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«Bioeconomy for Sustainable Development of Countries and Regions»

Application of Information Technologies in Precision Beekeeping

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Latvia University of Life Sciences and Technologies (Latvia)

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- Introduction
- Some facts about beekeeping in Latvia
- Definitions: Precision Agriculture > Precision Beekeeping
- Bee colony parameters
- Bee colony states
- Bee colony monitoring systems
- SAMS project
- Hiveopolis project
- Conclusions

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Some words about me

- 10 years as a student at Latvia University of Life Sciences and Technologies
- Associated prof., senior researcher at the Faculty of Information Technologies
- Director of the Computer Control and Computer Science study program (bachelor level)
- Project manager of International Scientific projects:

- Precision Agriculture: ITAPIC – Application of Information Technologies in Precision Apiculture; PigSys; SAMS – Smart Apiculture Management Services; HIVEOPOLIS

- Others: Enabling REsilient urban TRAnsportation systems in smart CITies; DiBiCoo – Digital Global Biogas Cooperation

Beekeeping in Latvia

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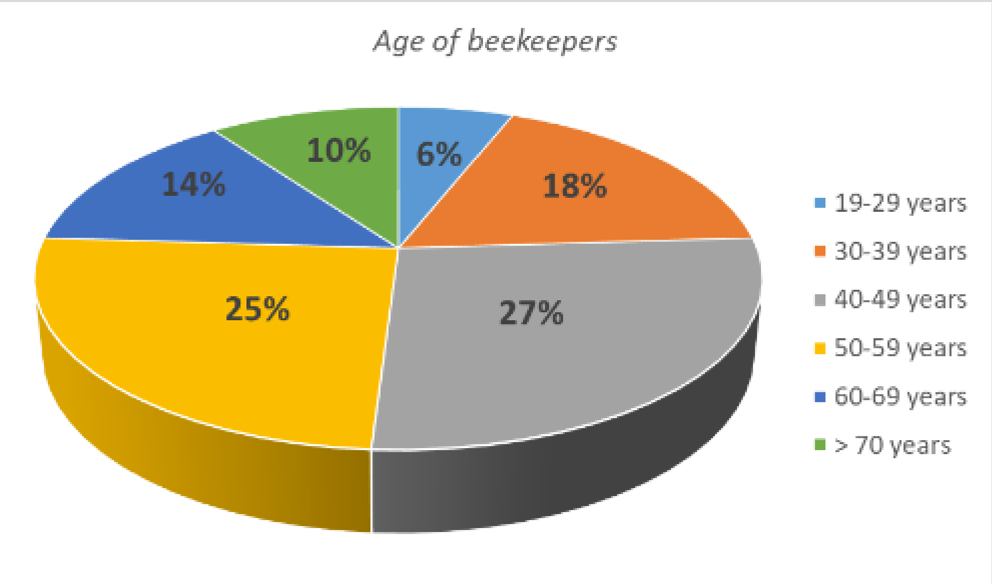
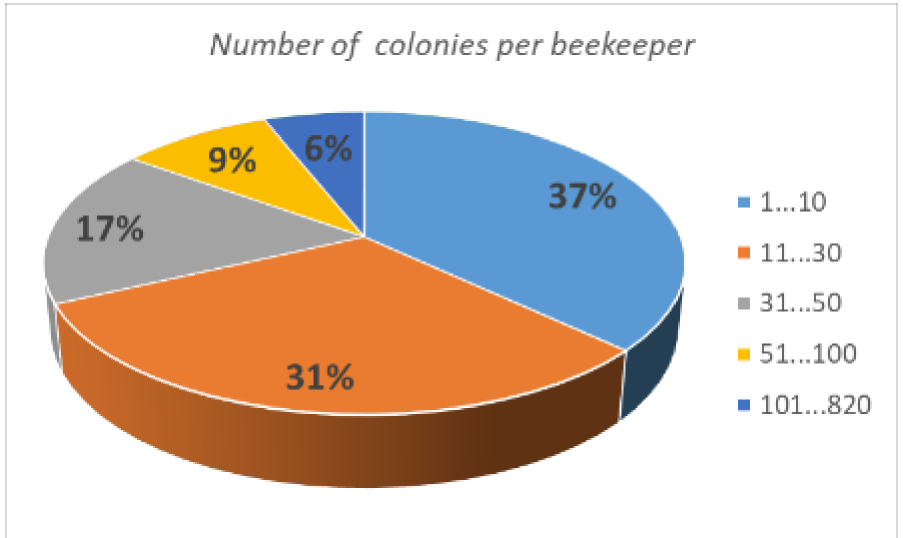
- Number of beekeepers: approx. 5 000
- Main association – Latvian Beekeeping Association (LBB)
- Number of association members: 3 200
- Number of hives: approx. 98 000
- Amount of collected honey: approx. 2 400 tons/year
- Beekeeping season: April - September





Building for passive bee wintering period

https://www.thoughtco.com/how-honey-bees-keep-warm-winter-1968101

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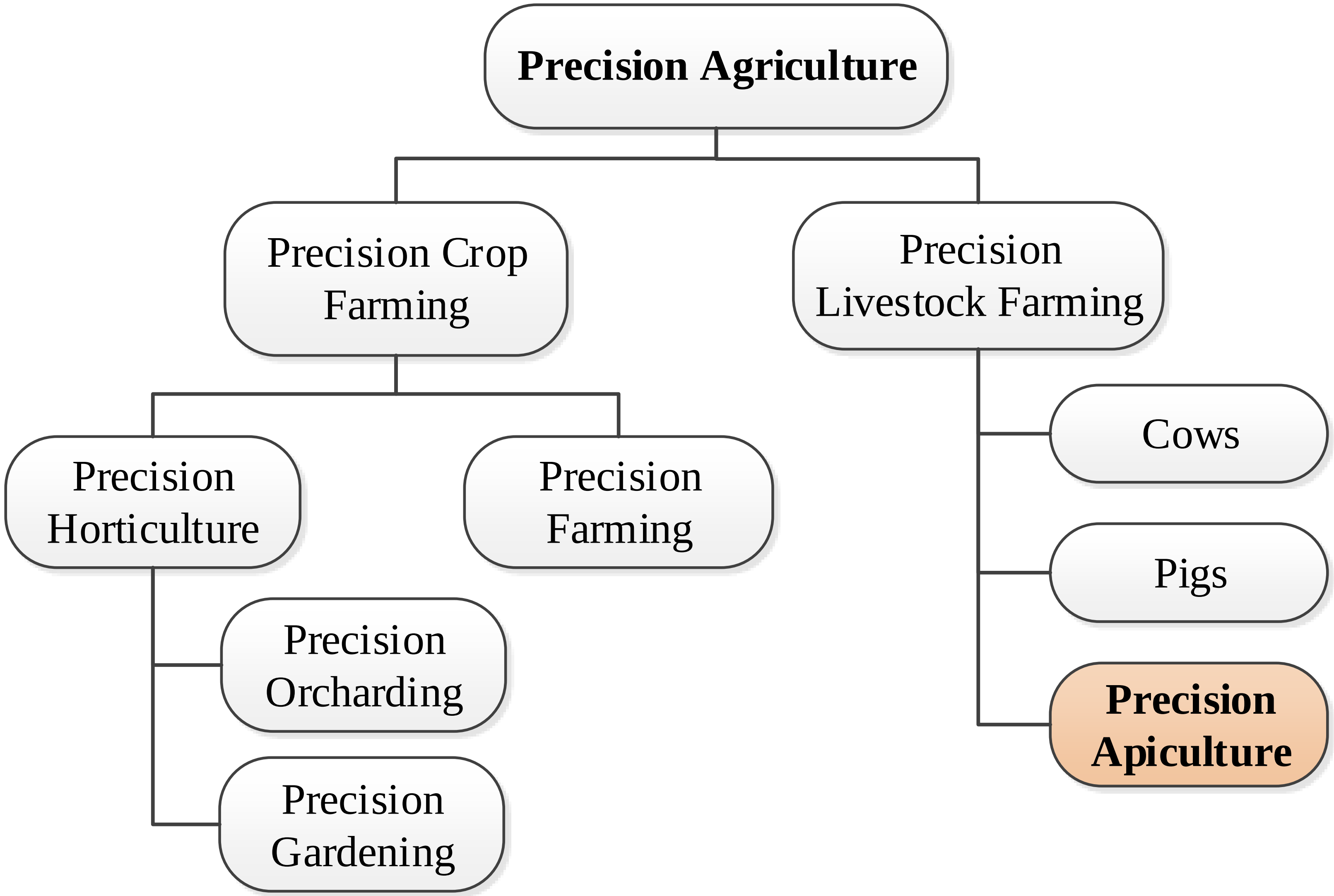
Precision Agriculture

- **Precision agriculture** is a management strategy that utilizes information technologies to collect useful data from distinct sources, with the aim of supporting the decisions associated to the production of crops.
- Main idea of the PA:
  - Instead of managing a whole land based on a hypothetical average condition, which may not exist anywhere in the field, a PA implementation uses a wide variety of technologies that collect site-specific data and applies site-specific management practice.

https://www.indiapigeon.com/latest/precision-agriculture-could-boost-indias-food-production-capacity-encourage-sustainable-farming-technology-news-firstpost/

https://www.foodandfarmingtechnology.com/news/livestock-monitoring/precision-livestock-farming-project-to-focus-on-sheep-welfare-management.html

Draft structure of the Precision Agriculture



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Precision Apiculture (Precision Beekeeping)

- The main agricultural object is bee colony
- **Precision Apiculture or Precision Beekeeping is an apiary management strategy based on the continuous, real-time remote monitoring of individual bee colonies to minimize resource consumption and maximize the productivity of bees.**
  - https://en.wikipedia.org/wiki/Precision_beekeeping
  - Zacepins A., Brusbardis V, Meitalovs J. and Stalidzans E. (2015) "Challenges in the development of Precision Beekeeping“, Biosystems Engineering. 130: 60–71. doi:10.1016/j.biosystemseng.2014.12.001

- Maintaining healthy bee colonies is a challenge:
  - Winter loses (mainly for North countries)
  - **Manual inspections**
    - «Even if you inspect your hive for 30 minutes every two weeks, it remains a mystery what is happening in there the other 99.7% of the time» [Lorenzo Lorraine Langstroth]

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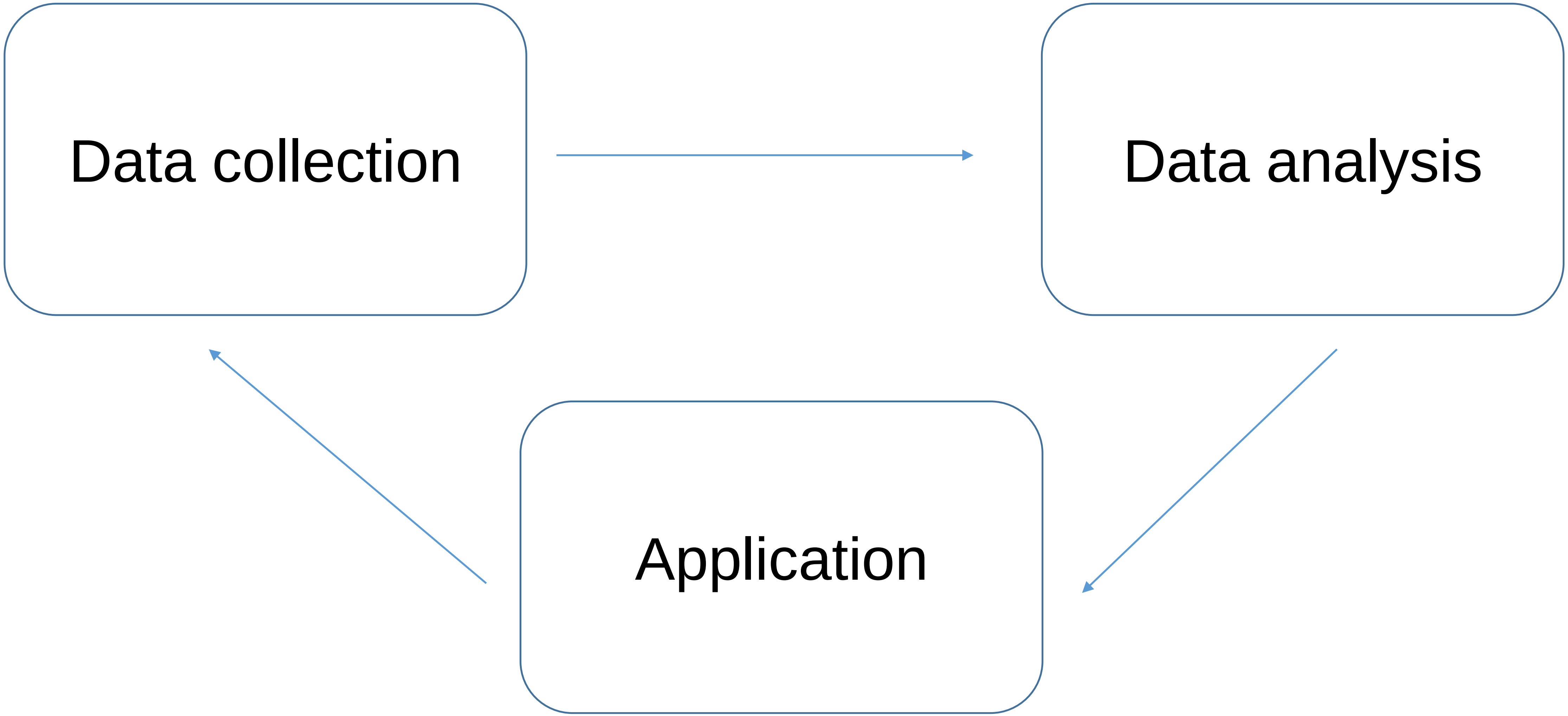
3 stage cycle in Precision Beekeeping



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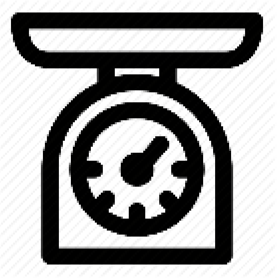
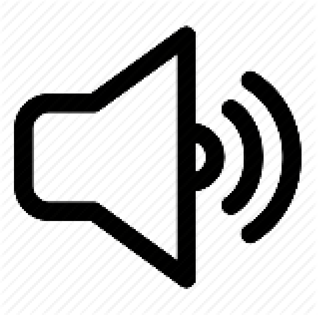
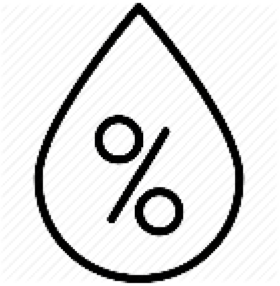
Monitoring parameters

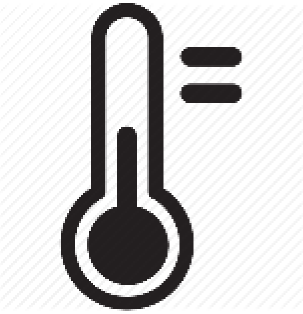


- **Bee colony parameters:**
  - Temperature
  - Humidity
  - Sound
  - Weight changes
  - Activity at the hive entrance
  - CO_2 concentration

- **Potential bee colony states**
  - Death
  - Pre-swarming
  - Swarming
  - Brood rearing
  - Broodless state
  - Passive state
  - Quenless state
  - Starvation
  - Active foraging







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Benefits of bee colony remote monitoring

- In a traditional approach, to evaluate the status of the bee colony, beekeepers have to make **frequent visual observation** of the bee colony, by opening the hive:
  - Intrusive actions
  - Time consuming
  - Stress of the colony
  - Travelling time to the apiary

- **Benefits** of the remote monitoring are:
  - Decrease of management costs
  - Minimisation of on-site inspections
  - Less disturbance to bees
  - Decrease the burden of death rate
  - Increase of bee colony production

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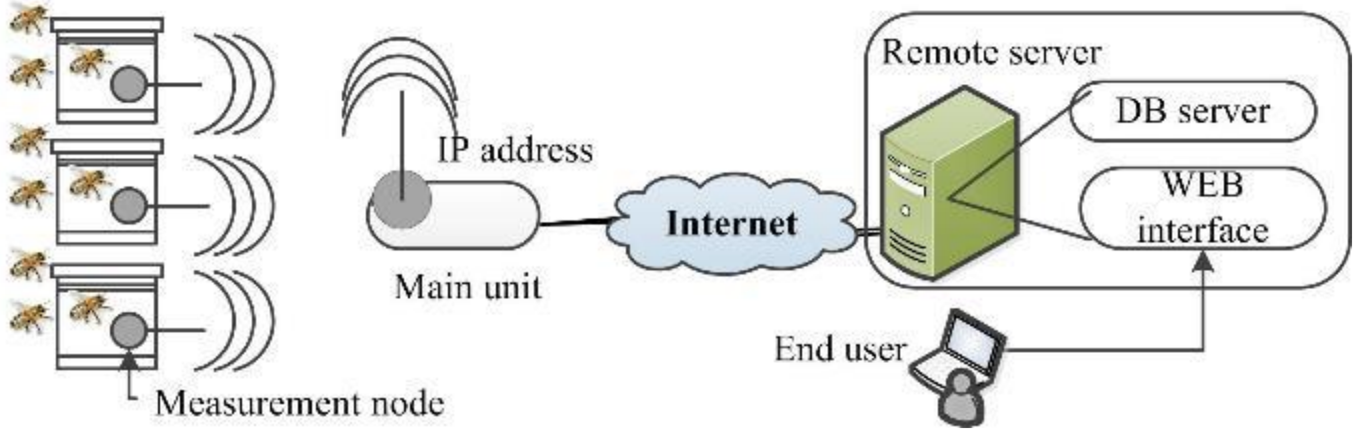
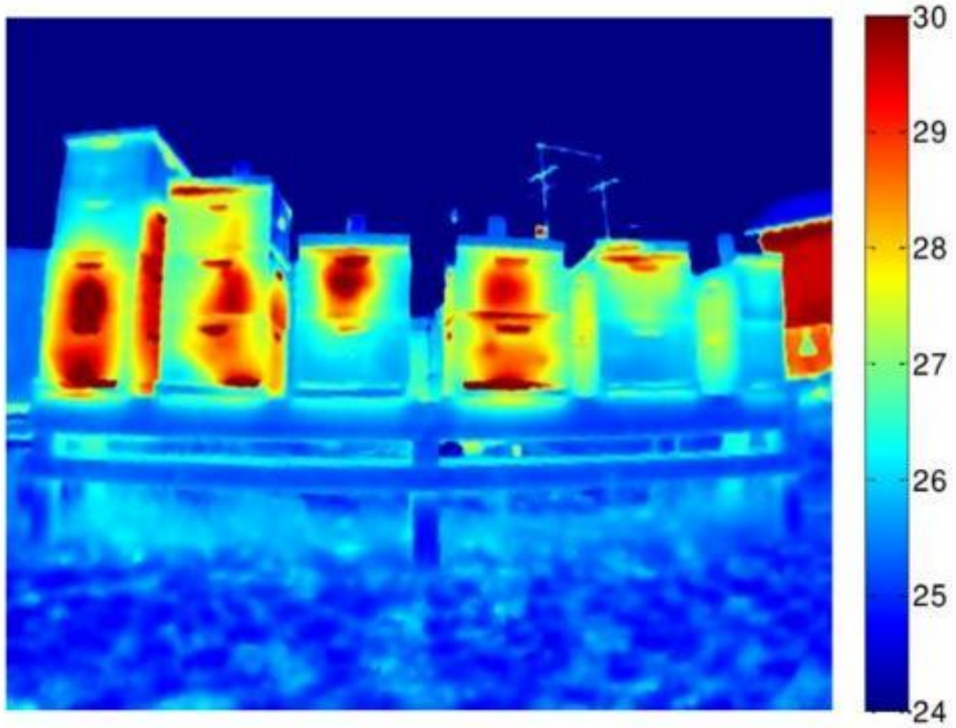
Temperature measurements

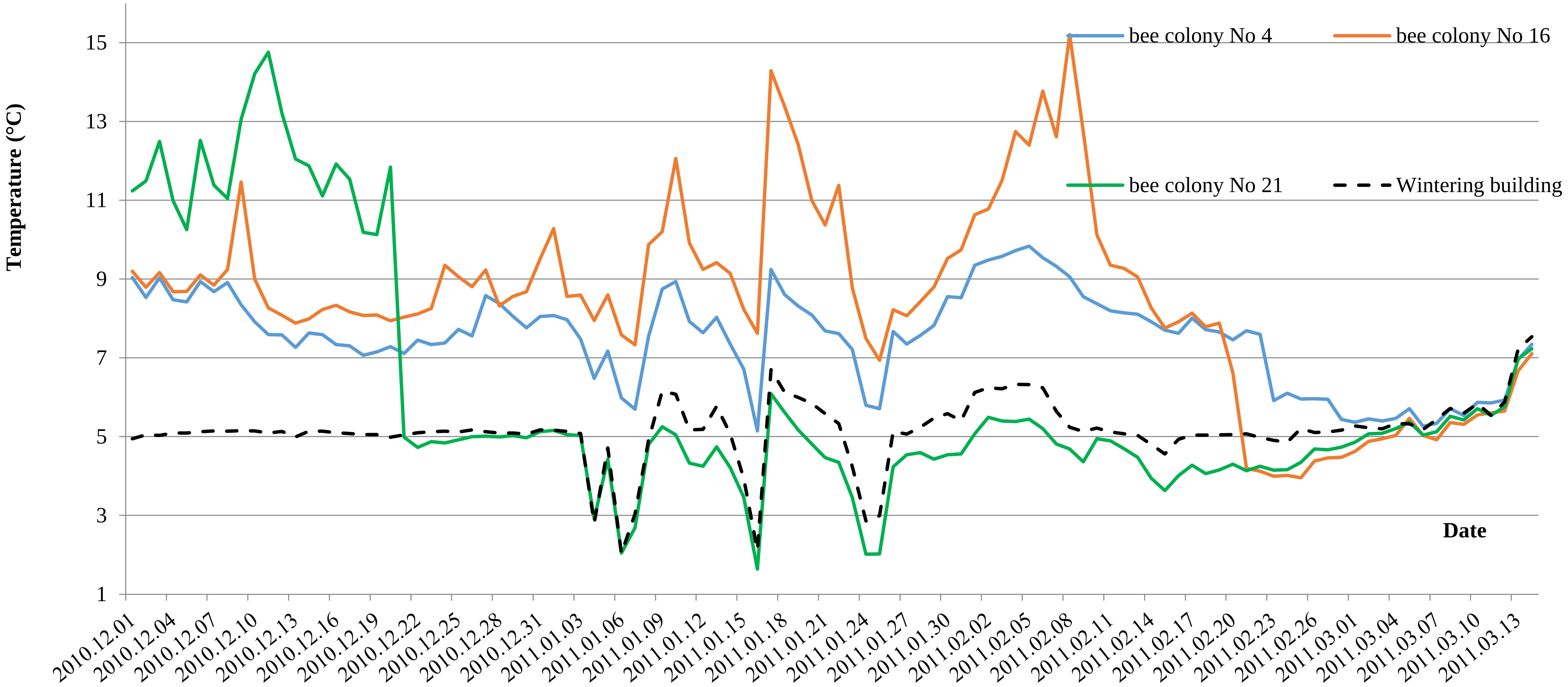
- Small sensors (iButtons)
- Wired sensor networks
- Wireless sensors
- Infrared imaging



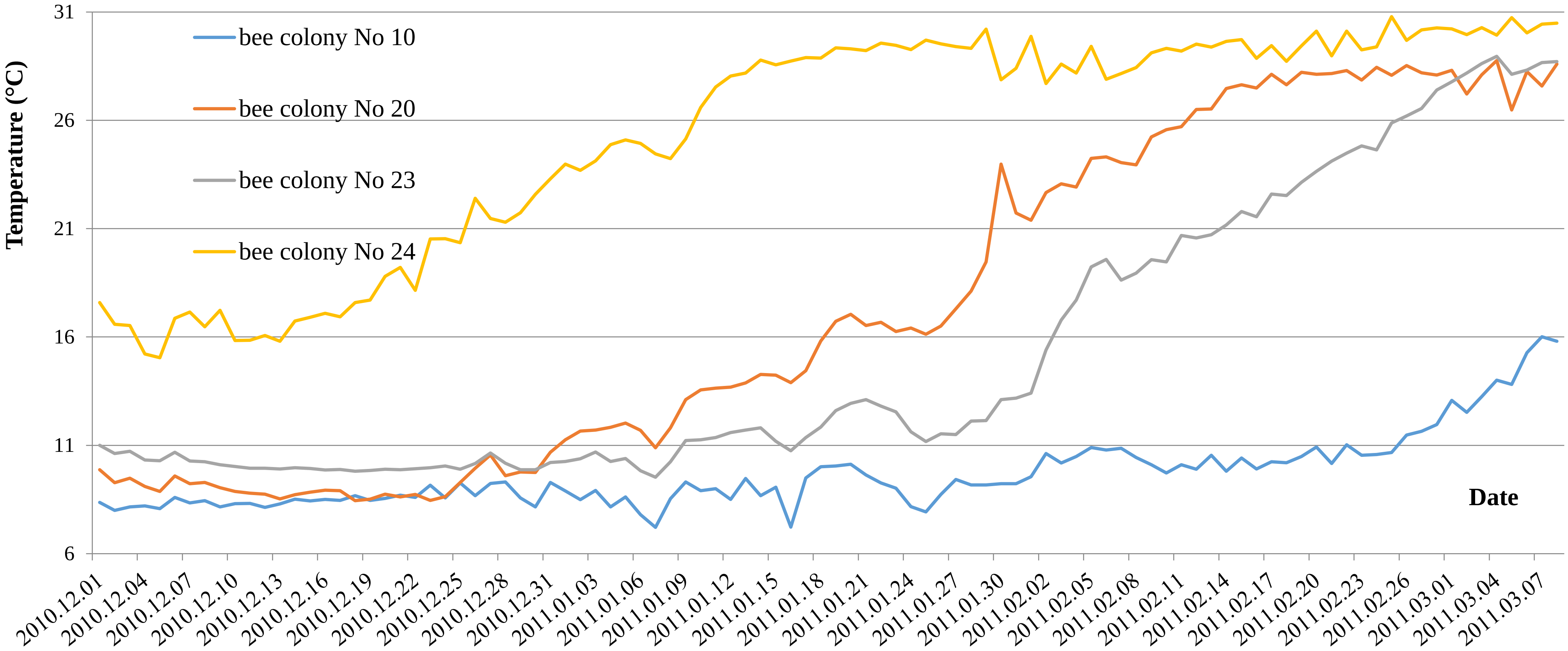


https://www.researchgate.net/publication/49782273_Long-wave_infrared_imaging_for_non-invasive_beehive_population_assessment/figures?lo=1

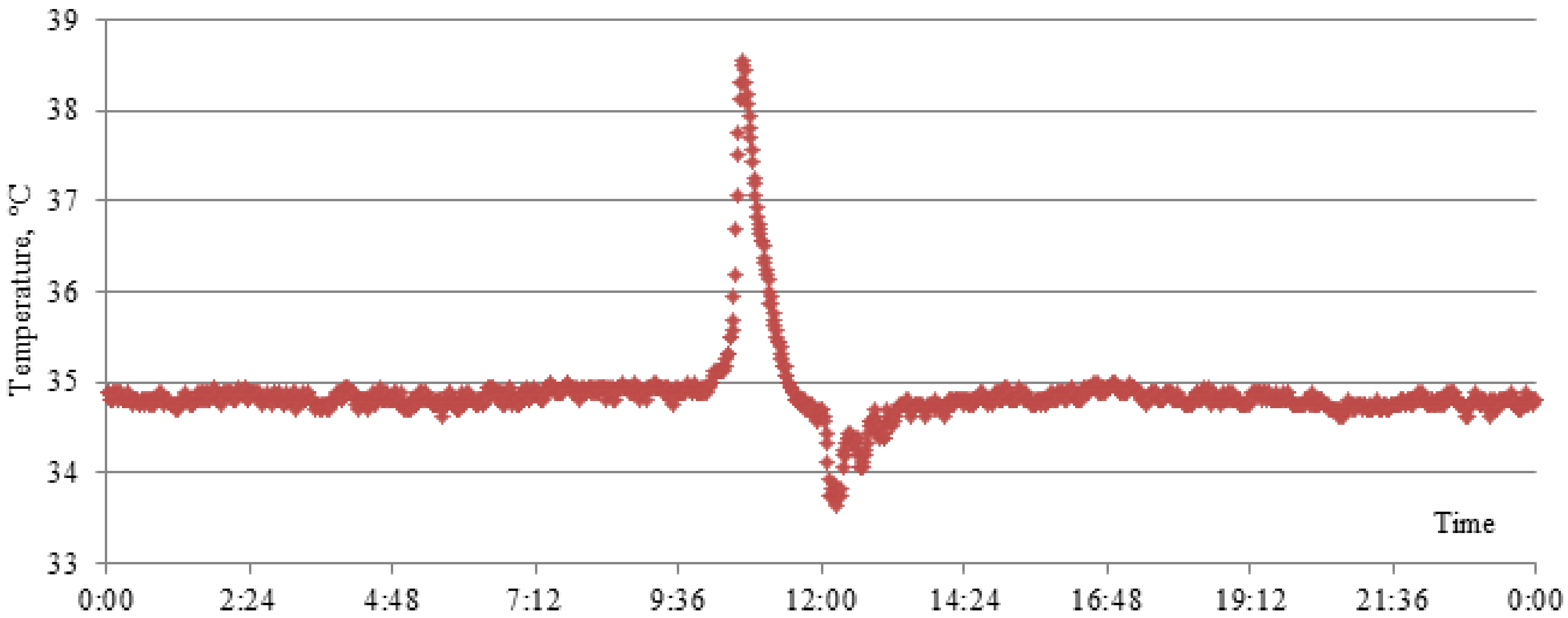
Temperature: Colony death



Temperature: Brood rearing



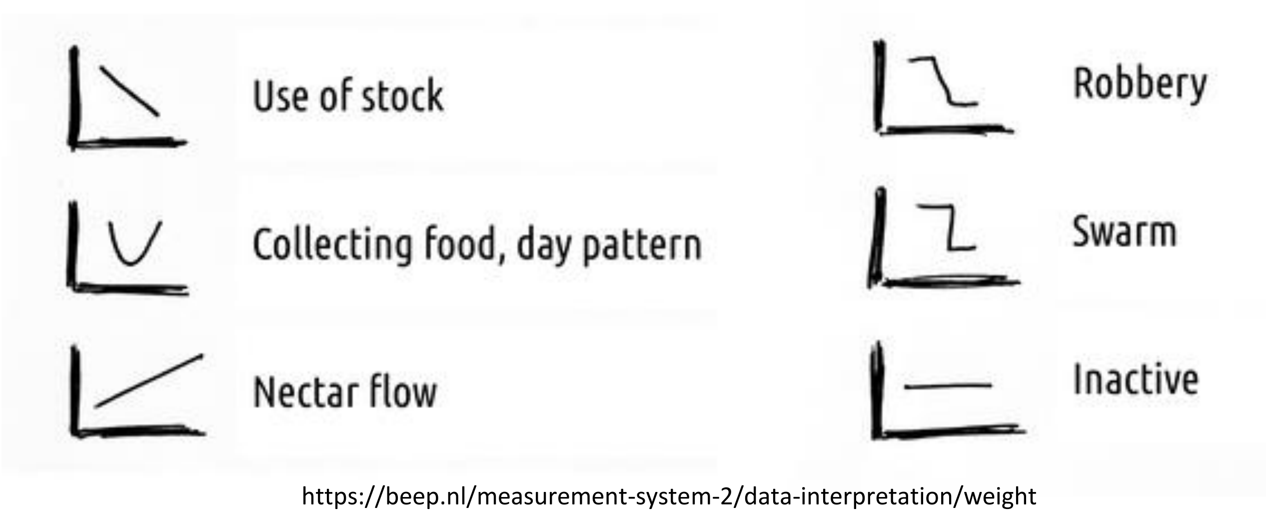
Temperature: Swarming



https://phillybeekeepers.org/its-a-swarm-who-do-you-call-a-beekeeper-of-course/

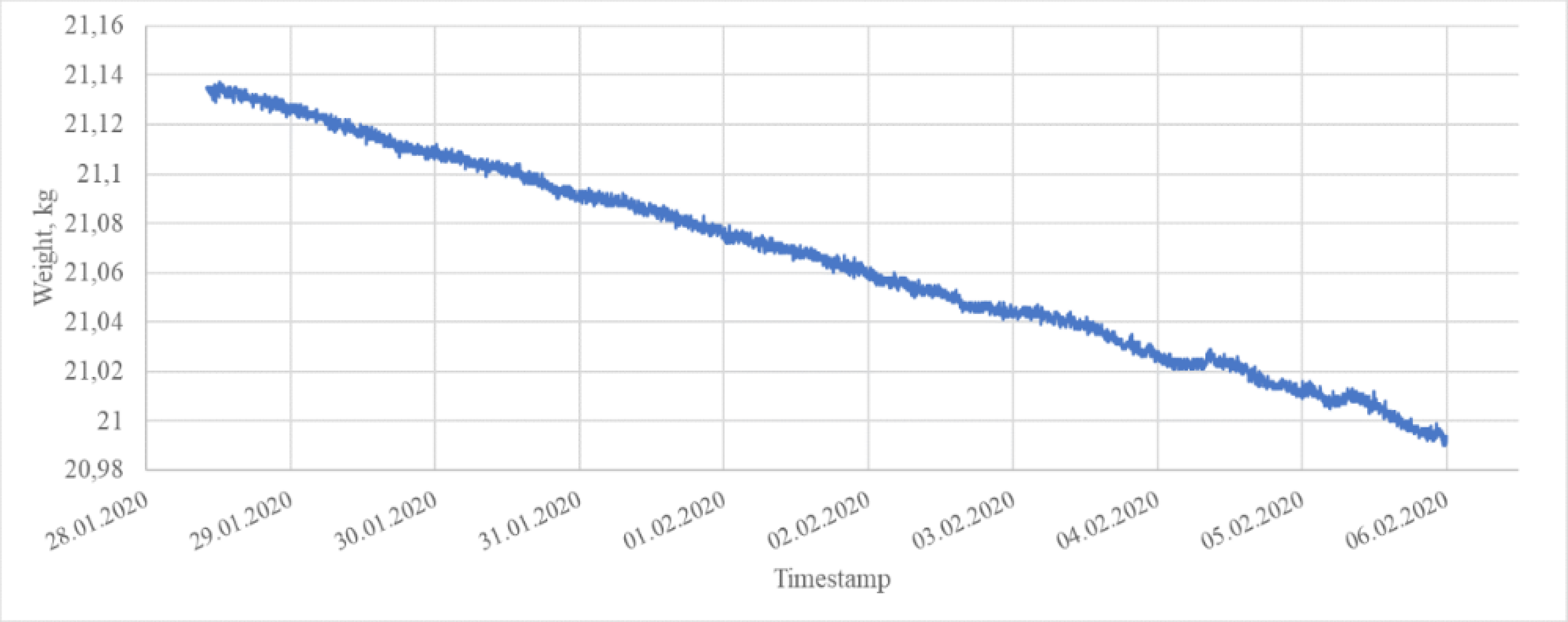
Weight monitoring

- The occurrence of nectar flow during the foraging season (start and end of nectar flow) or daily gain in nectar stores
- Consumption of food during non-foraging periods
- The occurrence of swarming events through a decrease in the hive weight



https://beep.nl/measurement-system-2/data-interpretation/weight

Weight: Passive period



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Weight: Swarming

Hive entrance monitoring

Developed system during the ITAPIC project

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Bee colony acoustics

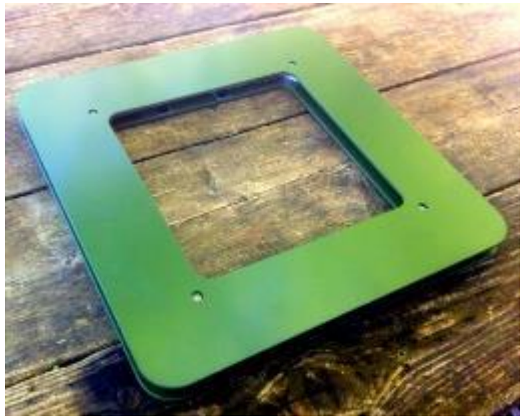
- Honey bees make sounds with their wings, thoracic muscles or breathing spiracles
- The most widely known/studied sound is a Queen piping
- The «Hum» of the hive: everyday hive sound as bees perform their daily tasks:
  - Worker bees thermoregulating the colony
  - Queen is present, laying eggs
  - Nurse bees feeding the young and the queen
  - Bees drawing honey comb, fanning and flying

Available commercial systems

https://www.wolf-waagen.de
900 EUR

www.bienenwaage.de
1310 EUR

https://pollenity.com/product/beebot/
315 EUR



http://www.arnia.co.uk/hive-scales/
380 EUR

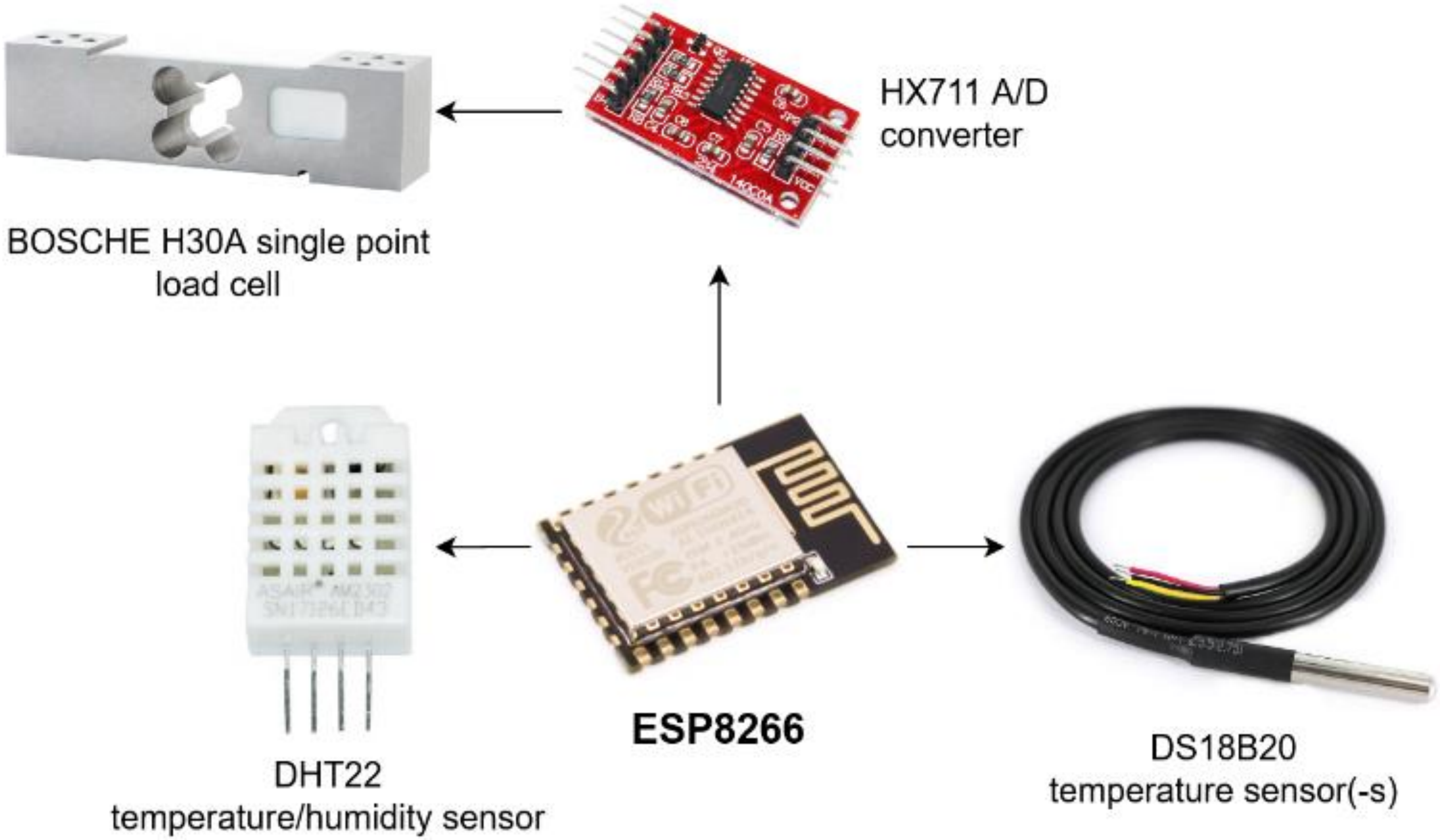
SAMS project

Smart Apiculture Management Services

- SAMS – International Partnership on Innovation in Smart Apiculture Management Services
- SAMS supports International Partnership Building in low and middle income countries in ASEAN and sub-Saharan Africa
- SAMS as an ICT solution:
  - allows active monitoring and managing of bee colonies
  - ensures bee health and bee productivity
  - gives answers to the requirements of beekeeping in developing countries
  - Is available as an open source technology

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 780755

SAMS monitoring system



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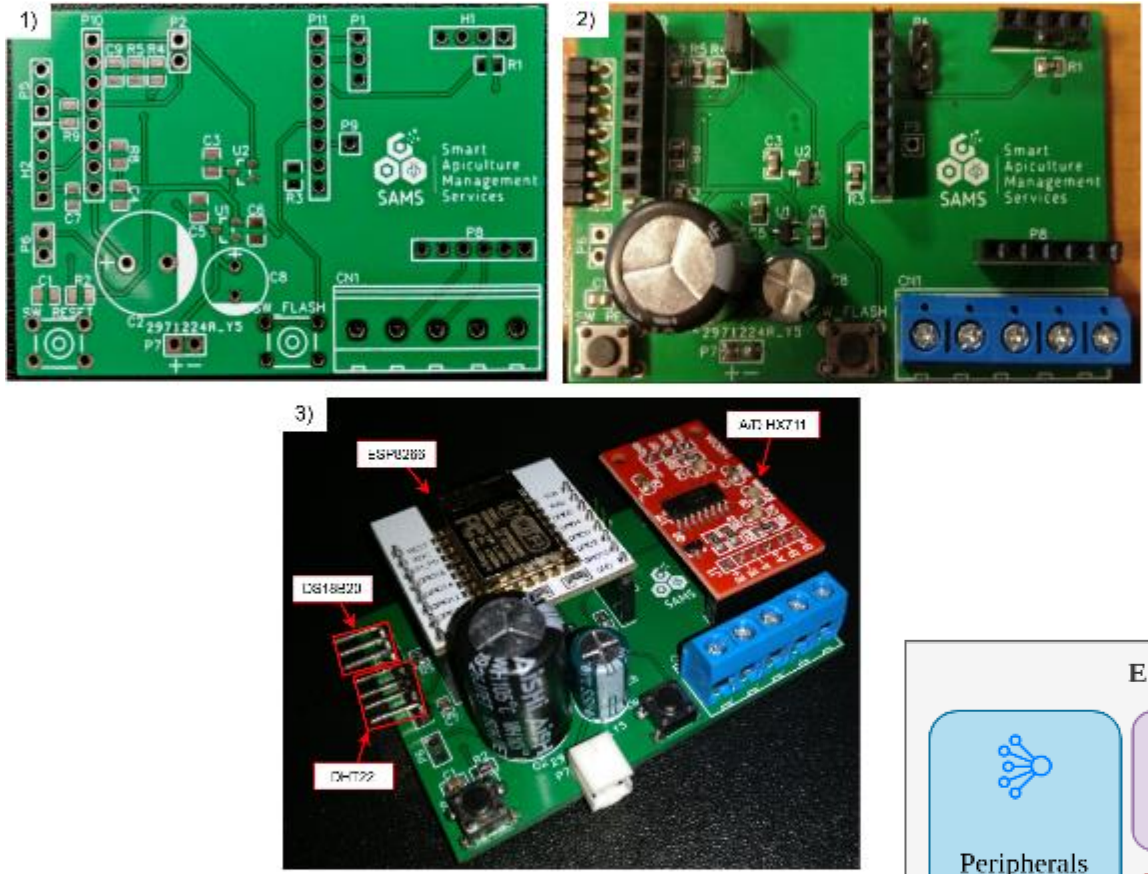
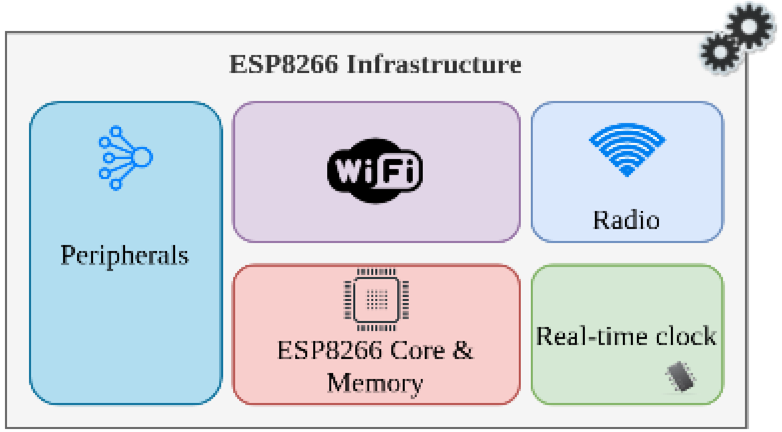
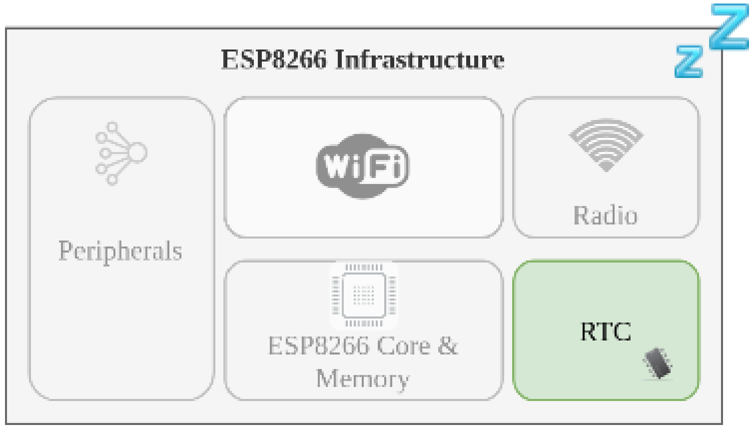
SAMS monitoring system



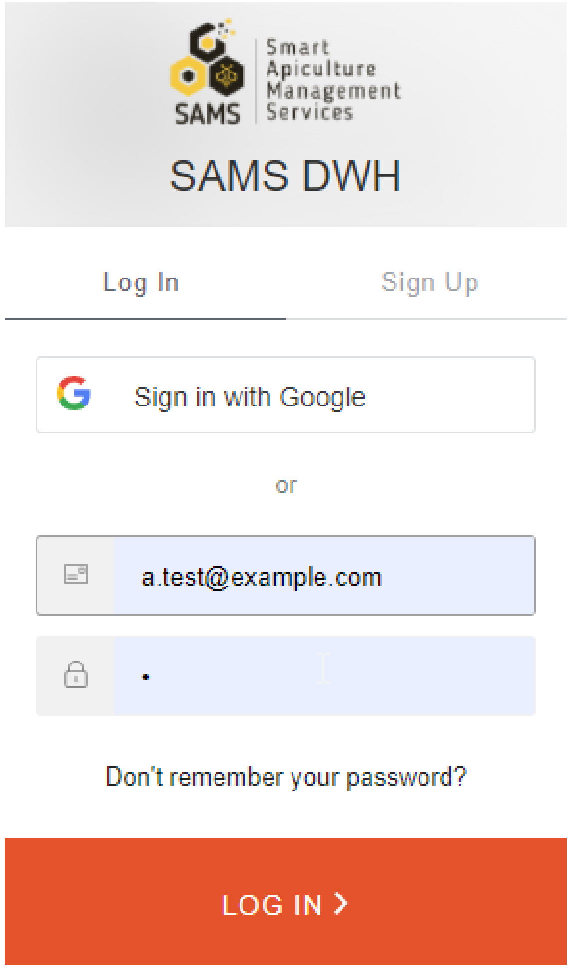
ESP8266 microchip

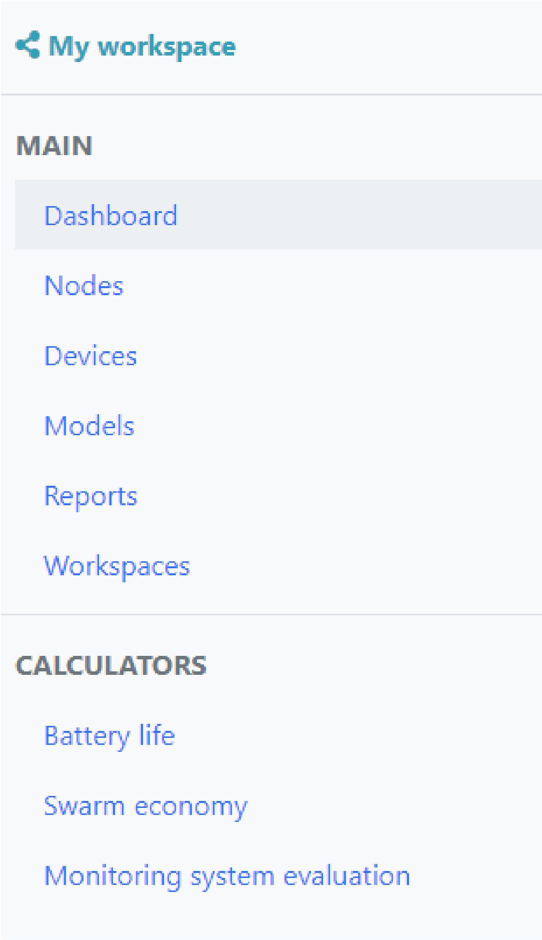
- WiFi microcontroller for IoT applications
- Power-saving architecture: active, sleep, deep sleep modes





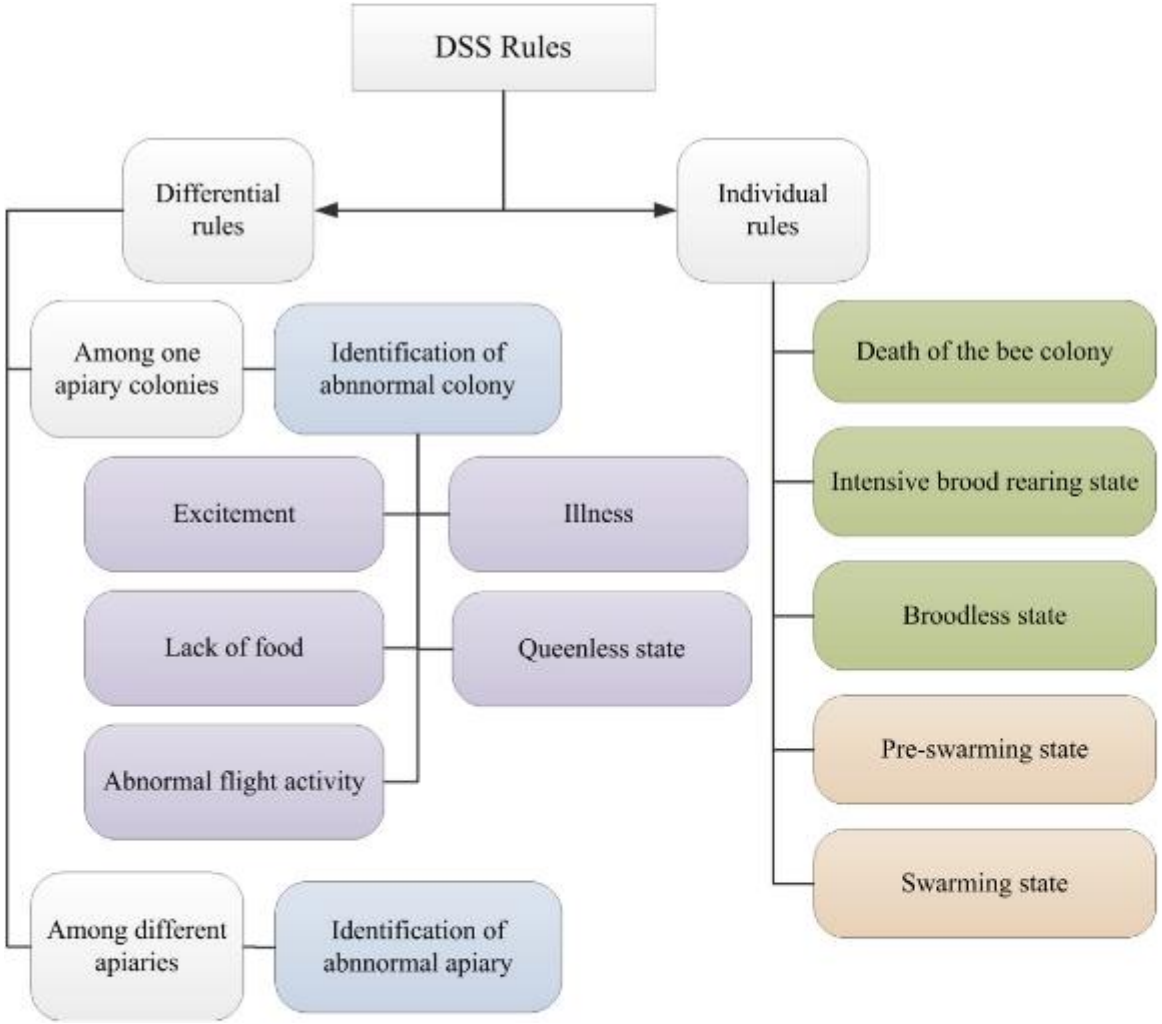
User interface of the system





Decision support system

- DSS in general is any system which helps someone with any aspect of making a decision (Bruen, 2006).
- Decision is a choice between options, where do nothing is also included.
- Decision support system (DSS) is a PC based system, which is used for automatic data analysis with main aim to recognize the status of the bee colony.



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WEB tool for calculation of costs for monitoring system implementation

Economic evaluation of remote monitoring systems

Profit calculation | Measurement systems

Basic income

Number of colonies (*): 20

Honey production per colony (kg): 25

Honey price (EUR/kg): 4.5

Income (EUR): 2,250.00

Expenses

Inspection expenses +

Costs due to bee colony death +

Costs due to swarming +

Total expenses (EUR): 1,230.74

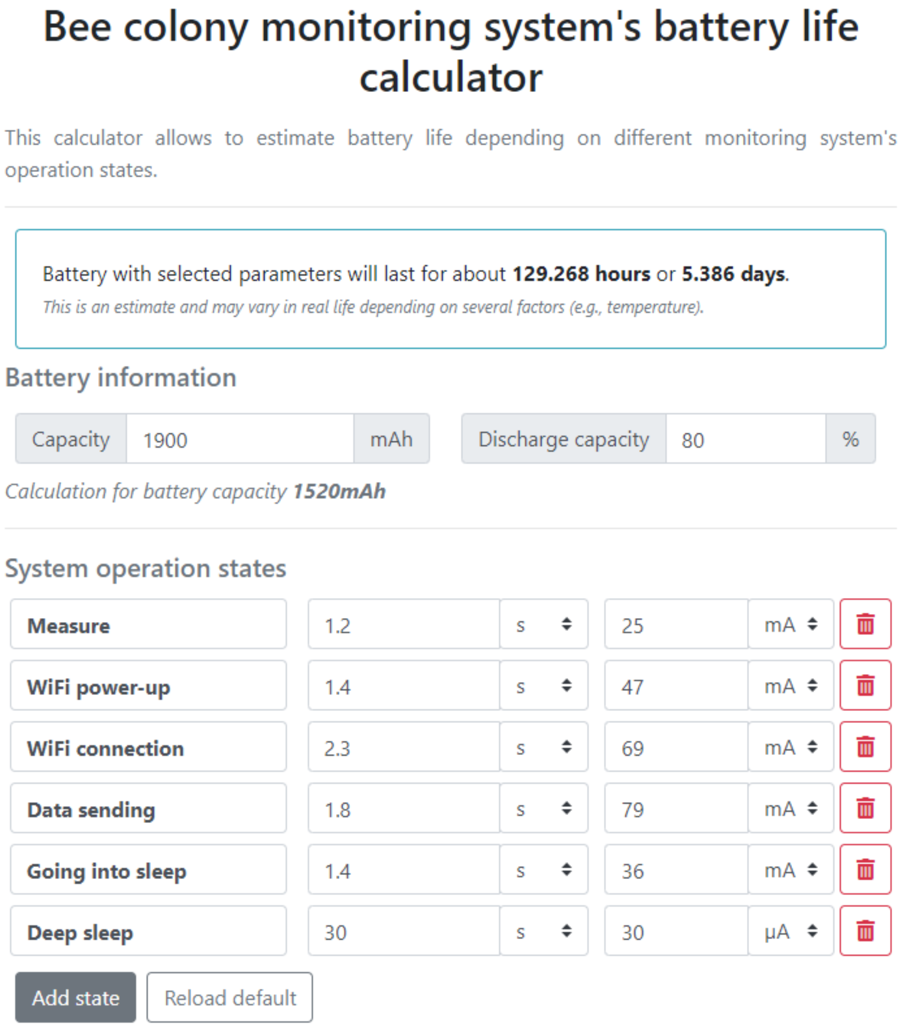
Profit (EUR): 1,019.26

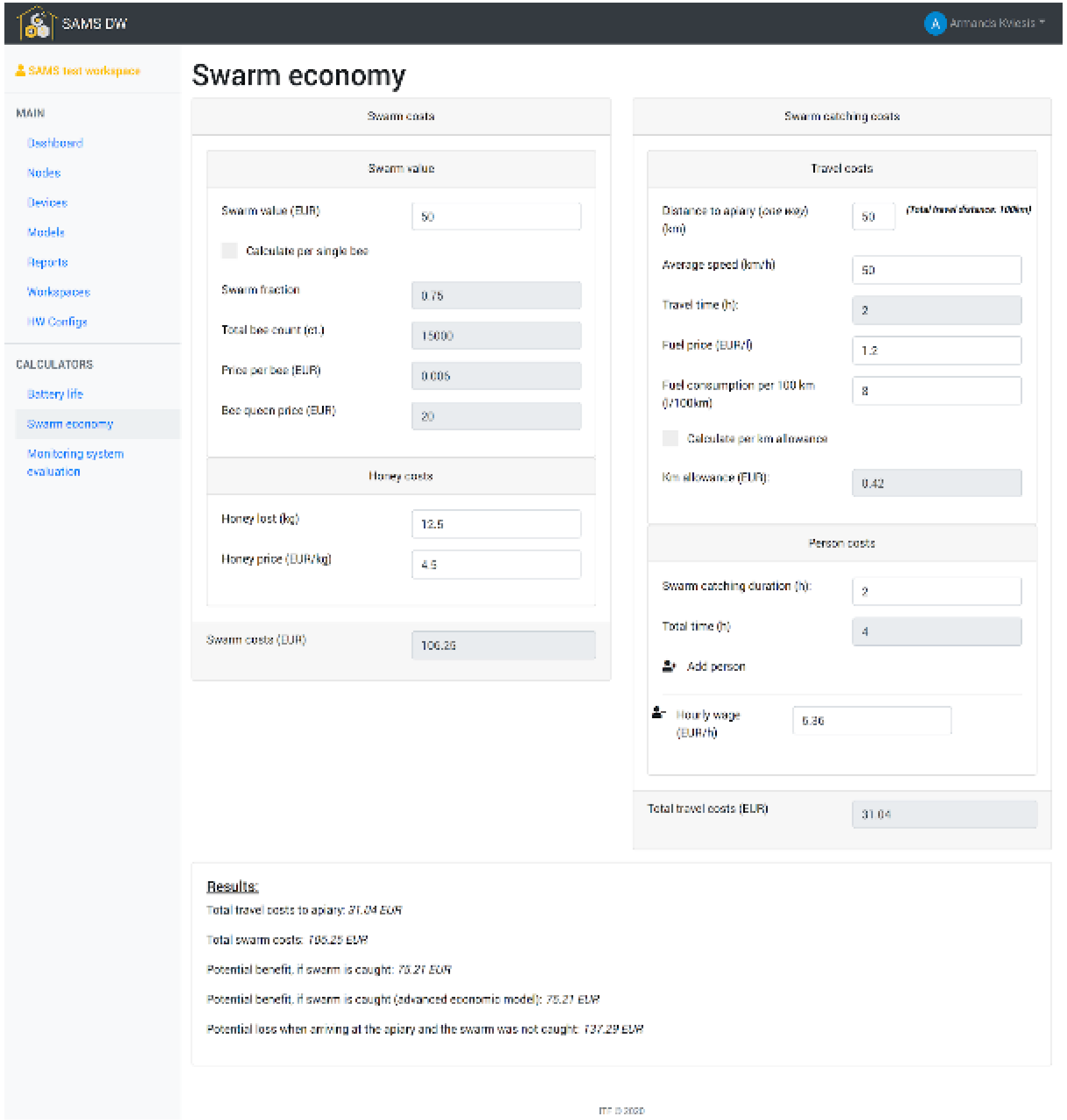
Economic evaluation of remote monitoring systems

Profit calculation | Measurement systems

	Without IT system	All hives with measuring system	One hive with system	Apiary with custom config
Production per hive	25.00	31.25	28.75	30.00
Basic income	2,250.00	2,812.50	2,587.50	2,700.00
Expenses				
Number of inspections	12	7	12	7
$EXP_{inspections}$	458.24	267.31	458.24	267.31
Number of dead colonies	4	3	4	3
EXP_{dead}	560.00	458.19	560.00	458.19
Number of swarmings	2	0	2	0
$EXP_{swarming}$	212.50	0.00	212.50	0.00
EXP_{total}	1,230.74	725.49	1,230.74	725.49
Profit and system installation costs				
Profit	1,019.26	2,087.01	1,356.76	1,974.51
System installation costs	---	5,780.00	289.00	500.00

Some tools


Bee colony monitoring system's battery life calculator
This calculator allows to estimate battery life depending on different monitoring system's operation states.
Battery with selected parameters will last for about 129.268 hours or 5.386 days.
This is an estimate and may vary in real life depending on several factors (e.g., temperature).
Battery information
Capacity
1900
mAh
Discharge capacity
80
%
Calculation for battery capacity 1520mAh
System operation states
Measure
1.2
s
25
mA
WiFi power-up
1.4
s
47
mA
WiFi connection
2.3
s
69
mA
Data sending
1.8
s
79
mA
Going into sleep
1.4
s
36
mA
Deep sleep
30
s
30
μA
Add state
Reload default


SAMS DW
Armanda Kviesis
SAMS test workspace
MAIN
Dashboard
Nodes
Devices
Models
Reports
Workspaces
HW Configs
CALCULATORS
Battery life
Swarm economy
Monitoring system evaluation
Swarm economy
Swarm costs
Swarm value
Swarm value (EUR)
50
Calculate per single bee
Swarm fraction
0.75
Total bee count (ct.)
15000
Price per bee (EUR)
0.005
Bee queen price (EUR)
20
Honey costs
Honey lost (kg)
12.5
Honey price (EUR/kg)
4.5
Swarm costs (EUR)
106.25
Swarm catching costs
Travel costs
Distance to apiary (one way) (km)
50
(Total travel distance: 100km)
Average speed (km/h)
50
Travel time (h):
2
Fuel price (EUR/l)
1.2
Fuel consumption per 100 km (l/100km)
8
Calculate per km allowance
Km allowance (EUR):
0.42
Person costs
Swarm catching duration (h):
2
Total time (h)
4
Add person
Hourly wage (EUR/h)
5.36
Total travel costs (EUR)
31.04
Results:
Total travel costs to apiary: 31.04 EUR
Total swarm costs: 105.25 EUR
Potential benefit, if swarm is caught: 75.21 EUR
Potential benefit, if swarm is caught (advanced economic model): 75.21 EUR
Potential loss when arriving at the apiary and the swarm was not caught: 137.29 EUR

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Hiveopolis project

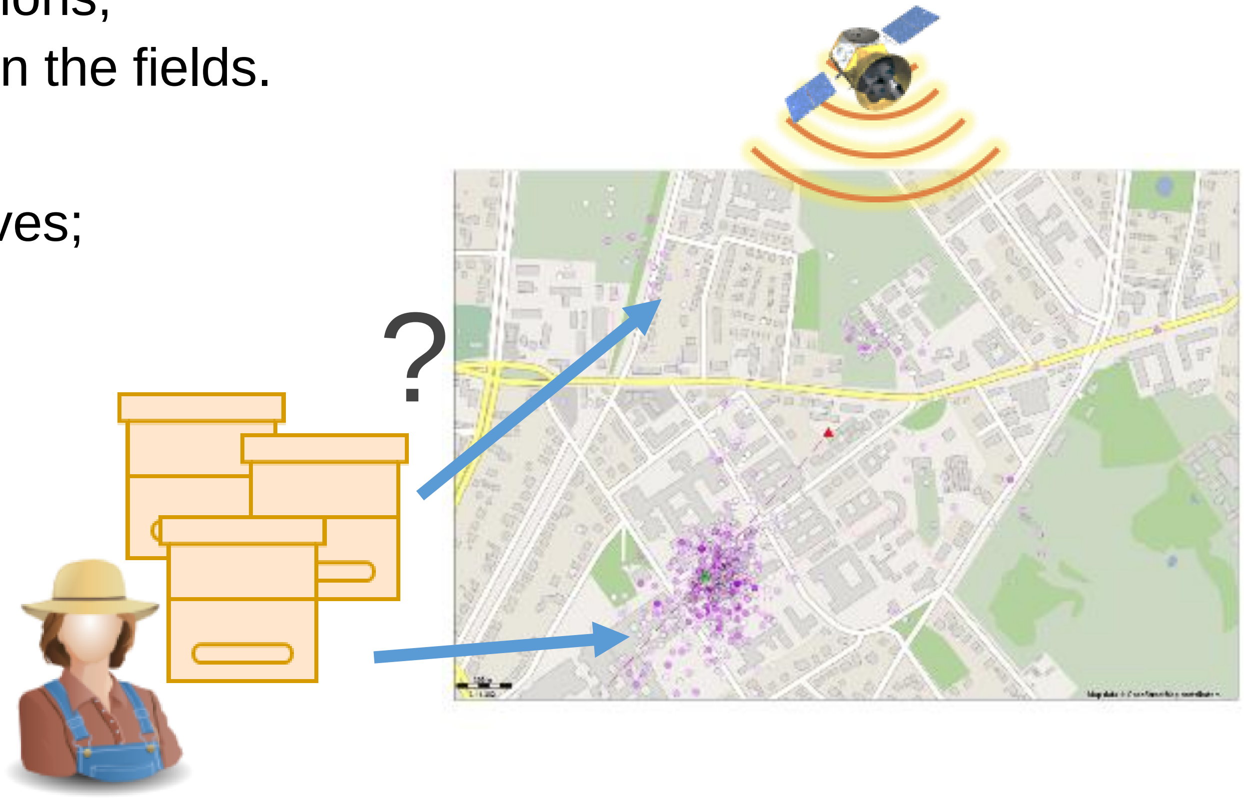
HIVEOPOLIS

- Futuristic Beehives for a Smart Metropolis
  - Horizon 2020 grant No. 824069
- The problem:
  - Ecosystem collapse
- Our approach is to use technology:
  - Organismic augmentation
  - Ecosystem hacking
  - Bio-hybrid socialization

UNI GRAZ artificial life lab
pollenity
Freie Universität Berlin
EPFL
ULB UNIVERSITÉ LIBRE DE BRUXELLES

Augmented map service

- Provide support for the beekeepers
  - finding and selecting good apiary locations;
  - modelling available honey resources on the fields.
- In the future
  - integrated into a system of futuristic hives;
  - find the best foraging location.
- From beekeepers perspective:
  - Where should I place my hives?
  - How many hives should I place?



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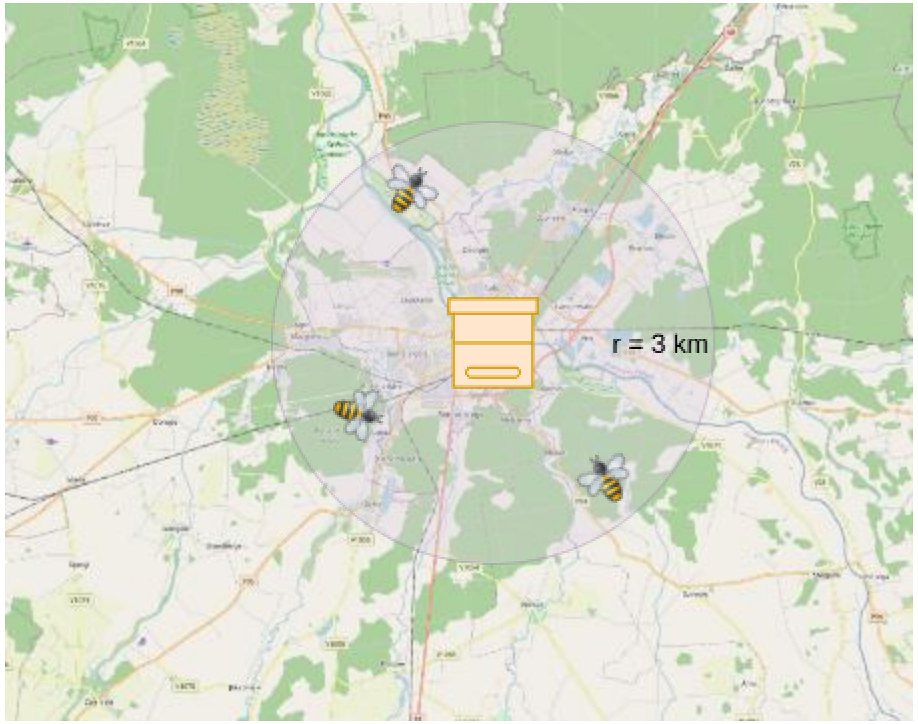
Model parameters / assumptions



- Flying radius of bees
  - 3 km
- Size of the remote apiary
  - min 15 hives
  - max 70 hives
- Honeybees foraging efficiency
  - k = 0.35
  - bees harvest ~35% of available nectar
- Nectar to honey production rate
  - h = 0.4
  - for 2 kg of honey production bees need to forage 5 kg of nectar
- Amount of honey needed for hive itself
  - 90 kg / hive / year
- Average amount of honey production
  - 60 kg / hive / year

Model steps 1

Step 1: Define polygons of agricultural fields

Example of terrain map used for model evaluation

Example of defined polygons

Step 2: Semantically annotated map of polygons

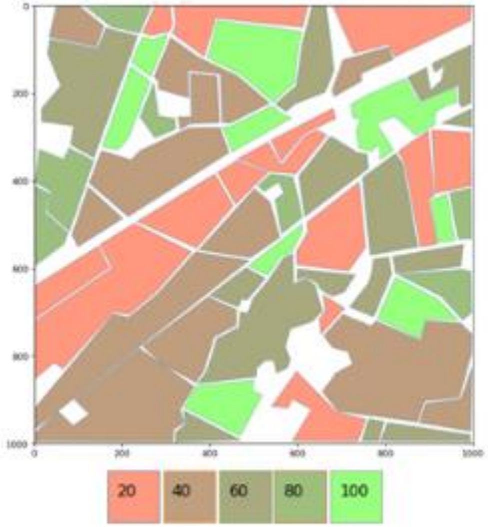
Generated digitized map of marked fields and regions

Digital map combined with the real map

Model steps 2

Step 3: Define field productivity

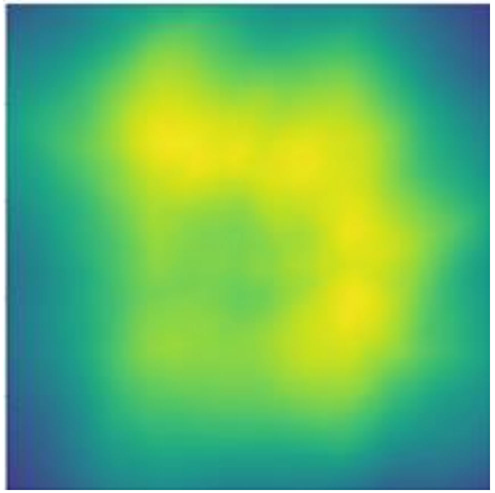
- Field productivity index
  - the amount of resources available for bee forage
  - 5 distinct values used for demonstration
- Information about specific plants and crops
  - index describing pollen and/or nectar production
  - randomly selected for demonstration purposes
  - (future) integration with external databases / flowering calendars



Field resources (color encoded)

Step 4: Calculate resource availability


Potential field resources covered by colony foraging area


Heat map of resource availability in each possible point

Step 5: Iteratively find place with maximum resources


Demonstration of optimal apiary locations

Flowering calendar of blooming crops

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Future development perspectives of Precision Beekeeping in Latvia

- Actual thing for the Latvian beekeepers is to prevent remotely located hives from the theft and animal demolition, that’s why video monitoring of the apiary and hive GPS systems are important.
- One more direction of PB development can be sharing of information about apiaries between various beekeepers and developing a beekeeping map with main aim to prevent the spread of possible illnesses.

- Some requirements for the bee colony monitoring:
  - Reduce risks of loosing bee colonies
  - Reduce hive theft risks
  - Minimize capacity risks during harvests
  - Avoid unnecessary activities
  - Help on bee product quality

Thank you for attention!

- Any questions?