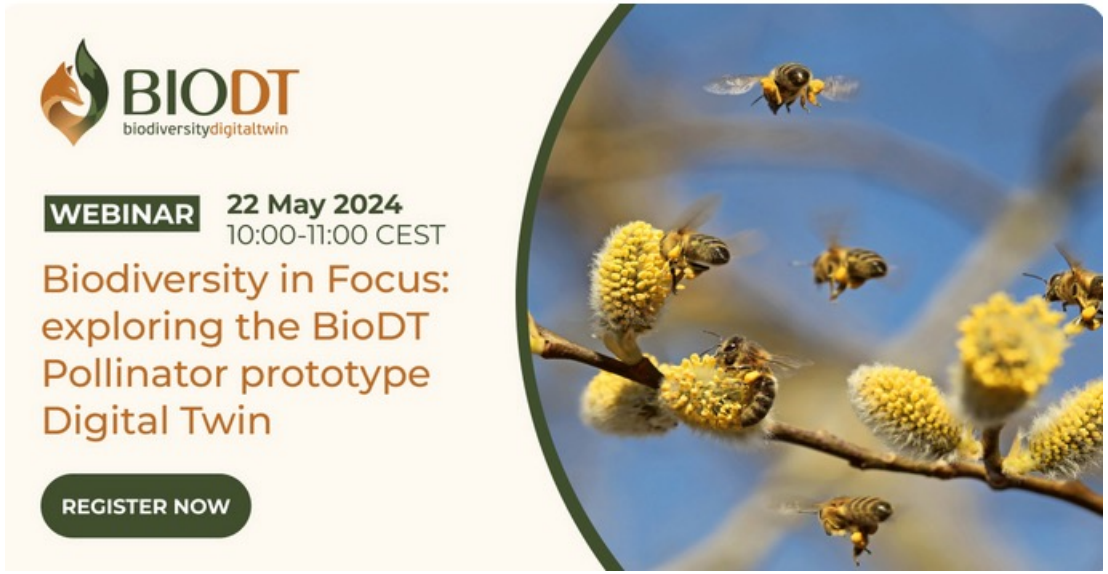


# Honey bee prototype Digital Twin - Workflow

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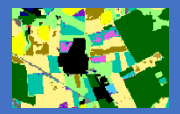
Tuomas Rossi (CSC, Finland)
Ondrej Salamon (IT4I, Czech Republic)
Kata Sara-aho (CSC, Finland)
Volker Grimm (UFZ, Germany)

# 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)

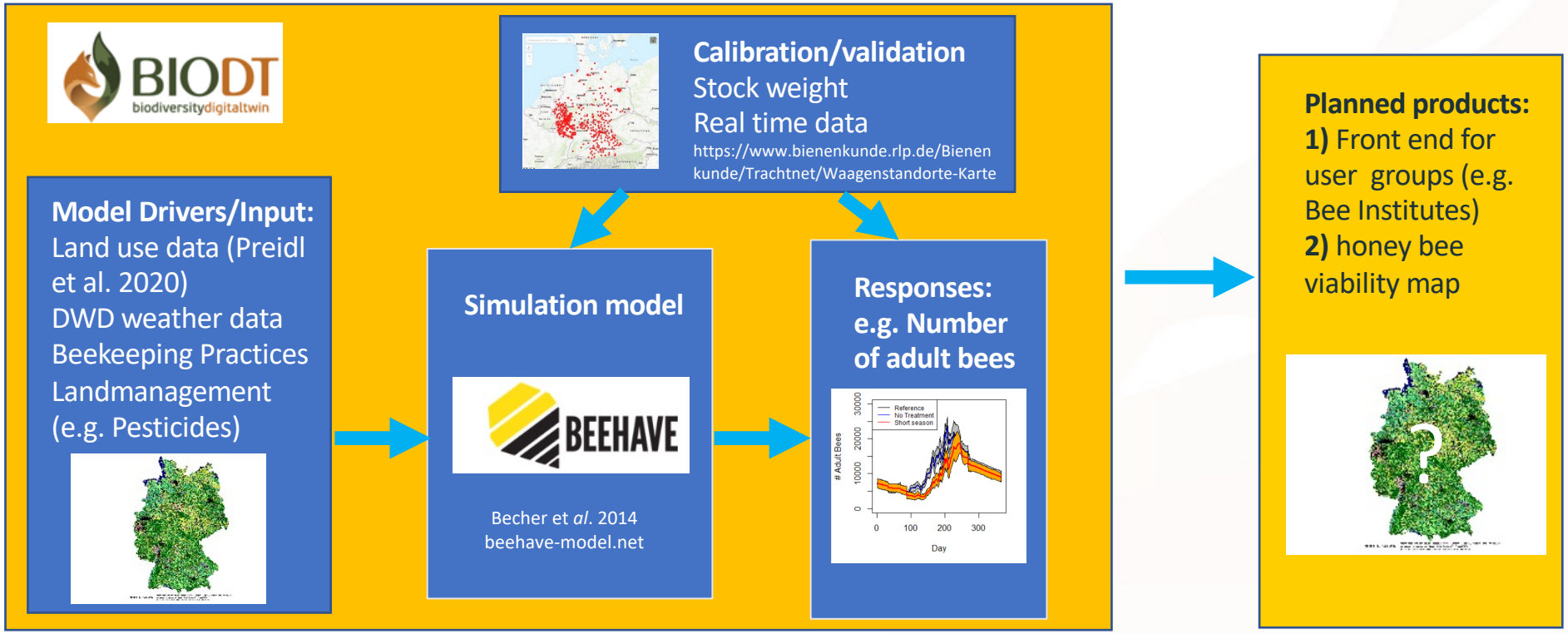
Honey bees face multiple stressors

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

## Honey bee pDT



„BEEHAVE simulates the development of a honeybee colony and its foraging of nectar and pollen in different landscapes…“ (Matthias Becher, https://beehave-model.net/)

50 YEARS WITH IMPACT

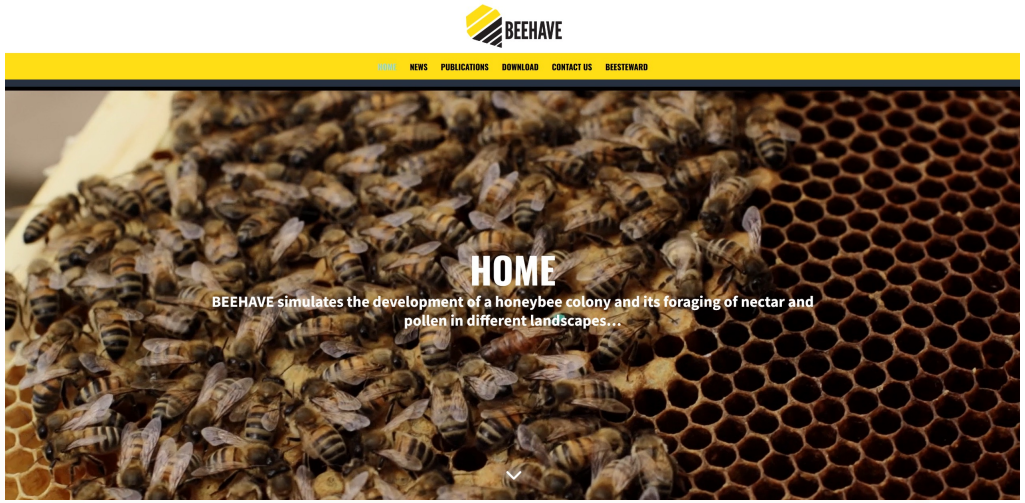
Journal of Applied Ecology

1913 2013 British Ecological Society — CELEBRATING 100 YEARS —

*Journal of Applied Ecology* 2014 doi: 10.1111/1365-2664.12222

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

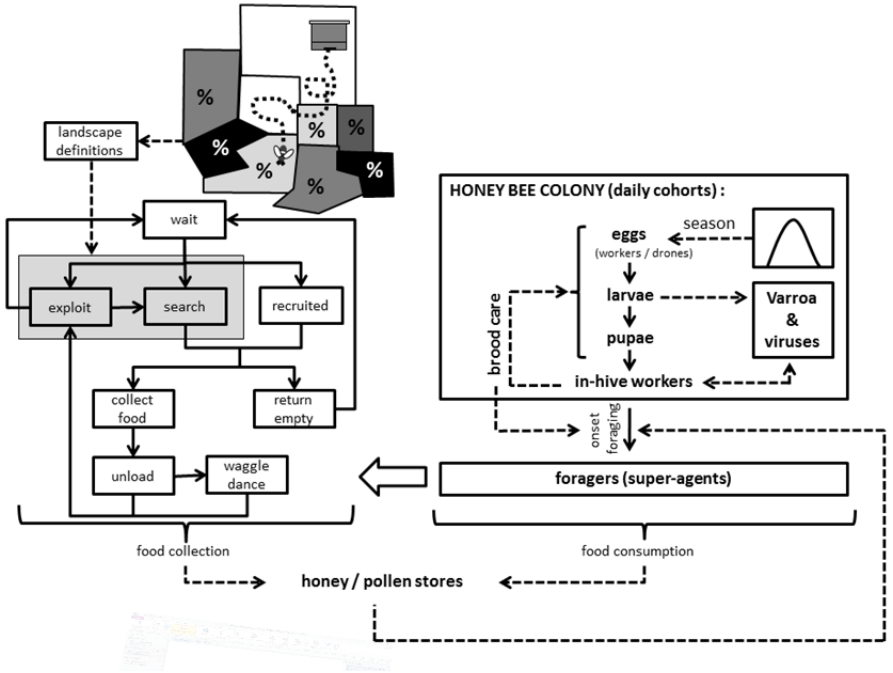
Matthias A. Becher[1,2]*, Volker Grimm[3,4,5], Pernille Thorbek[6], Juliane Horn[3], Peter J. Kennedy[1,2] and Juliet L. Osborne[1,2]




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

Well documented, freely accessible

# Model choice




Becher et al. 2014, Journal of Applied Ecology

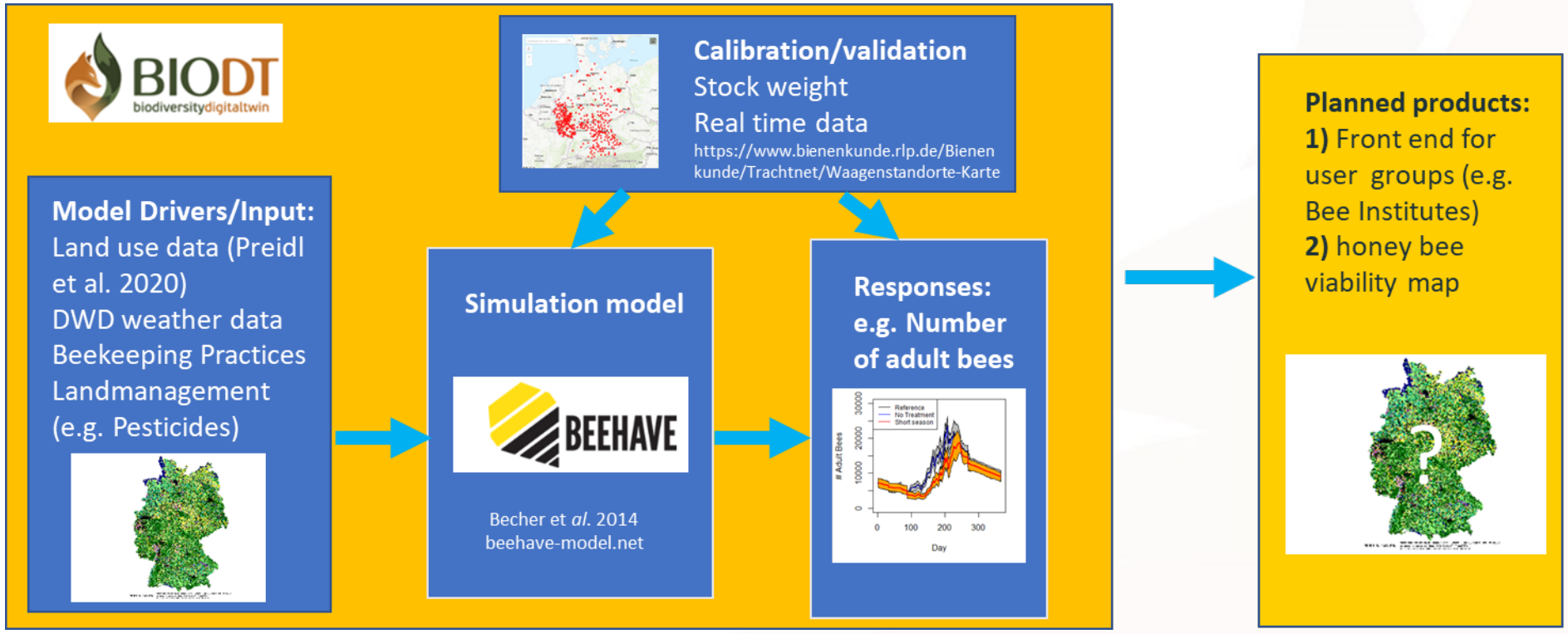
>6000 lines of source code, NetLogo

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


BIODT
biodiversitydigitaltwin
Model Drivers/Input:
Land use data (Preidl et al. 2020)
DWD weather data
Beekeeping Practices
Landmanagement (e.g. Pesticides)
Calibration/validation
Stock weight
Real time data
https://www.bienenkunde.rlp.de/Bienenkunde/Trachtnet/Waagenstandorte-Karte
Simulation model
BEEHAVE
Becher et al. 2014
beehave-model.net
Responses:
e.g. Number of adult bees
Reference
No Treatment
Short season
# Adult Bees
Day
Planned products:
1) Front end for user groups (e.g. Bee Institutes)
2) honey bee viability map

**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:

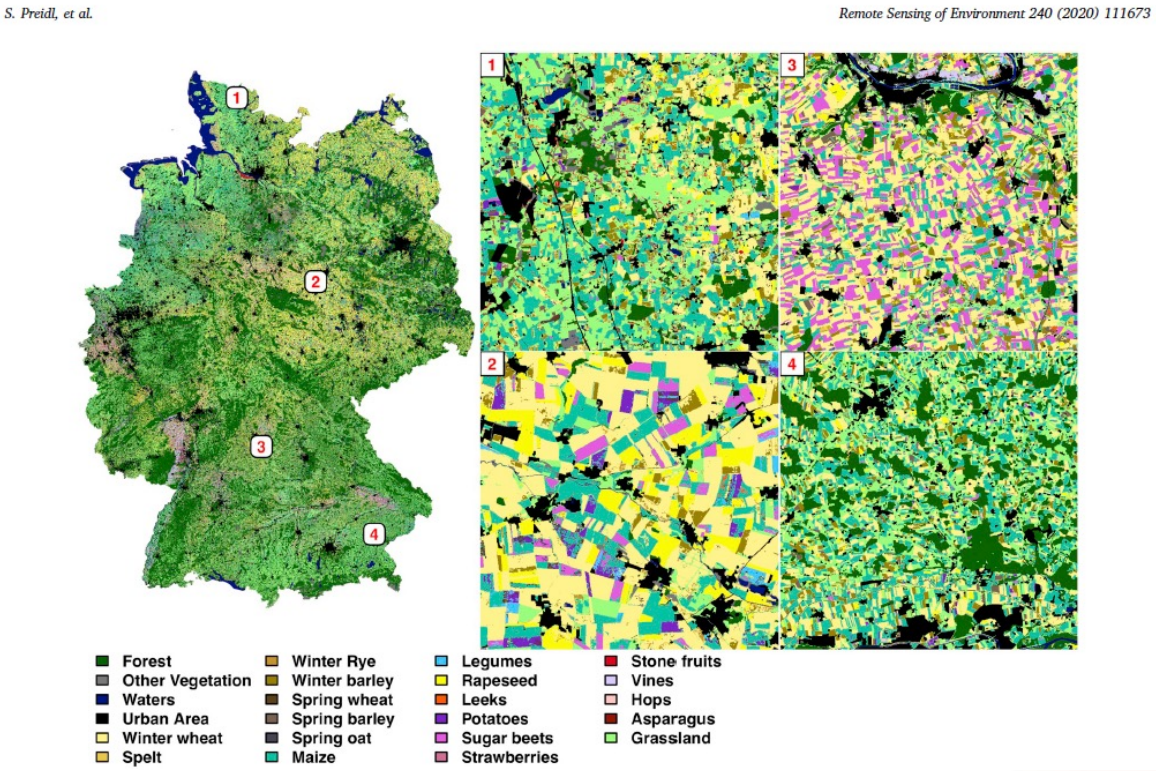
- further details on the data: DWD FTP server documentation
- website source code and files
- feedback is very welcome via github or berry-b@gmx.de!
- app for comparing weather periods

*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):




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

**Translating Land Cover into: Nectar and Pollen availability**:

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 utilitize own data

Lookup Table

In the landscape surrounding the hive, floral resources are considered only in the fields and meadows, called 'food patches'. Each food patch is characterised by the metrics listed below (the area in m² is given and cannot be changed). Pollen and nectar quantities are based on estimates of quantity per flower, number of flowers per plant and number of plants per square metre. For simplicity, and in the absence of more detailed data, the daily supply of nectar and pollen provided by the plants was assumed to be constant throughout the flowering period.

All values are based on previous studies (e.g. Horn et al. 2020, https://doi.org/10.1002/eap.2216 ) or a best guesses.

The user is encouraged to use own estimates or experiment using alternative values. You can double click the value to enter edit mode.
Hover over the , ⓘ to get detailed description of the variables.

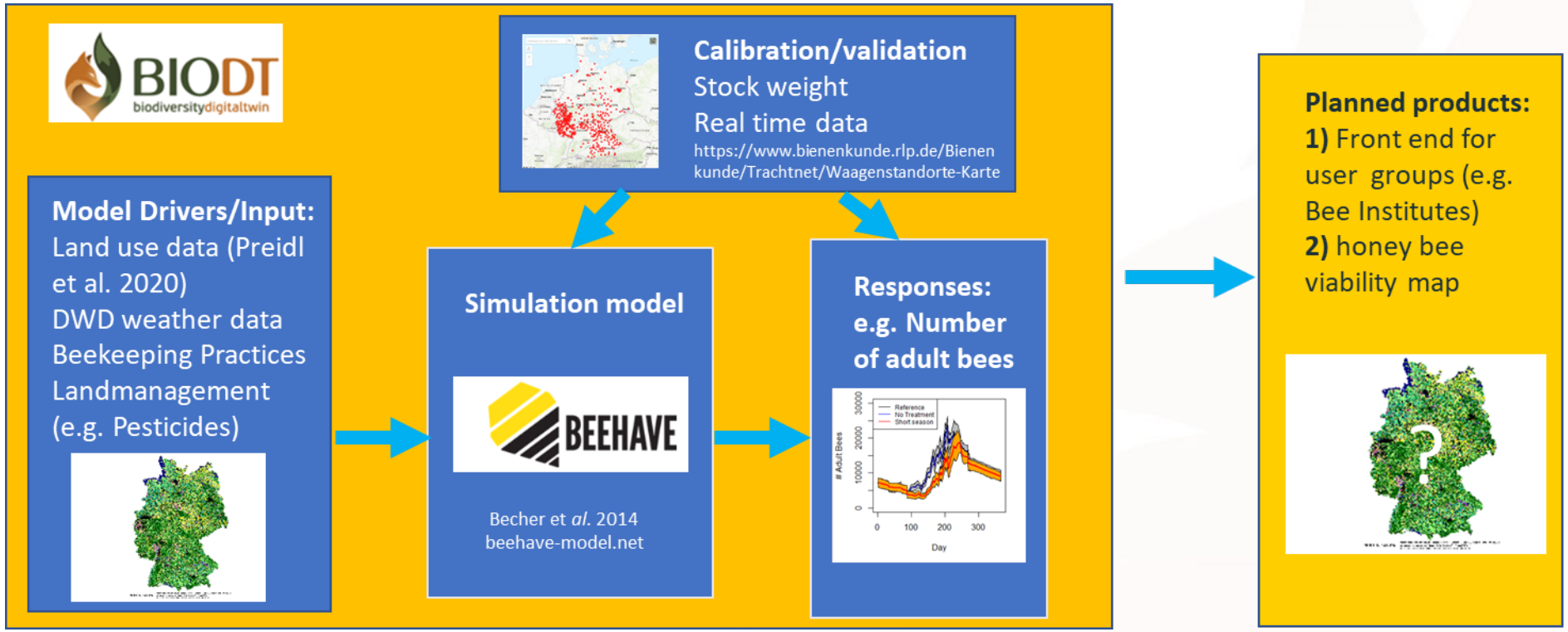
| | PatchType | quantityPollen_g ⓘ | concentration ⓘ | quantityNectar_l ⓘ | nectarGathering_s ⓘ | pollenGathering_s ⓘ | flowerStart ⓘ | flowerEnd ⓘ |
|---|---|---|---|---|---|---|---|---|
| 1 | Rapeseed | 0.13 | 1.3 | 0.0003 | 1200 | 600 | 114 | 136 |
| 2 | Maize | 0.752 | 0 | 0 | 0 | 600 | 197 | 210 |
| 3 | Legumes | 0.0302 | 1.242 | 0.0001019 | 1200 | 600 | 142 | 182 |
| 4 | Strawberries | 0.0078 | 1.161 | 0.0000055 | 1200 | 600 | 135 | 196 |
| 5 | Stone Fruits | 0.058 | 0.971 | 0.000186 | 1200 | 600 | 95 | 148 |
| 6 | Asparagus | 0.1861 | 1.811 | 0.0001198 | 1200 | 600 | 152 | 212 |
| 7 | Vines | 0.91 | 1.71 | 0.000133 | 1200 | 600 | 152 | 227 |
| 8 | Grassland | 0.0121 | 1.262 | 0.00001 | 1200 | 600 | 1 | 365 |
| 9 | GrasslandSeason | 0.0121 | 1.262 | 0.0001 | 1200 | 600 | 151 | 273 |

BIODT
biodiversitydigitaltwin

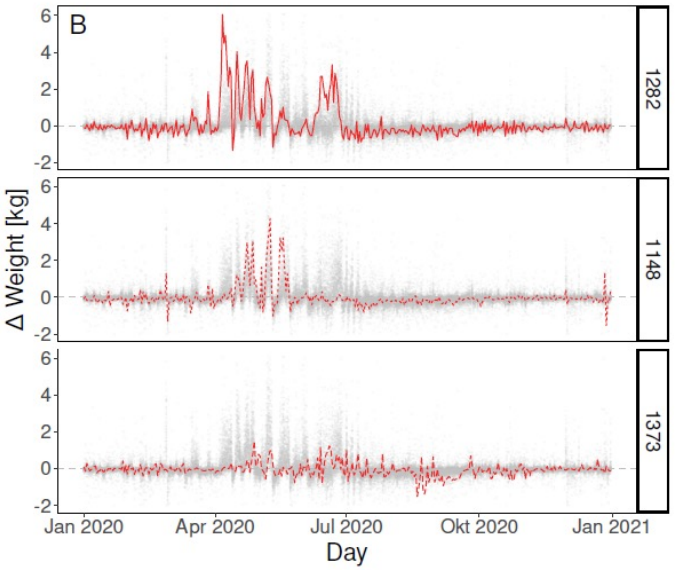
# Beehave input file: for one location (~10 km$^2$) ~ 5 MB

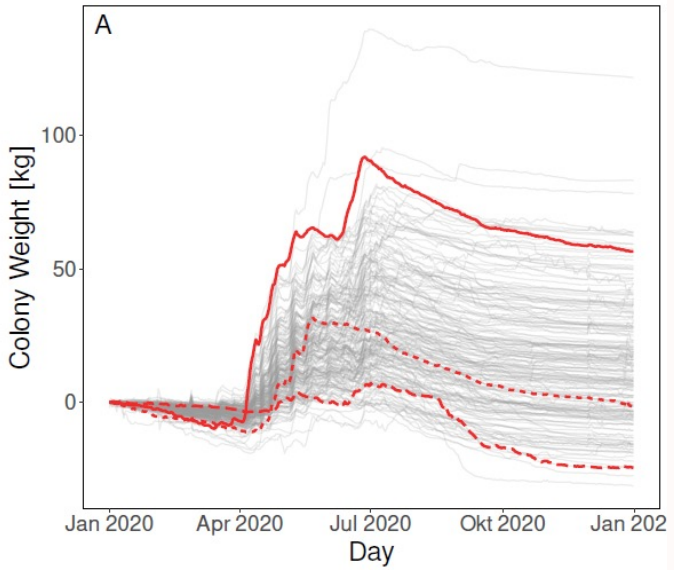
| day | id | oldPatchID | patchType | distance_m | xcor | ycor | size_sqm | quantityPollen_g | concentration | quantityNectar_l | calculatedDetectionProb_per_trip | modelledDetectionProb_per_trip | nectarGathering_s | pollenGathering_s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 2 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 3 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 4 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 5 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 6 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 7 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 8 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 9 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 10 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 11 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 12 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 13 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 14 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 15 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 16 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 17 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |
| 18 | 0 | 0 | Lolio cynosuretum | 1143,4 | 994,7 | 563,8 | 5227,2 | 12 | 1 | 0,006502039 | 0,434012475 | 0,434012475 | 1200 | 600 |

# Calibration

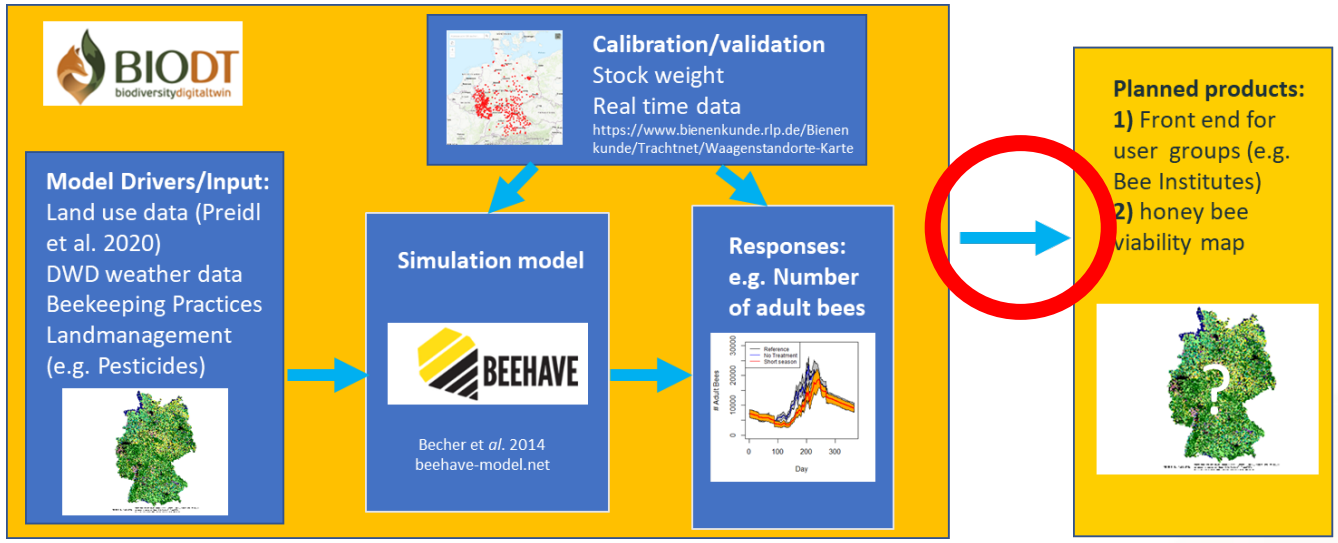


TrachtNet data (2020) – Data on colony weights:


Anna Wendt (Master Thesisi 2024)




GUI implemented as an R shiny app (next contribution by Kata)

Software required for executing the model (NetLogo, Java, R with relevant packages) have been bundled in a Docker container image.

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

# Next steps

Calibration to increase predictive power of the pDT

Allowing tailored application depending on the user group (upload own model version)

Allowing simulations on national extent

State of the art soon as RIO paper (preprint available https://doi.org/10.3897/arphapreprints.e124639)