



Database on Nectar & Pollen Production

Deliverable D3.2

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B-GOOD

Giving Beekeeping Guidance by cOmputatiOnal-assisted Decision making



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Preface

The main objective of WP3 'Ecology and Environmental Drivers' is to develop dynamic landscape models across the EU capturing the spatio-temporal dynamics of floral resources (flower resource models), considered as key driver of bee health status for honey bees. The models will be used as input in the ApisRAM model in WP5 to predict changes in bee health status.

This deliverable (D3.2) 'Database on Nectar and Pollen Production' is the second of five deliverables from WP3 and is the main outcome of Subtask 3.2.1 focused on collection of quantitative data on nectar and pollen production and floral phenology for bee-important species across the EU. The database will be used as a main source of data for modelling phenology of floral resources for different types of landscape elements / habitat units in Subtask 3.2.2 by scaling up information at the plant level to landscape elements / habitat units.

This deliverable consists of two parts: (1) the database itself (xlsx document) being appendix to this document (Appendix 1) as well as deposited as open access in the Jagiellonian University Repository (<https://ruj.uj.edu.pl/>), and (2) the supporting documentation for the database including methodology of data collection, details of data structure, description of the botanical data and units of recorded values, and summary of the database content, as provided here.

Summary

The deliverable (D3.2) 'Database on Nectar and Pollen Production' summarizes the process of collection of detailed qualitative data on pollen and nectar production and floral phenology for bee-important plants across the EU.

1. Background

To be able to predict the quantity and quality of resources (nectar and pollen) available for honey bees in different landscape elements / habitat units over time it is necessary to collect detailed qualitative data on pollen and nectar production and floral phenology for plants across the EU. The most important plant species that are known to be visited by the honey bee and produce nectar or pollen from early spring to late autumn were pre-selected (the initial list included 445 plant species) to target the literature review. The number of species increased during the search, to the final number of almost 1600 species.

There are two types of floral resources of interest: (1) nectar, providing adult bees with the energy required to perform their daily tasks, and (2) pollen, which is one of the food sources fed directly to larvae (juvenile stage) but which is also consumed in large amounts by adult worker bees, converted into jelly (brood food, royal jelly) in their hypopharyngeal glands and then fed directly to larvae, which they need to consume to grow and develop. Since nectar is highly variable in sugar content, we chose the amount of sugar produced as a measure of both quantity and quality of available energy sources for bees. For pollen, we used the weight produced by a flower.

2. Methodology

2.1. Collection of data

A review of the literature was conducted between July 2019 and October 2020 using three main approaches:

- Digitally searching through specialized journals and books, including both local ones available only in Spanish or Polish and international, English language, ones;
- Digitally searching in the WEB of Science database (all databases) based on the keywords: ["pollen production" OR "nectar production" OR "pollen value*" OR "nectar value*" OR "pollen secretion" OR "nectar secretion" OR "pollen dynamic*" OR "nectar dynamic*" OR "pollen asses*" OR "nectar asses*" – title] [NOT airborne OR reconstruction - topic];
- Searching using a web browser for the information addressing our priority plant species, using the keywords: ["pollen production" OR "nectar production" AND "species name"], for each species from the list separately.

The content of the database was consulted with UCOI researchers who are simultaneously working on the typology (and species composition) of landscape element types / habitat units important for bees at the EU scale, to be sure that all of the most important “bee-friendly” plant species are included in the database.

2.2. Data structure

The data collected in the database are divided into the following thematic groups:

- Basic information including plant taxon (family, genus and species) and community in which it was studied (natural / semi-natural vs. experimentally designed), as well as reference data (complete reference and link to online resource) and information on who entered the data to the database;
- Information regarding the study site of data collection (from the reference paper)
 - Syntaxonomic classification of the plant community studied;
 - Geographical information including country, region, geographical coordinates and altitude of study site where the data were collected, as well as year/years of data collection;
 - Weather information including temperature and precipitation for the year/years of data collection (if provided in the reference paper);
- Information on plant phenology and resources (see details in Table 1):
 - Timing and duration of flowering;
 - Number of plants and flowers per unit area and information on flower longevity;
 - Nectar and sugar production;
 - Pollen production.

Table 1: Variables and units of recorded values with respect to plant phenology

Information type	Column	Description
Timing & duration of flowering	flowering start	Flowering start date for given species, location and year. Number means specific day in a year, e.g. 1 = 1st January and 365 = 31 December.
	flowering end	Flowering end date for given species, location and year. Number means specific day in a year, e.g. 1 = 1st January and 365 = 31 December.
	flowering peak	Flowering peak date for given species, location and year. Number means specific day in a year, e.g. 1 = 1st January and 365 = 31 December.
	flowering peak 2 (if occurred)	Second flowering peak date, if occurred for given species, location and year. Number means specific day in a year, e.g. 1 = 1st January and 365 = 31 December.
	flowering length	Length of flowering in number of days.
Number of plants & flowers & flower longevity	total number of plants per m ²	Plant density in number of plant specimens per m ² . Mean calculated for given year(s), habitat and plant species.
	total number of trees examined	Number of trees examined in the study.
	total number of flowers per m ²	Flower density in number of all flowers (both flowering and NOT flowering) per m ² . Mean calculated for given year(s), habitat and plant.
	total number of inflorescences per m ²	Flower density in number of inflorescences per m ² . Concerns plants with small flowers. Mean calculated for given year(s), habitat and plant.
	total number of flowers per m ² of crown surface	Flower density in number of flowers per m ² of the crown. Mean calculated for given year(s), habitat and plant species.
	total number of inflorescences per m ² of crown surface	Flower density in number of inflorescences per m ² of the crown. Mean calculated for given year(s), habitat and plant species.
	total number of flowers per m ² of vegetative cover of the species	Flower density in number of flowers per m ² covered by the plant species' vegetative parts. Mean calculated for given year(s), habitat and plant species.

	total number of flowers per a single tree	Number of all flowers calculated for a given tree specimen.
	total number of flowers per plant	Flower density in total number of flowers per one plant specimen. Mean calculated for given year(s), habitat and plant species.
	total number of inflorescences per a single tree	Flower density in total number of inflorescences per one specimen of a tree. Mean calculated for given year(s), habitat and plant species.
	total number of inflorescences per plant	Flower density in total number of inflorescences per one plant specimen. Mean calculated for given year(s), habitat and plant species.
	tree age	Age of considered tree specimen.
	mean number of flowering flowers per m ² per day	Flowering flowers density in number of flowering flowers per m ² . Mean calculated for given year(s), habitat and plant.
	peak number of flowering flowers per m ²	Flowering flowers density during flowering peak in number of flowering flowers per m ² . Mean calculated for given year(s), habitat and plant.
	flower longevity [days]	Length of flowering of a single flower. Every value is mean given for specific year(s), habitat and plant species.
Nectar & sugar	total nectar in µg per flower	Mass of nectar produced by one flower during its life time - mean for a given year(s), habitat and plant species.
	total nectar in µL per flower	Volume of nectar produced by one flower during its life time - mean for a given year(s), habitat and plant species.
	nectar in µg/flower/day	Mass of nectar produced by one flower in 24h - mean for a given year(s), habitat and plant species.
	nectar in µL/flower/day	Volume of nectar produced by one flower in 24h - mean for a given year(s), habitat and plant species.
	nectar in µg/inflorescence/day	Mass of nectar produced by one inflorescence in 24h - mean for a given year(s), habitat and plant species.
	sugar concentration % in nectar	Concentration of sugar in nectar (%).

	total sugar in mg per flower	Amount of sugar produced by one flower during its life time - - mean for a given year(s), habitat and plant species.
	sugar in µg/flower/day	Amount of sugar produced by one flower in 24h - mean for a given year(s), habitat and plant species.
	sugar in µg/inflorescence/day	Amount of sugar produced by one inflorescence in 24h - mean for a given year(s), habitat and plant species.
	honey yield in kg/ha per 1 year	Potential mass of honey that could be produced yearly. Estimated considering flower density, total amount of nectar produced per flower and concentration of sugar in nectar.
	honey yield in kg/tree per 1 year	Potential mass of honey that could be produced yearly. Estimated considering flower density, total amount of nectar produced per flower and concentration of sugar in nectar.
	sugar yield in g per tree per 1 year	Total mass of carbohydrates produced by one tree in one year - mean for a given year(s), habitat and plant species.
	sugar yield in g per 1 m ³ of the tree crown	Mass of carbohydrates produced by one tree in one year per one cubic meter of the tree crown - mean for a given year(s), habitat and plant species.
	honey yield in kg/ha per 1 year	Estimated mass [kg] of honey produced by European honey bee in one year per one hectare of considered area based on nectar and sugar production of plants of given species inhabiting this area - mean for a given year(s), habitat and plant species.
	honey yield from 1000 flowers in g per 1 year	Estimated mass [g] of honey produced by European honey bee in one year per every 1000 flowers of a given plants species flowering in a considered area - mean for a given year(s), habitat and plant species.
	honey yield in g per 1 m ³ of the tree crown	Estimated mass [g] of honey produced by European honey bee in one year per one cubic tree of a given tree species - mean for a given year(s), habitat and plant species.
	honey yield in kg/tree per 1 year	Estimated mass [kg] of honey produced by European honey bee in one year per every single tree of a given species - mean for a given year(s), habitat and plant species.
Pollen	total pollen yield per 1 year in kg/ha	Mass of pollen produced during one year given in kg per hectare - mean for a given year(s), habitat and plant species.
	total pollen yield per 1 year in kg per a single tree	Mass [kg] of pollen produced during one year by one tree - mean for a given year(s), habitat and plant species.
	total pollen yield per 1 year in number of grains per a single tree	Amount of pollen grains produced during one year by one tree - mean for a given year(s), habitat and plant species.

	total pollen in $\mu\text{g}/\text{flower}$	Total mass of pollen produced by one flower during its life time - mean for a given year(s), habitat and plant species.
	total pollen in $\mu\text{L}/\text{flower}$	Total volume of pollen produced by one flower during its life time - mean for a given year(s), habitat and plant species.
	total pollen per flower (the number of grains)	Total amount of pollen grains produced by one flower during its life time - mean for a given year(s), habitat and plant species.
	total pollen in $\mu\text{g}/\text{inflorescence}$	Total mass of pollen produced by one inflorescence during one year - mean for a given year(s), habitat and plant species.
	total pollen in $\mu\text{L}/\text{inflorescence}$	Total volume of pollen produced by a single inflorescence per year - mean for a given year(s), habitat and plant species.
	total pollen in $\mu\text{g}/\text{plant}/\text{year}$	Total mass of pollen produced during one year by one plant of considered species - mean for a given year(s), habitat and plant species.
	total pollen in number of grains per inflorescence	Total amount of pollen produced by one inflorescence during one year - mean for a given year(s), habitat and plant species.
	pollen in $\mu\text{g}/\text{flower}/\text{day}$	Mass of pollen produced by one flower in 24h - mean for a given year(s), habitat and plant species.
	pollen in $\mu\text{L}/\text{flower}/\text{day}$	Volume of pollen produced by one flower in 24h - mean for a given year(s), habitat and plant species.
	pollen in $\mu\text{g}/\text{inflorescence}/\text{day}$	Mass of pollen produced by one inflorescence in 24h - mean for a given year(s), habitat and plant species.
	pollen in $\mu\text{L}/\text{inflorescence}/\text{day}$	Volume of pollen produced by one inflorescence in 24h - mean for a given year(s), habitat and plant species.
	yearly pollen yield in number of grains per m^2 of the crown surface	Total amount of pollen grains produced yearly by a tree per every square meter of its crown - mean for a given year(s), habitat and plant species.
	yearly pollen yield in g per 1 m^3 of the tree crown	Total mass of pollen produced yearly by a tree per every cubic meter of its crown - mean for a given year(s), habitat and plant species.

3. Summary of data collected

In total, 357 literature items (scientific papers, databases, monographs, habilitation theses etc.) were reviewed. The full list of references can be found at the end of this report. To our best knowledge we collected all the information currently available via international (English language) and Polish language scientific literature sources. Considering the Spanish language sources, we were not able to collect all the information available, but data on most important species are present in the database.

The database consists of 5993 records, where each record is an entry of information for a given plant species / subspecies / variety given as an average from several measurements (see examples in Table 2). Several records for the same plant species / subspecies / variety can originate from the same reference paper if measurements were provided for several years or from several study sites (see examples in Table 2).

Table 2: Exemplary data records for selected tree species

Plant species	Reference	Country	Location name	Year of the data collection	Flower-ing start	Flower-ing end	Total number of flowers per a single tree	Total sugar in mg per flower
<i>Lavatera trimestris</i>	Wróblewska 1996	Poland	Lublin area	1993	196	271	212.5*	1.10
<i>Acer pseudoplatanus</i>	Dmitruk 2019	Poland	Lublin	2011	118	146	978929*	0.57
<i>Acer pseudoplatanus</i>	Dmitruk 2019	Poland	Lublin	2012	122	149	1196668*	0.60
<i>Acer pseudoplatanus</i>	Dmitruk 2019	Poland	Lublin	2013	120	150	1003262.6*	0.65
<i>Robinia pseudoacacia</i>	Jabłoński & Kołtowski 1993	Poland	Puławy	1988	150	165	71300**	2.36
<i>Robinia pseudoacacia</i>	Jabłoński & Kołtowski 1993	Poland	Puławy	1988	153	165	172100**	1.82
<i>Robinia pseudoacacia</i>	Jabłoński & Kołtowski 1993	Poland	Puławy	1988	155	165	54100**	2.13

* an average from several trees

** value for a single tree, i.e., each tree in that study has its own record in a database

The majority of the records are from study sites located in Europe (4862 records). Records from other continents were added for taxa which are present also in Europe. More than 60% of records originate from Polish studies, but those species are generally representative for the Central European region (Figure 1).

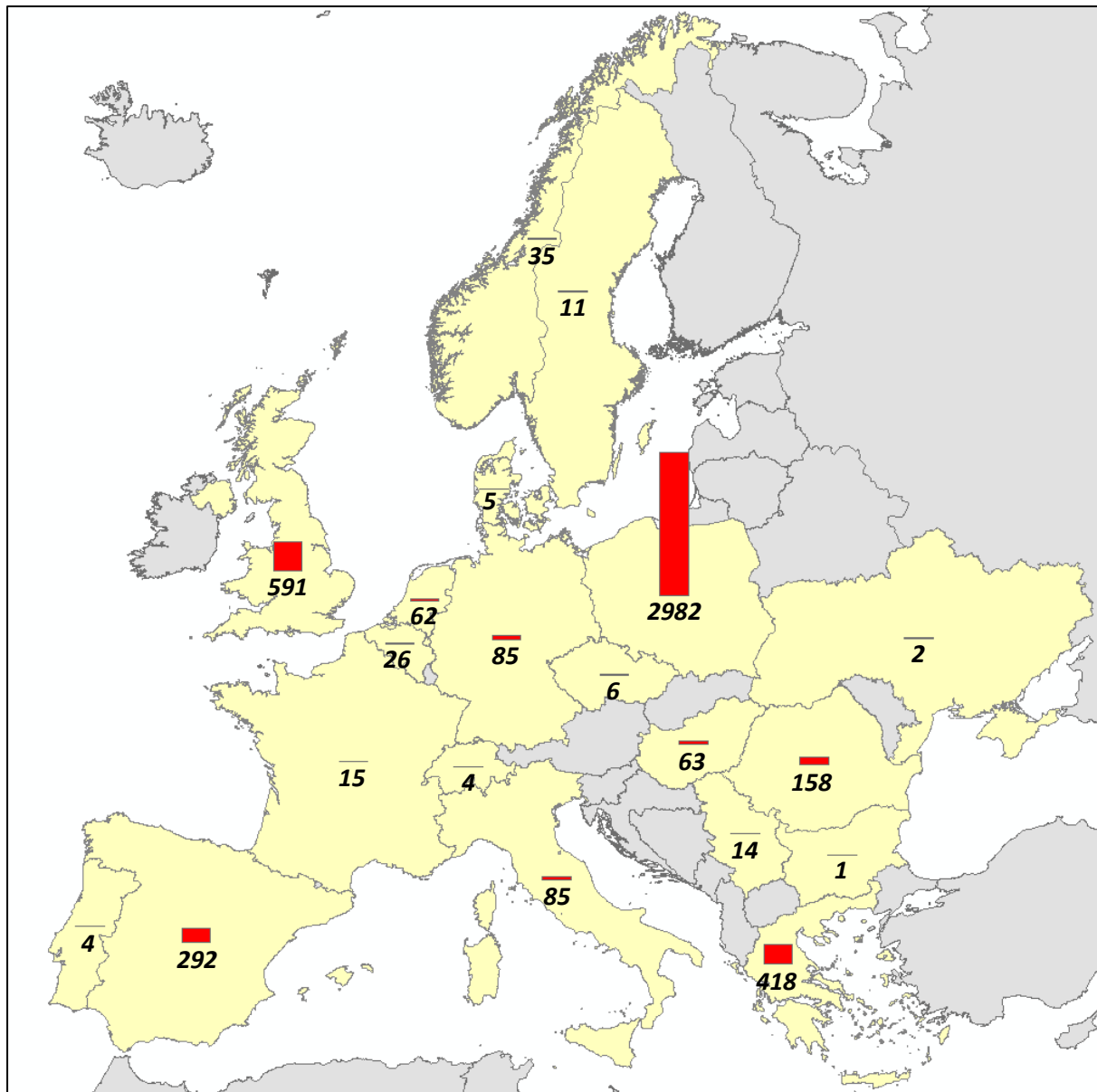


Figure 1: Number of records collected across European countries

There are 1561 plant species (with subspecies / varieties pooled together) recorded in the database, representing 136 plant families (Table 3). The most represented plant families in the database (with more than 300 records) are Fabaceae, Rosaceae, Asteraceae, Lamiaceae, and Brassicaceae (Table 3), while the most represented plant species in the database (with more than 100 records) include *Trifolium pratense*, *Helianthus annuus*, *Brassica napus*, *Rubus idaeus* and *Malus* species (Figure 2).

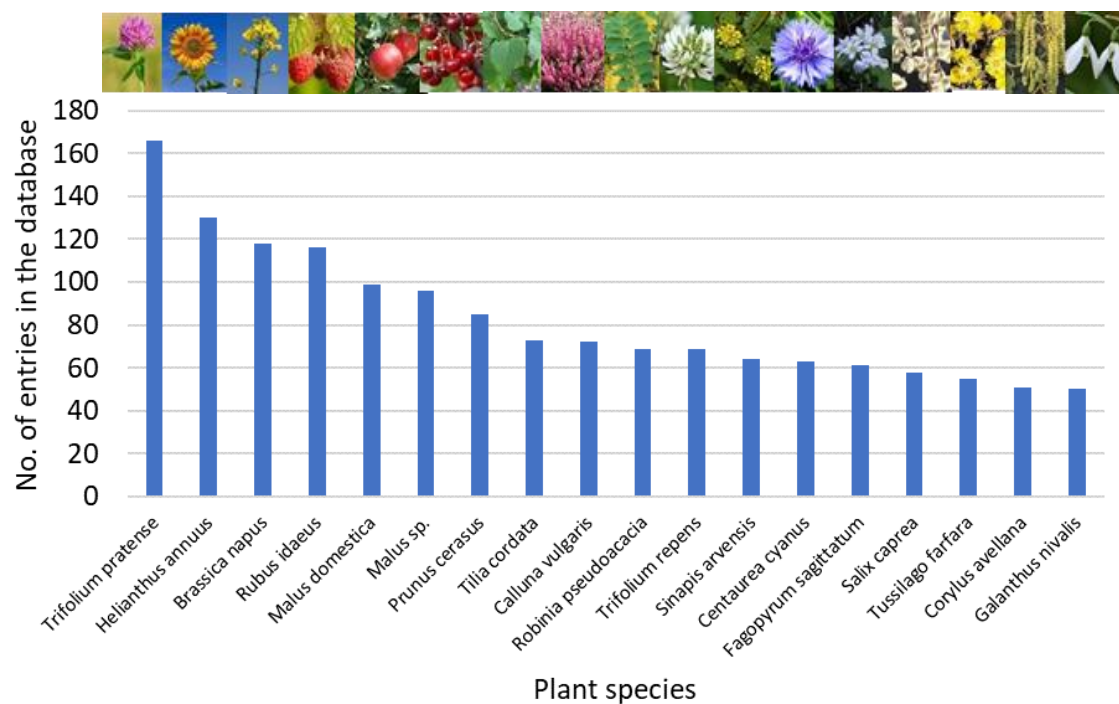


Figure 2: Plant species with more than 50 records in the database

Table 3: Plant families represented in the database

Plant family	No. of records in the database
Fabaceae	774
Rosaceae	733
Asteraceae	645
Lamiaceae	495
Brassicaceae	356
Malvaceae	269
Ericaceae	184
Salicaceae	156
Ranunculaceae	153
Boraginaceae	143
Amaryllidaceae	111
Betulaceae	108
Apiaceae	102
Polygonaceae	101
Poaceae	96
Onagraceae	93
Grossulariaceae	91
Caprifoliaceae	68
Oleaceae	65
Caryophyllaceae	58

Scrophulariaceae	49
Campanulaceae	44
Cucurbitaceae	44
Fagaceae	44
Plantaginaceae	43
Geraniaceae	41
Asparagaceae	38
Euphorbiaceae	38
Sapindaceae	38
Solanaceae	36
Papaveraceae	35
Amaranthaceae	32
Cistaceae	32
Convolvulaceae	32
Crassulaceae	29
Violaceae	29
Apocynaceae	28
Orobanchaceae	27
Rutaceae	26
Rubiaceae	24
Iridaceae	22
Pinaceae	21
Resedaceae	21
Balsaminaceae	16
Polemoniaceae	16
Rhamnaceae	16
Liliaceae	15
Gesneriaceae	14
Primulaceae	14
Saxifragaceae	14
Asphodelaceae	13
Lythraceae	12
Cyperaceae	11
Linaceae	11
Myrtaceae	10
Bignoniaceae	9
Capparaceae	9
Orchidaceae	9
Proteaceae	9
Thymelaeaceae	9
Verbenaceae	9
Gentianaceae	8
Acanthaceae	7
Araliaceae	7
Bromeliaceae	6
Cornaceae	6

Cupressaceae	6
Urticaceae	6
Vitaceae	6
Anacardiaceae	5
Berberidaceae	5
Colchicaceae	5
Hypericaceae	5
Loranthaceae	5
Oxalidaceae	5
Santalaceae	5
Alstroemeriaceae	4
Cactaceae	4
Caricaceae	4
Dipsacaceae	4
Heliconiaceae	4
Montiaceae	4
Nothofagaceae	4
Nyctaginaceae	4
Arecaceae	3
Elaegnaceae	3
Ericaceae	3
Hydrangeaceae	3
Juglandaceae	3
Passifloraceae	3
Plumbaginaceae	3
Ulmaceae	3
Valerianaceae	3
Zygophyllaceae	3
Adoxaceae	2
Araceae	2
Begoniaceae	2
Dioscoreaceae	2
Droseraceae	2
Lentibulariaceae	2
Magnoliaceae	2
Platanaceae	2
Simmondsiaceae	2
Smilacaceae	2
Stylidiaceae	2
Aizoaceae	1
Asclepiadaceae	1
Astraceae	1
Burseraceae	1
Cannaceae	1
Casuarinaceae	1
Chrysobalanaceae	1

Cleomaceae	1
Clusiaceae	1
Commelinaceae	1
Desfontainiaceae	1
Empetraceae	1
Escalloniaceae	1
Labiaceae	1
Lecythidaceae	1
Losaceae	1
Martyniaceae	1
Mimosaceae	1
Nartheciaceae	1
Palmae	1
Philesiaceae	1
Piperaceae	1
Polygalaceae	1
Portulacaceae	1
Simaroubaceae	1
Styracaceae	1
Tamaricaceae	1
Theaceae	1
Tiliaceae	1
Tropaeolaceae	1
Xyridaceae	1

4. Next steps and connections with other WPs

Next step within WP3, Task. 3.2.2 includes generation of models for the phenology of floral resources, first for individual plants and then for landscape elements types / habitat units based on data gathered in this database, as well as climate and environmental data. Phenological models will describe, for all habitat types containing resources important for bees (identified in Task 3.1), the quantity and quality of those resources (nectar and pollen) as a function of time (day in year) and climatic conditions. Floral resource models for landscape element types / habitat units will be further coded into the ApisRAM model developed under the ALMaSS modelling platform as a part of its landscape component in close collaboration with WP5.

The landscape component in ALMaSS includes the detailed spatio-temporal representation of the landscape from which modelled species obtain the information necessary to simulate their behavior. In this representation, spatial landscape heterogeneity is described through a detailed raster land cover map with spatial resolution of 1m², in which farmed areas are represented as accurate maps of fields grouped into farm units of different types (e.g., cattle or arable farms). The temporal component of agricultural landscape heterogeneity refers to both crop management throughout a year, described through individually tailored management plans for each crop, and the cropping system understood as a pluriannual crop rotation. Crop management plans consist of combinations of farm activities (including

pesticide treatments), as well as time windows and probabilities of carrying out activities. The temporal component also includes weather conditions and vegetation growth models for all vegetation types and crops. Such approach gives a highly realistic, updated on a daily basis, dynamic landscape simulation with vegetation growing in response to the weather, and the pattern of farming activities related to each specific crop, farm, and field. The models for the phenology of floral resources will be incorporated into that spatio-temporal representation of a landscape. That would mean that each landscape elements of the land cover map will be assigned a habitat unit (according to Task 3.1), and therefore a phenological model associated with that habitat unit. This will allow to assess quantity and quality of pollen and nectar resources for each habitat patch (element) of the landscape at each simulation day and pass that information to the ApisRAM model to predict changes in bee health status.

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