honey bees, their pollination behavior and relation to livelihoods', in Proceedings of International Conference on Biodiversity, Livelihood and Climatic Change, pp. 197–208.

Partap, U. (2011) ‘The pollination role of honey bees’, in Honey bees of Asia. Berlin: Springer., pp. 227–255.

Pirk, C. W. W. et al. (2015) ‘Honeybee health in Africa—a review’, Apidologie, pp. 276–300. doi: 10.1007/s13592-015-0406-6.

Potter, C. et al. (2019) ‘Pollen metabarcoding reveals broad and species-specific resource use by urban bees’, PeerJ, 2019(2). doi: 10.7717/peerj.5999.

Rodriguez, L. G. A. et al. (2017) ‘MyBee: An information system for precision beekeeping’, in ICEIS 2017 - Proceedings of the 19th International Conference on Enterprise Information Systems, pp. 577–587. doi: 10.5220/0006285205770587.

Roffet-Salque, M. et al. (2015) ‘Widespread exploitation of the honeybee by early Neolithic farmers’, Nature, 527(7577), pp. 226–230. doi: 10.1038/nature15757.

Rosenkranz, P., Aumeier, P. and Ziegelmann, B. (2010) ‘Biology and control of Varroa destructor’, Journal of Invertebrate Pathology, 103, pp. S96–S119. doi: 10.1016/j.jip.2009.07.016.

Schouten, C., Lloyd, D. and Lloyd, H. (2019) ‘Beekeeping With the Asian Honey Bee (Apis cerana javana Fabr) in the Indonesian Islands of Java , Bali , Nusa Penida , and Sumbawa’, Bee World. Taylor & Francis, 0(0), pp. 1–11. doi: 10.1080/0005772X.2018.1564497.

Seeley, T. (1977) ‘Measurement of nest cavity volume by the honey bee (Apis mellifera)’, Behavioral Ecology and Sociobiology, 2(2), pp. 201–227. doi: 10.1007/BF00361902.

Segeren, P. and Mulder, V. (1997) Beekeeping in the tropics. The Netherlands: Agromisa.

Tekle, Y. and Ababor, S. (2018) ‘Beekeeping Practice, Opportunities, Marketing and Challenges in Ethiopia: Review’, Journal of Dairy & Veterinary Sciences, 5(3), pp. 1–21. doi: 10.19080/jdvs.2018.05.555663.

Tesfay, H. (2014) ‘Honey bee diseases , pest and their economic importance in Ethiopia’, International Journal of Innovation and Scientific Research, 10(2), pp. 527–535.

Wakjira, K. and Alemayehu, G. (2019) ‘Assessment of Colony Carrying Capacity and Factors Responsible for Low Production and Productivity of Beekeeping in Horro Guduru Wollega Zone of Oromia, Ethiopia’, International Journal of Natural Resource Ecology and Management, 4(1), pp. 14–21. doi: 10.11648/j.ijnrem.20190401.13.

Yirga, G. et al. (2012) ‘Assessment of beekeeping practices in Asgede Tsimbla district, Northern Ethiopia: Absconding, bee forage and bee pests’, AFRICAN JOURNAL OF AGRICULTURAL RESEEARCH, 7(1). doi: 10.5897/AJAR10.1071.

Yirga, G. and Teferi, M. (2010) ‘Participatory Technology and Constraints Assessment to Improve the Livelihood of Beekeepers in Tigray Region, northern Ethiopia’, Momona Ethiopian Journal of Science, 2(1). doi: 10.4314/mejs.v2i1.49654.

Zacepins, A. et al. (2015) ‘Challenges in the development of Precision Beekeeping’, Biosystems Engineering, 130, pp. 60–71. doi: 10.1016/j.biosystemseng.2014.12.001.

Zacepins, A. et al. (2016) ‘Beekeeping in the future – smart apiary management’, in ICCC 2016, pp. 808–812.

Van Der Zee, R. et al. (2012) 'Managed honey bee colony losses in Canada, China, Europe, Israel and Turkey, for the winters of 2008-9 and 2009-10', Journal of Apicultural Research, 51(1), pp. 100–114. doi: 10.3896/IBRA.1.51.1.12.
Zetterman, B. E. A. (2018) Beekeepers usage of IoT. Linnaeus University, Faculty of Technology.

Figure 1

Human Centred Design Process [ISO 9241-210:210(E)]

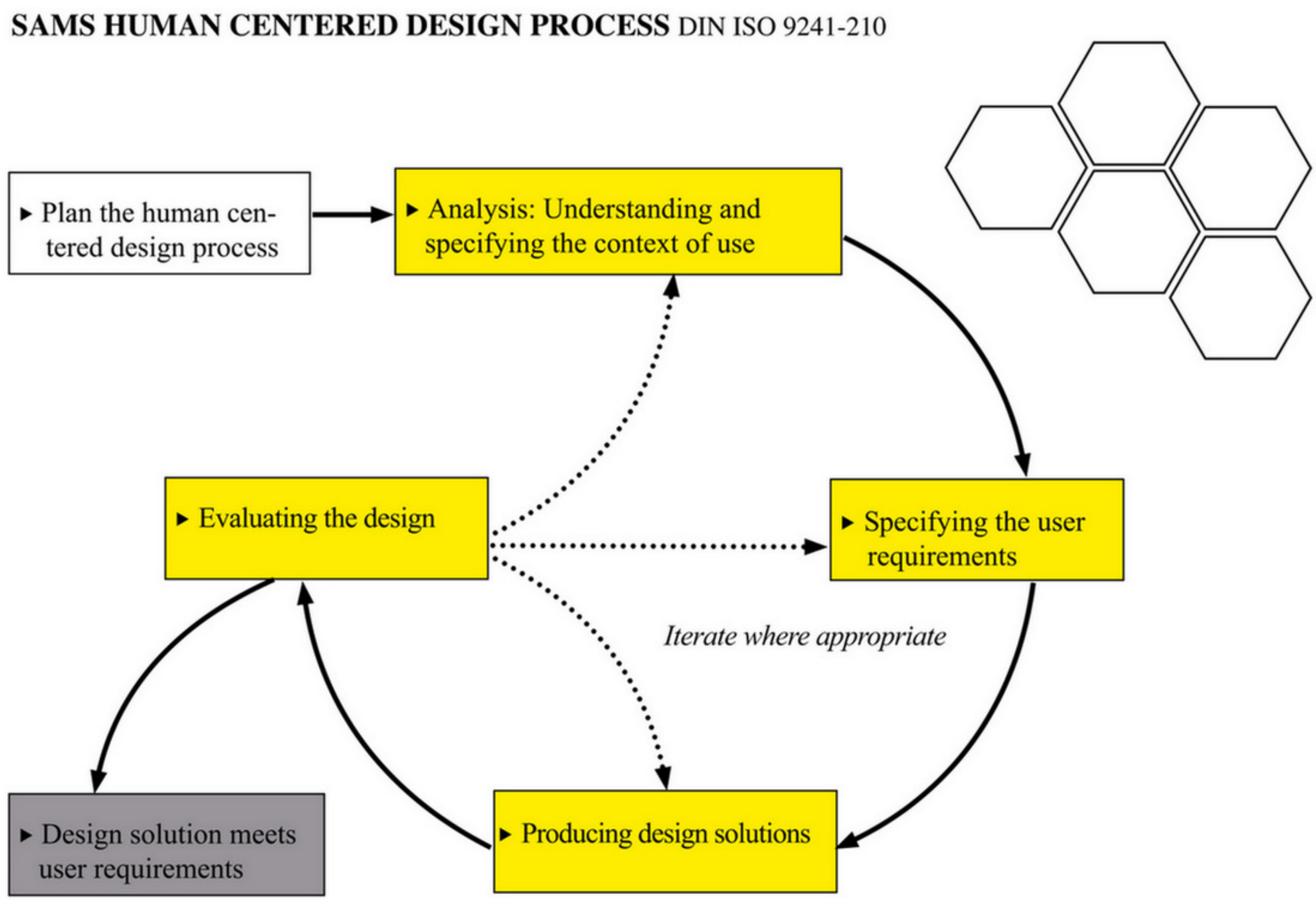

Figure 2

A complete proposed SAMS beehive system sketch taken from SAMS Manual on Beehive Construction and Operation

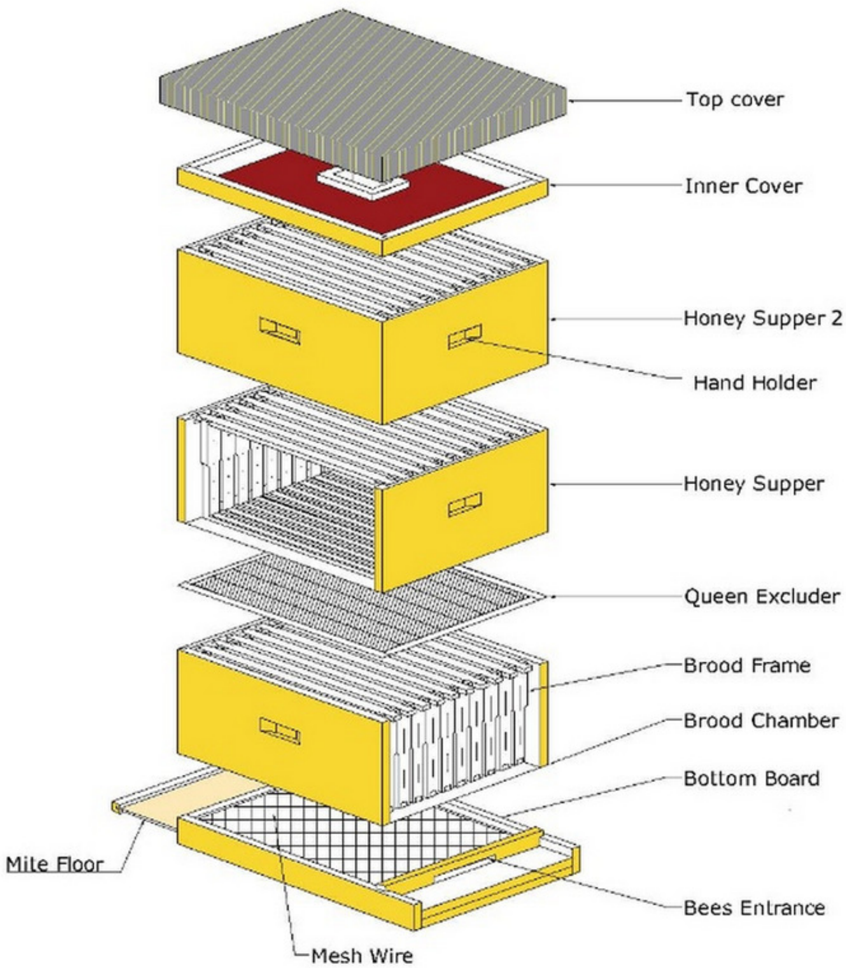

Figure 3

Flow chart of the SAMS HIVE System with Power unit, Scale unit and Sensor frame

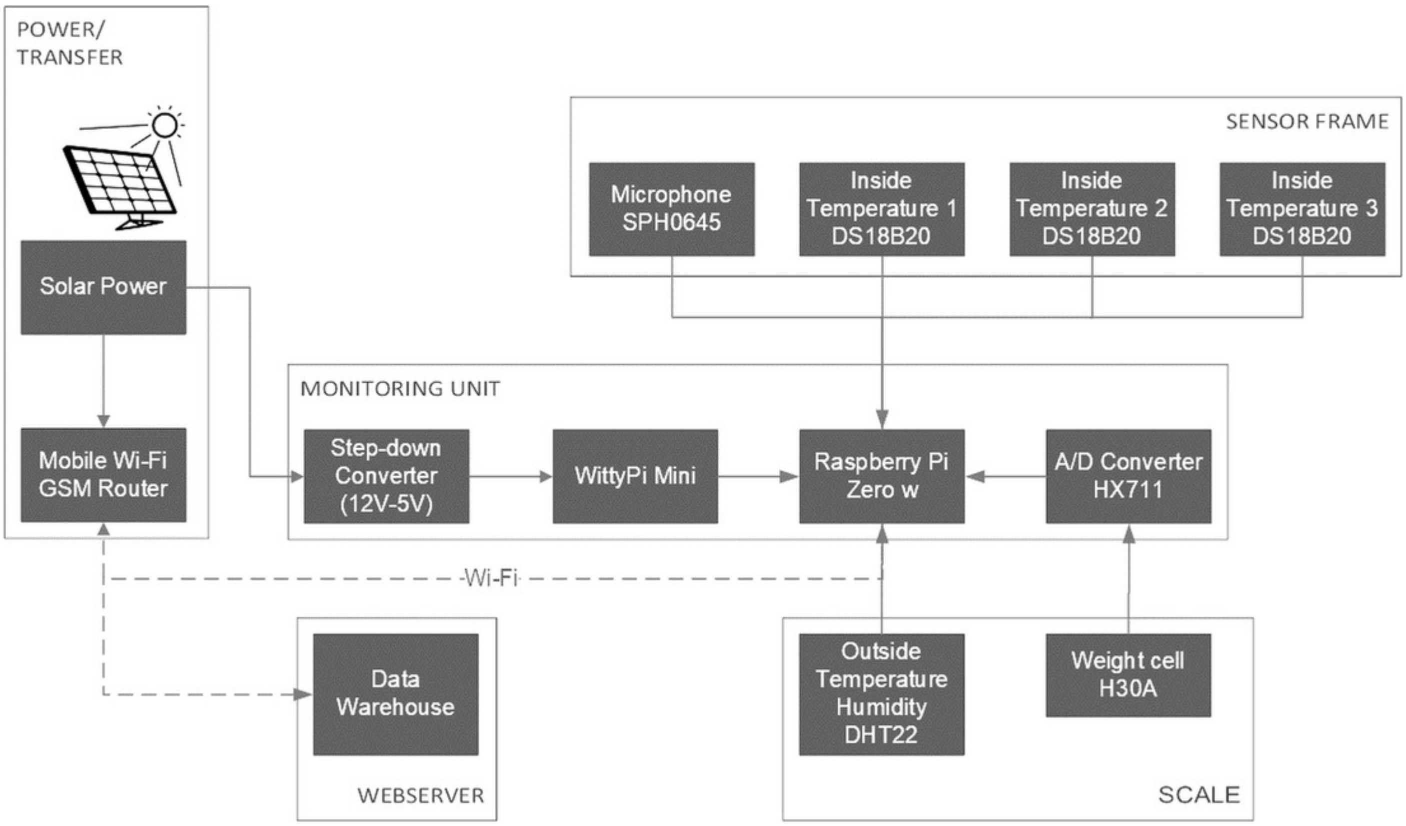

Figure 4

Connection sketch of internet-compatible devices

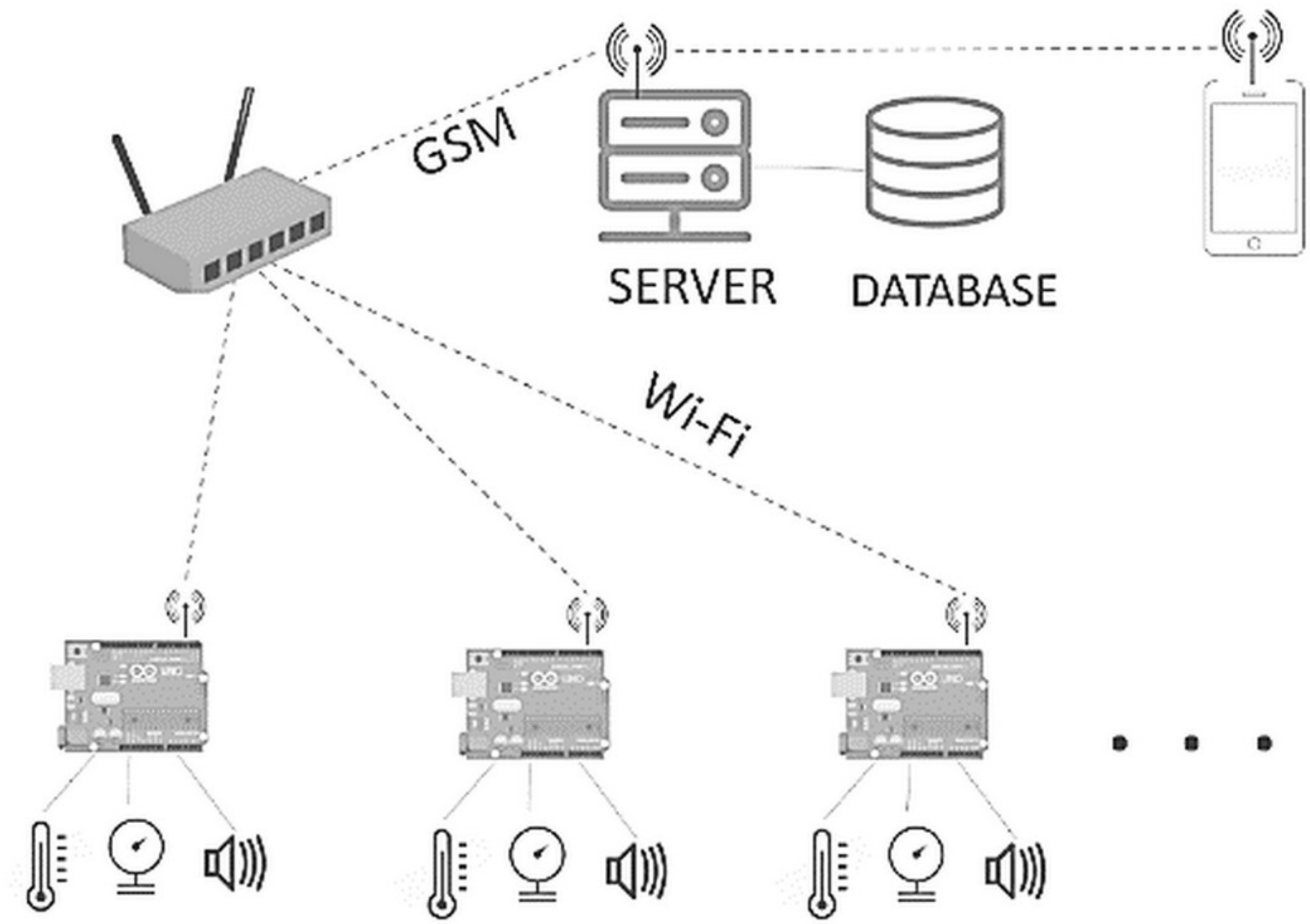

Figure 5

Sensor placement in extra sensor frame between honey and brood chamber as well as scale below the brood chamber

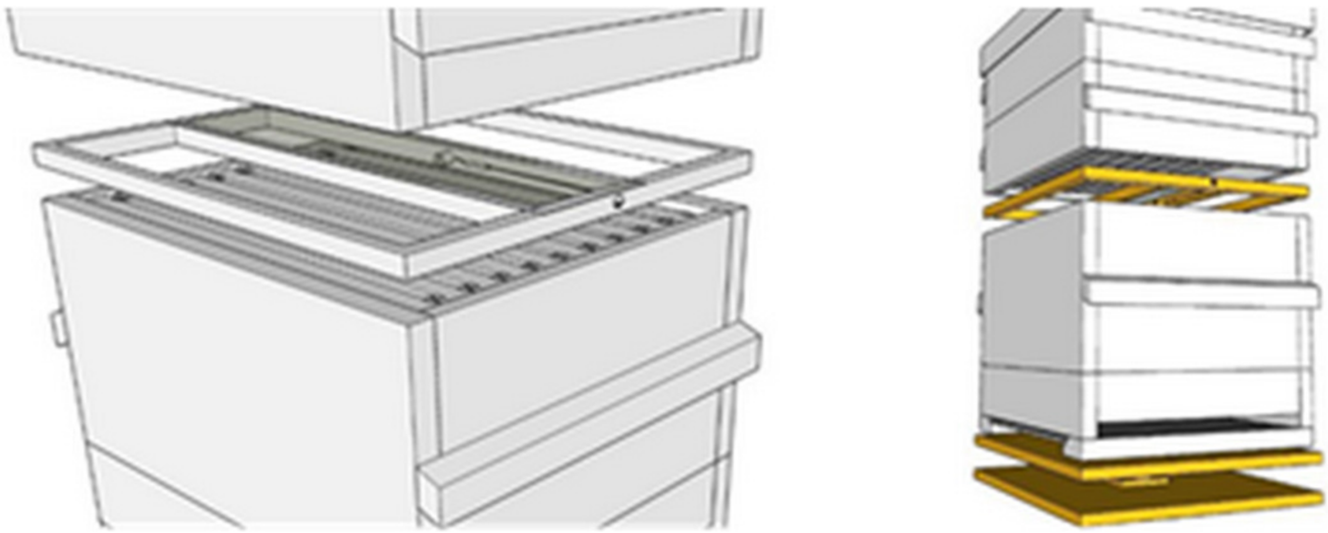

Figure 6

Architecture of the proposed SAMS data warehouse

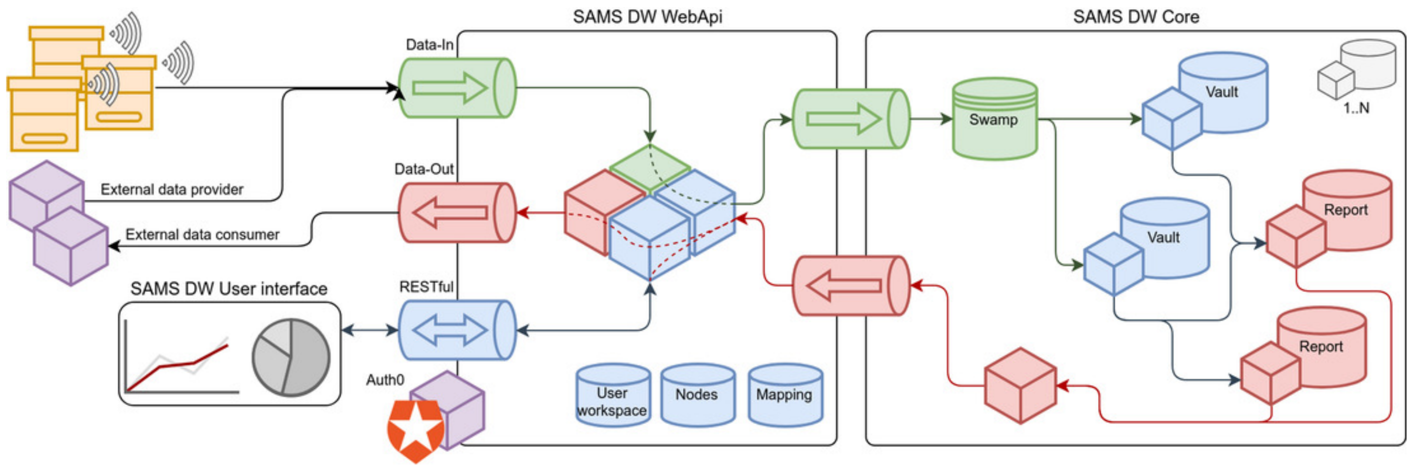

Figure 7

Illustration of the nectar flow: detection by SAMS system, alert on smartphone and recommendations for beekeeper

Figure 8

Overall concept of the SAMS business model

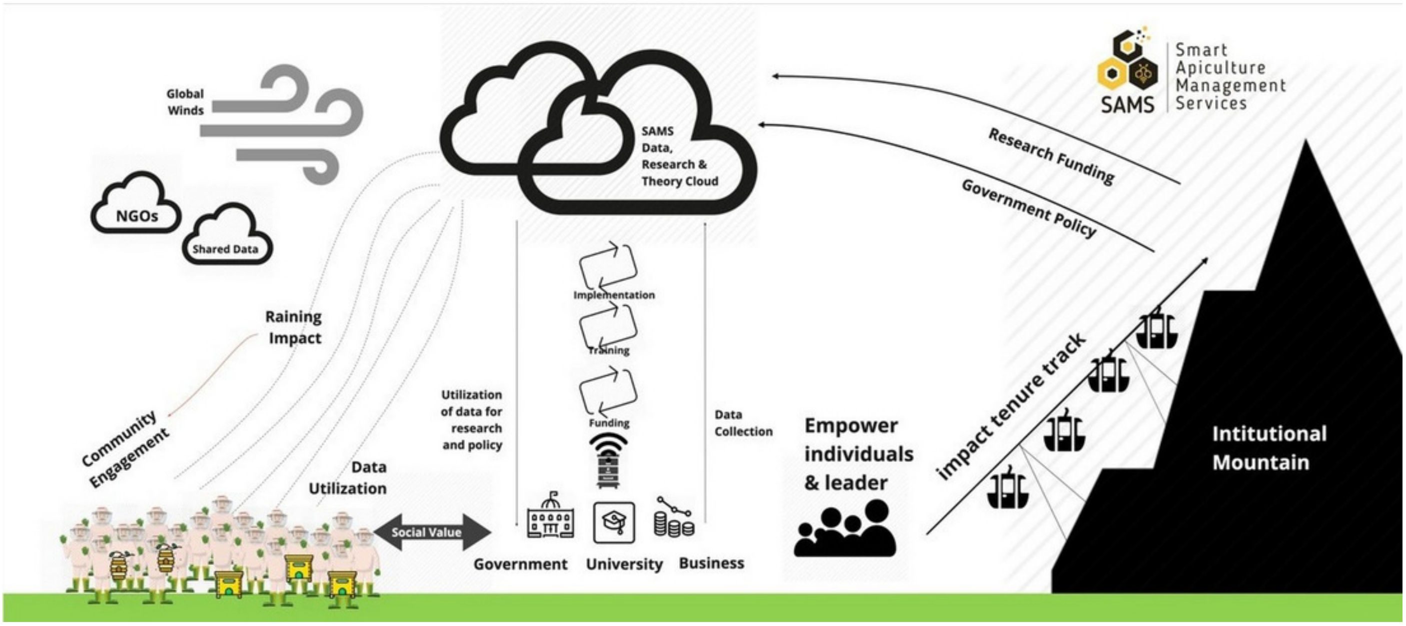

Table 1 (on next page)

Ranking of smart management possibilities for bee colony state detection in Ethiopia and Indonesia. Bold events/states were identified to be most relevant for the SAMS project.

Asterisks (*) rank the importance, technical feasibility, grade of innovation and predictability of each event or colony state.

Table 1: Ranking of smart management possibilities for bee colony state detection in Ethiopia and Indonesia. Bold events/states were identified to be most relevant for the SAMS project. Asterisks (*) rank the importance, technical feasibility, grade of innovation and predictability of each event or colony state.

Event or State of the colony/hive	**Importance to the beekeeper** (from less* to most important***)	**Traditional detection methods**	**Parameter to measure**	**Technical Feasibility** (from easy* to complicated***)	**Innovation** (from already existing* to new***)	**Predictability** (not- or from easy* to complicated***)
Start of the mass nectar flow	***	Observation of the flight activity outside the hive; internal inspection of the hive	Weight	*	*	Flowering calendar
End of the nectar flow	**	internal inspection of the hive; observation of the surrounding environment (flowers in bloom)	Weight	**	*	**
Swarming	**	Detection of the swarmed colony (after event happened)	Temperature, sound, weight	***	**	***
Pre-Swarming	**	Internal and external inspection of the hive	Sound	***	***	-
Queenless	**(*)	internal inspection of the hive	Temp., sound	***	**	-
Broodless	**(*)	External and internal inspection of the hive	Temp., sound	**	**	-
Absconding	***	Detection after event happened	Temp., weight	*	***	-
Colony Collapse	**	Detection after event happened	Temp., weight	*	***	-
Death	***	Internal and external inspection of the hive	Temp., sound, weight	*	*	-
Colonisation of an empty hive	?	External and internal inspection of the hive	Temp., sound, weight	*	***	-