

Digital Twins – potentials and challenges in the context of honey bee vitality

Jürgen Groeneveld (UFZ, Germany)

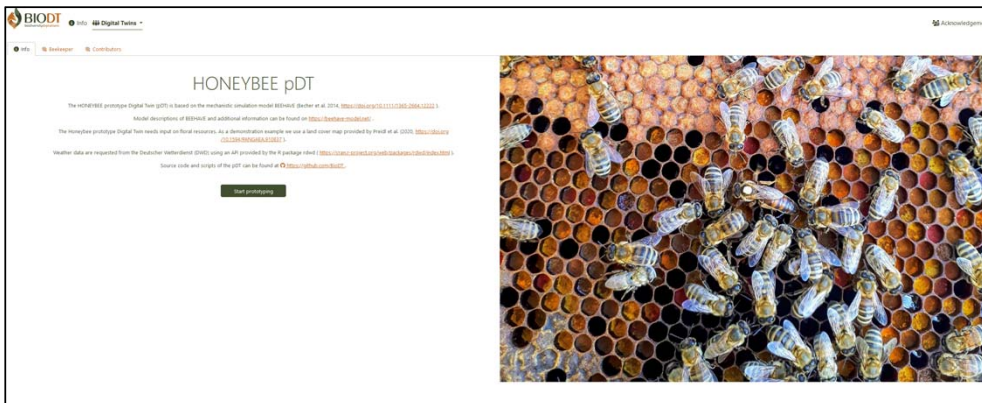
Tomas Martinovic (IT4I, Czech Republic)

Tuomas Rossi (CSC, Finland)

Ondrej Salamon (IT4I, Czech Republic)

Kata Sara-aho (CSC, Finland)

Volker Grimm (UFZ, Germany)



Honey bees as test species for future Digital Twins of insect pollinators:

Drivers/Stressors:



Pesticides

Honey bees are important pollinators (e.g. oil seed rape)

Honey bees face multiple stressors

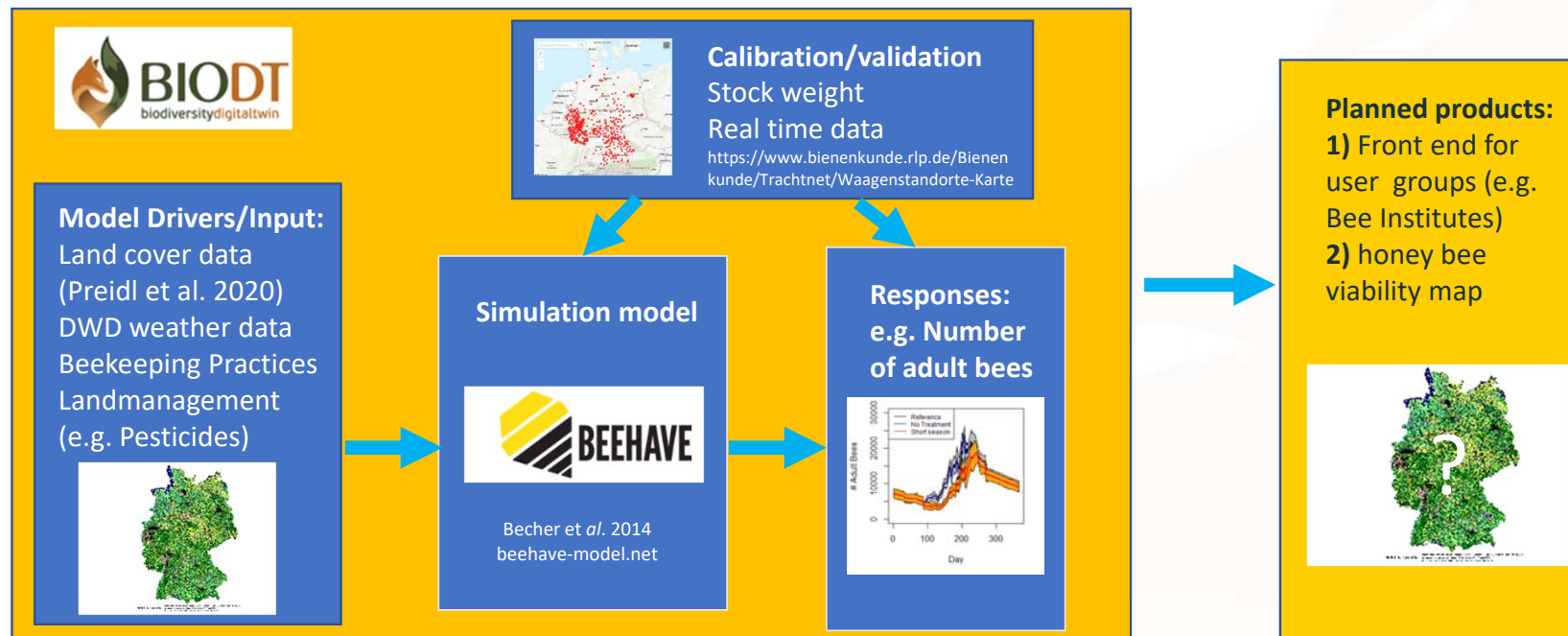
Availability of Tools/Models and data

Impact of single stressors is well documented (at least better than for any other insect species)

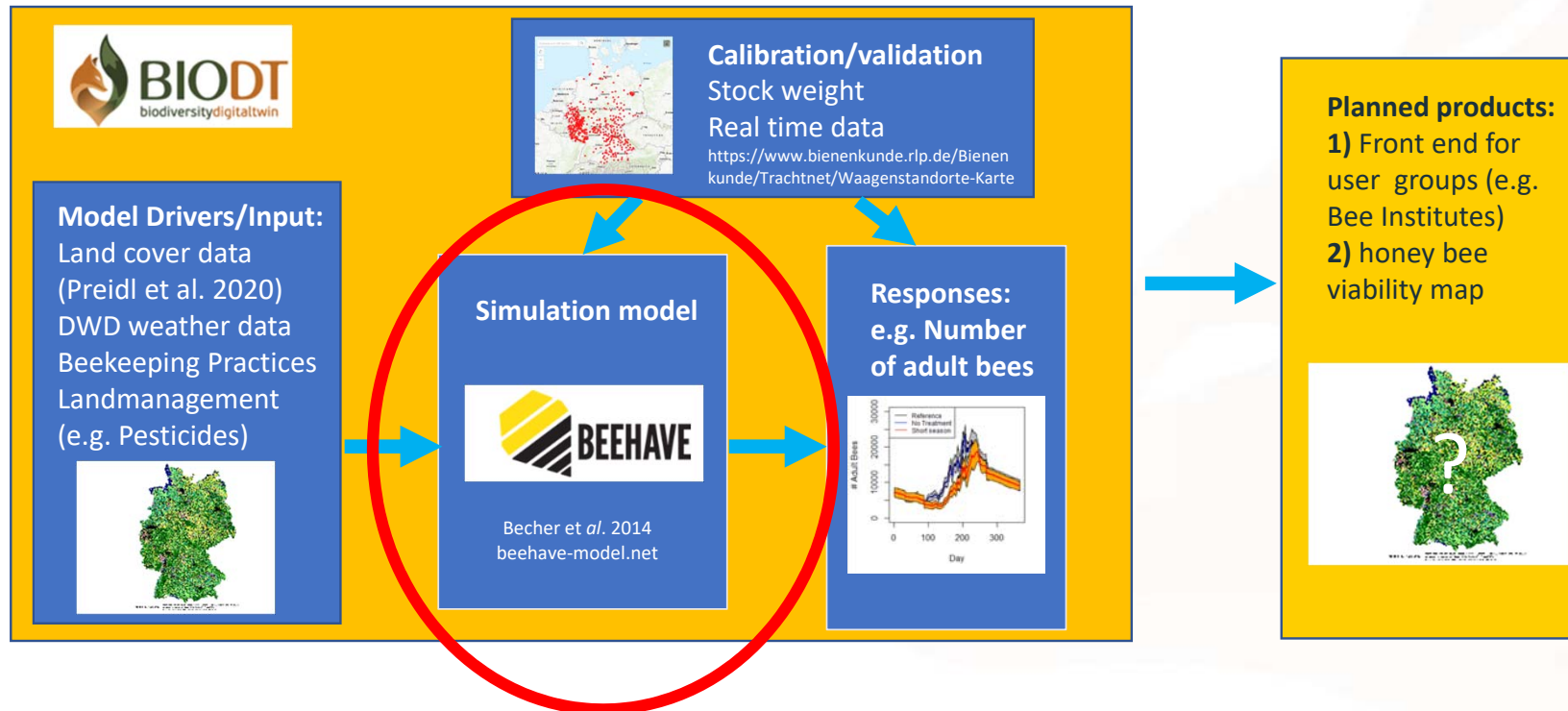
Landscape assessment on a large spatial extent (national, European) and for trends in climate and land use is useful/needed

1) The original uploader was Tullius at German Wikipedia., Public domain, via Wikimedia Commons;
<https://commons.wikimedia.org/wiki/File:Varroamilbe.jpg>;

Honey bee **prototype** Digital Twin



Simulation model BEEHAVE as virtual twin.

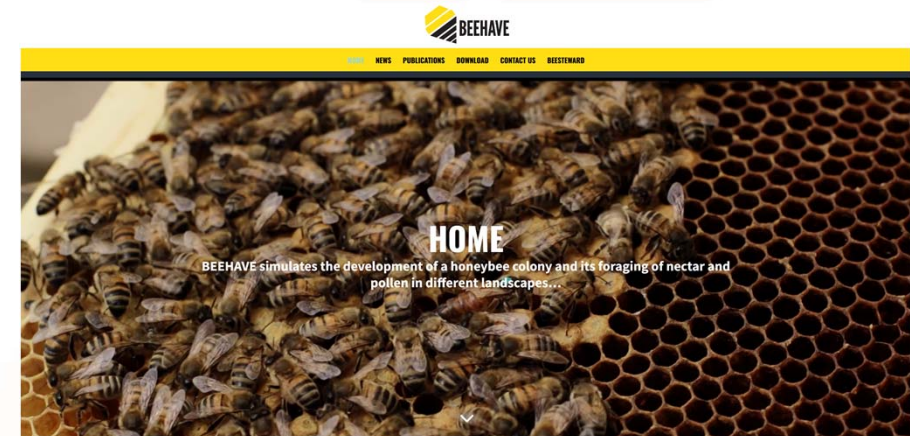


Simulation model BEEHAVE as virtual twin.



BEEHAVE: a systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure

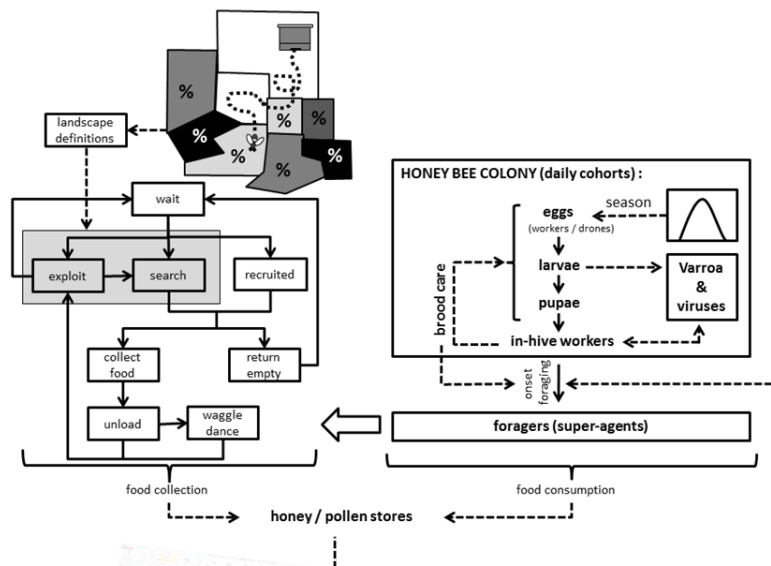
Matthias A. Becher^{1,2*}, Volker Grimm^{3,4,5}, Pernille Thorbek⁶, Juliane Horn³, Peter J. Kennedy^{1,2} and Juliet L. Osborne^{1,2}



WoS 168 citations (21th May 2024) , >20 published applications

Well documented, freely accessible

Existing user group, tested by EFSA



Becher et al. 2014, Journal of Applied Ecology

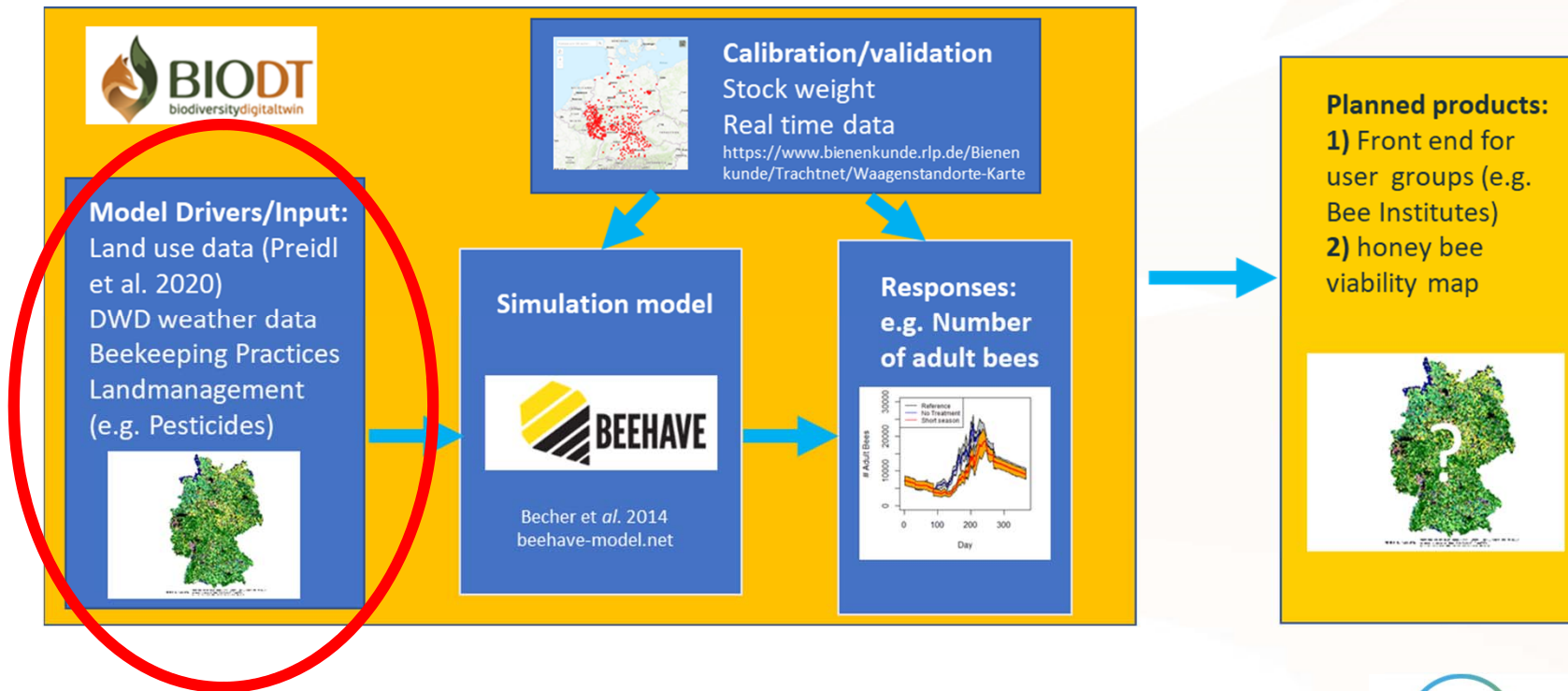
>6000 lines of source code, NetLogo

BEEHAVE:

Three main compartments

- 1) Foraging/landscape
- 2) Population dynamics – cohort based (eggs, larvae, pupae, in-hive bees, foragers, drones)
- 3) Mite model

Input data for the virtual twin:



Weather data (determining the foraging activity of honey bees):

Daily

Closest weather station

Max Temperature, sun shine hours

Missing data

rdwd

Berry Boessenkool, berry-b@gmx.de

built 2024-05-14 with rdwd version 1.8.11 and dwdradar version 0.2.10

1 Intro

`rdwd` is an R package to handle data from the German Weather Service (DWD).

This website has 3 main sections:

- time series from meteorological stations (chapters 3-7)
- raster data from radar + interpolation (chapter 8)
- use cases, i.e. extended usage examples (chapter 9-end)

Important links:

- further details on the data: [DWD FTP server documentation](#)
- website [source code](#) and [files](#)
- feedback is very welcome via [github](#) or berry-b@gmx.de!
- app for [comparing weather periods](#)

The remainder of this intro chapter is a copy of the [github README file](#).



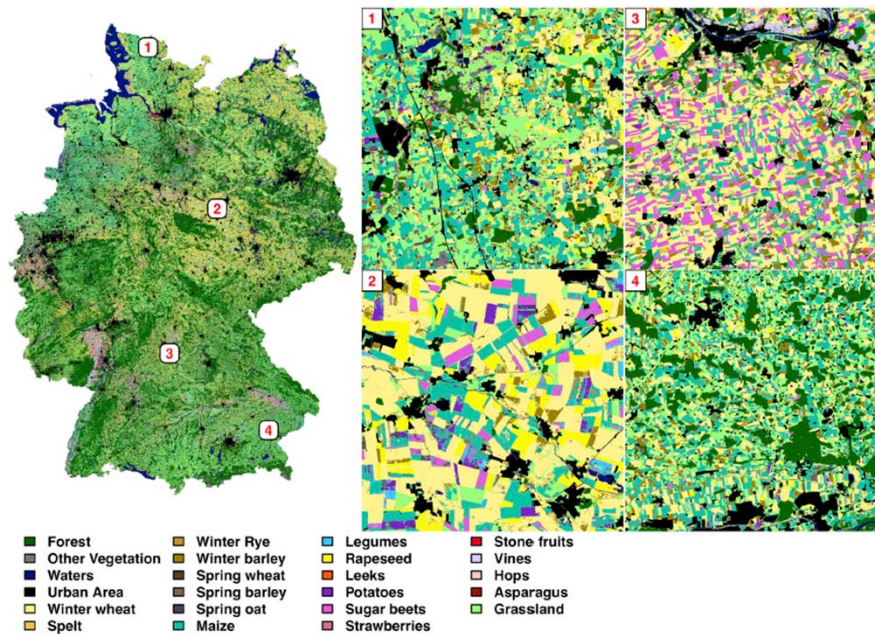
`rdwd` is an R package to select, download and read climate data from the German Weather Service

<https://bookdown.org/brry/rdwd/>

Land cover data (needed to determine floral resources):

S. Preidl, et al.

Remote Sensing of Environment 240 (2020) 111673



20 m resolution

19 vegetation classes

2016 more years are currently
Computed

Annual updates planned

Preidl, Sebastian; Lange, Maximilian; Doktor, Daniel
(2020): Land cover classification map of Germany's
agricultural area based on Sentinel-2A data from
2016. PANGAEA,
<https://doi.org/10.1594/PANGAEA.910837>

Preidl, S., Lange, M., & Doktor, D. (2020). Introducing APiC for regionalised land cover mapping on the national scale using Sentinel-2A imagery. Remote Sensing of Environment, 240, Article 111673. <https://doi.org/10.1016/j.rse.2020.111673>

Land cover data needs to be translated into floral resources (nectar and pollen):

From the literature: Nectar: Baude et al. 2016 (U.K.), Jachula et al. (Poland) and Hicks et al. 2016 (urban meadows)

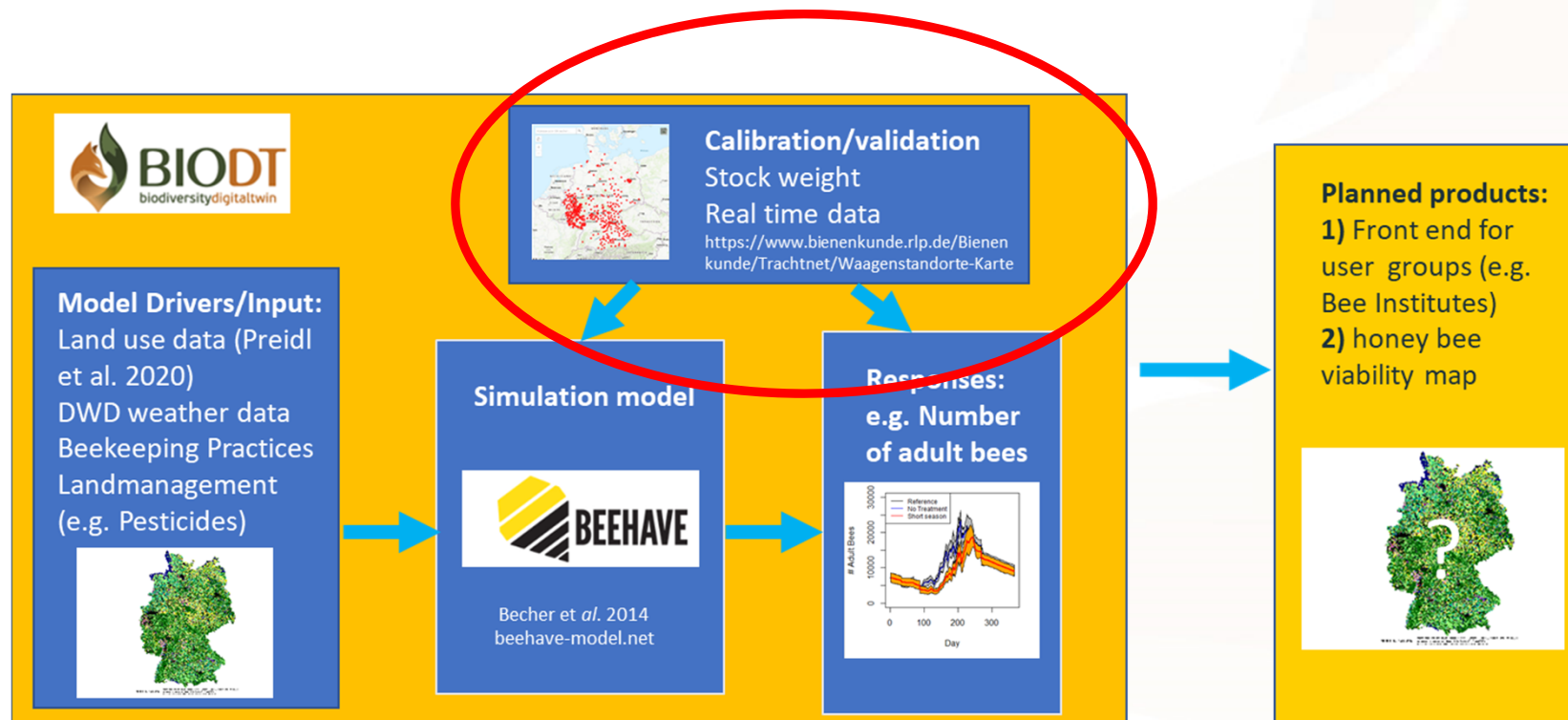
B-GOOD Database: <https://ruj.uj.edu.pl/xmlui/handle/item/267833>

More data on nectar – pollen data is scarce – many modes of measurements and units

Crop/non-crop bias (e.g. excellent data for oil seed rape, difficult for grasslands, urban areas)

Look up table – work in progress – user can utilize own data

Meeting the physical twin:



TrachtNet data (2020) – Data on colony weights – Thanks to Christoph Otten and Jes Johannesen:

Johannesen J, Wöhl S, Berg S, Otten C (2022) Annual Fluctuations in Winter Colony Losses of *Apis mellifera* L. Are Predicted by Honey Flow Dynamics of the Preceding Year. *Insects* 13 (9). URL: <https://www.mdpi.com/2075-4450/13/9/829>



<https://www.bienenkunde.rlp.de/Bienenkunde/TrachtNet/Waagenstandorte-Karte>



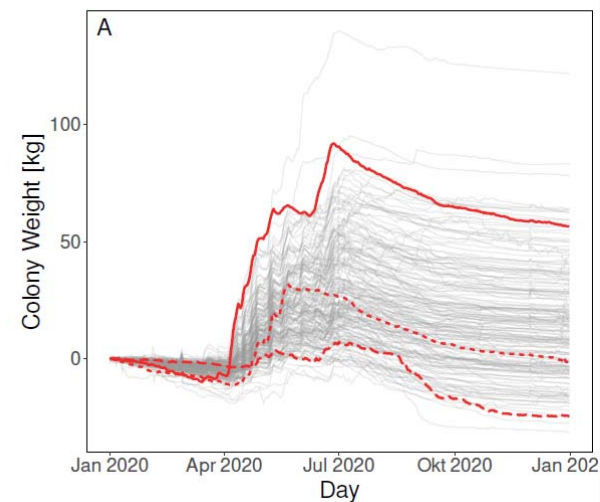
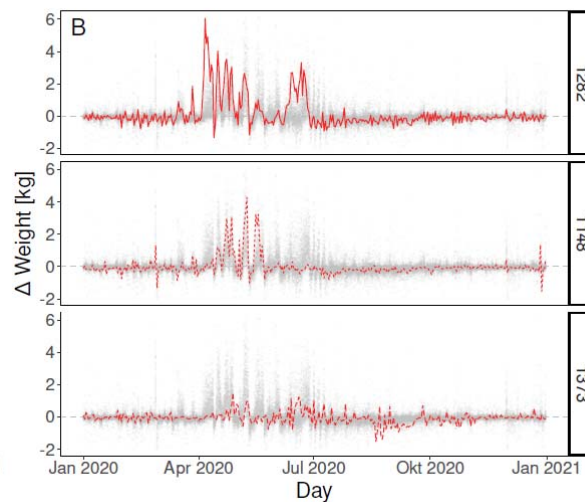
Measuring the weight of a colony every 5 minutes
<https://wolf-waagen.de/en/>

TrachtNet data (2020) – Data on colony weights – Thanks to Christoph Otten and Jes Johannesen:

Johannesen J, Wöhl S, Berg S, Otten C (2022) Annual Fluctuations in Winter Colony Losses of *Apis mellifera* L. Are Predicted by Honey Flow Dynamics of the Preceding Year. *Insects* 13 (9). URL: <https://www.mdpi.com/2075-4450/13/9/829>

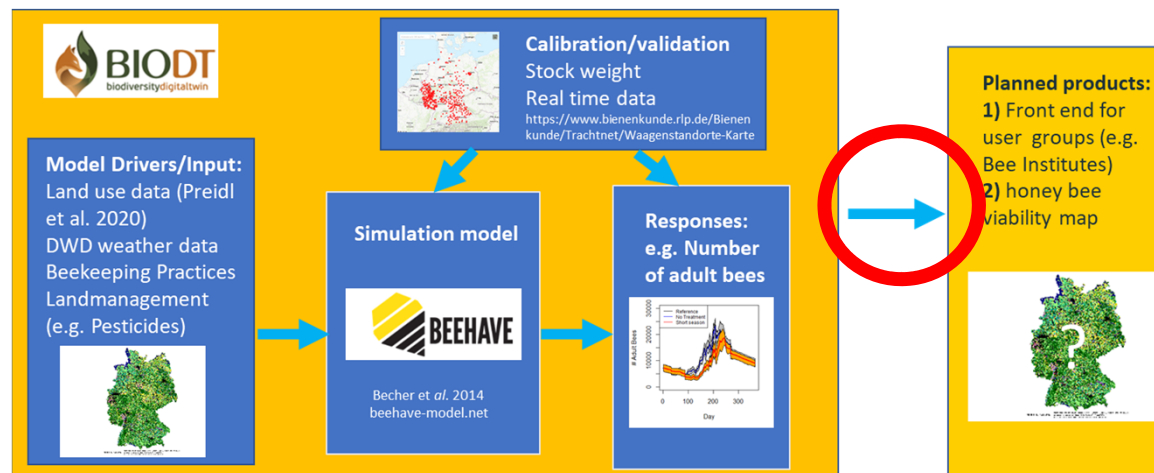


<https://www.bienenkunde.rlp.de/Bienenkunde/TrachtNet/Waagenstandorte-Karte>



Anna Wendt (Master Thesis 2024)

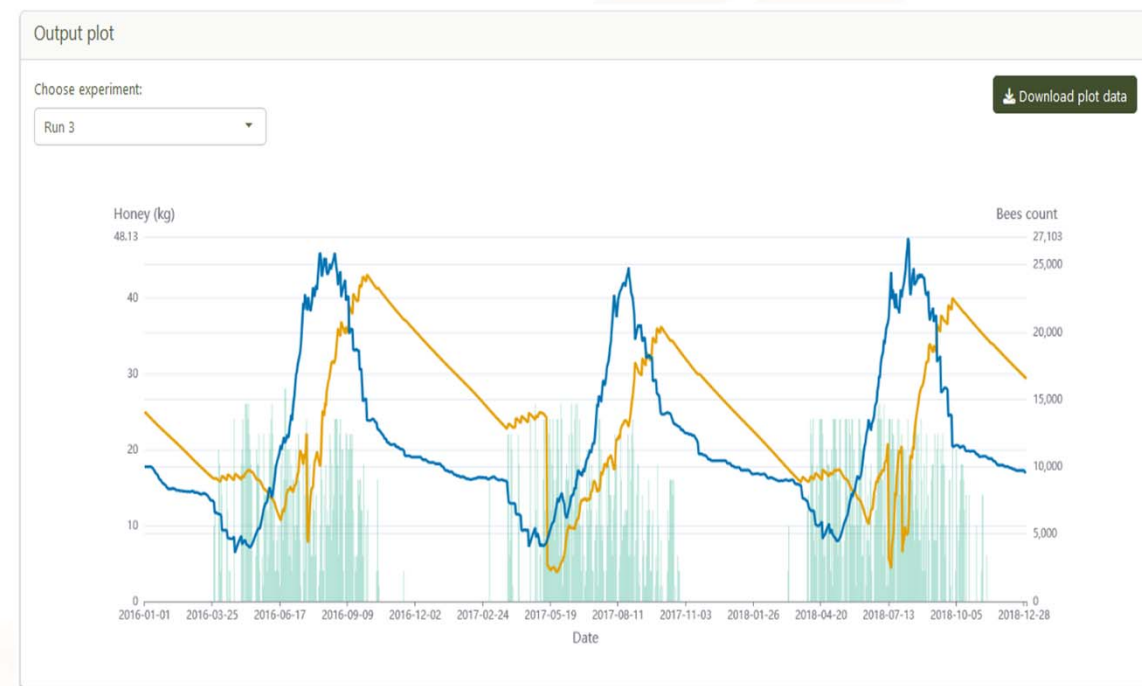
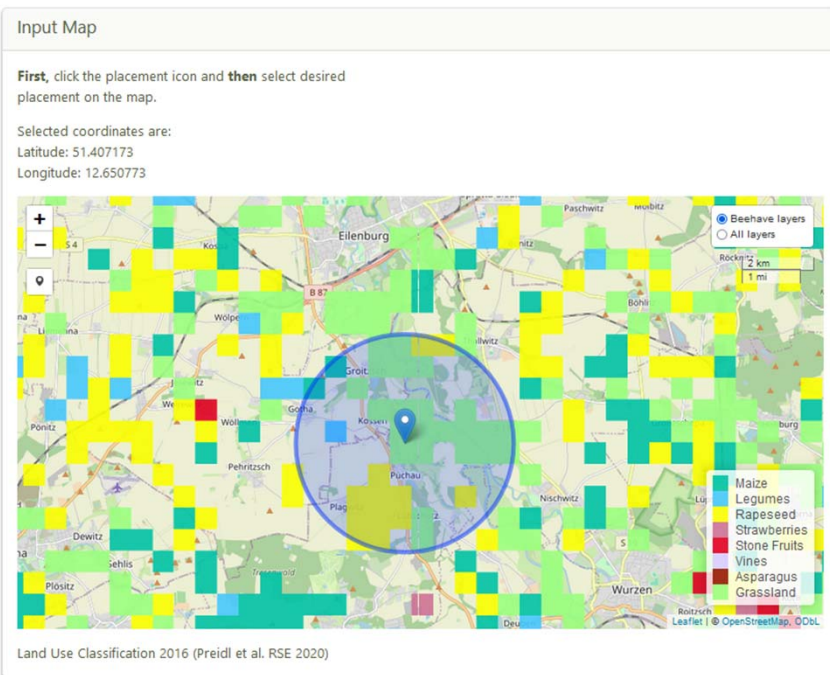
Interaction between pDT and user:



GUI implemented as an R shiny app (R is popular statistical language among ecologists)

pDT has been run on HPCs (Lumi CPU, Carolina) and other platforms successfully.

pDT not yet an operational DT: Calibration needed, but also fundamentally overcoming unknowns (floral resources, colony status)



Digital Twin concept useful?

It has changed our thinking and designing model products towards the requirements of DTs.

Feedback of the pDT to the physical world through the user (Beekeeper) possible (Treatment).

Description of the state of the art of the honeybee pDT (<https://riojournal.com/article/125167/>)



Research Ideas and Outcomes 10: e125167
doi: [10.3897/rio.10.e125167](https://doi.org/10.3897/rio.10.e125167)



Forum Paper

Prototype Biodiversity Digital Twin: honey bees in agricultural landscapes

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Isabel Schödl

Thanks!