CropPol: a dynamic, open and global database on crop pollination

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Seventy five percent of fruit production of the major global crops benefit from insect pollination. Hence, there has been increased interest in how global change drivers impact this critical ecosystem service. Because standardized data on crop pollination are rarely available, we are limited in our capacity to understand the variation in pollination benefits to crop yield, as well as to anticipate changes in this service, develop predictions, and inform management actions. Here, we present CropPol, a dynamic, open and global database on crop pollination. It contains measurements recorded from 189 crop studies, covering 3,216 field observations, 2,421 yield measurements (i.e. berry weight, number of fruits and kg per hectare, among others), and 46,262 insect records from 49 commercial crops distributed around the globe. CropPol comprises 32 of the 87 leading global crops and commodities that are pollinator dependent. *Malus domestica* is the most represented crop (25 studies), followed by *Brassica napus* (22 studies), *Vaccinium corymbosum* (13 studies), and *Citrullus lanatus* (12 studies). The most abundant pollinator guilds recorded are honey bees (33.12% counts), bumblebees (18.65%), flies other than Syrphidae and Bombyliidae (13.76%), other wild bees (13.51%), beetles (11.47%), Syrphidae (4.86%), and Bombyliidae (0.06%). Locations comprise 32 countries distributed among European (70 studies), Northern America (59), Latin America and the Caribbean (27), Asia (22), Oceania (10), and Africa (7). Sampling spans three decades and is concentrated on 2001-05 (21 studies), 2006-10 (38), 2011-15 (87), 2016-20 (40). This is the most comprehensive open global data set on measurements of crop flower visitors, crop pollinators and pollination to date and we encourage researchers to add more datasets to this database in the future. No copyright restrictions are associated with the use of this dataset. Please cite this data paper when the data are used in publications and cite individual studies when appropriate.

Introduction

Over 37% of Earth's ice-free land area is directly being used by humans for agriculture or settlements (Klein Goldewijk *et al.*, 2017). In fact, agricultural expansion is the main driver of land use change across the planet (Venter *et al.*, 2016). Along with other human-induced global change drivers, such as global warming and nitrogen deposition, land use change is accelerating extinction rates for most taxonomic groups (MEA, 2005). This biodiversity crisis has led many researchers to investigate how species loss affects nature's contributions to people (NCPs), the set of benefits we obtain from nature directly, including crop pollination, water purification, climate regulation, or food production (Díaz *et al.*, 2018).

Crop pollination is a critical NCP delivered by multiple species of pollinators, mainly insects (Rader *et al.*, 2016). The annual market value of crop pollination worldwide is estimated to be of US$235 billion-US$577 billion (IPBES, 2016), with over 75% of agricultural crops benefiting from pollination by animals, mainly insects (Klein *et al.*, 2007). Recent meta-analyses have documented the importance of wild bee (Garibaldi *et al.*, 2013) and non-bee pollinators (Rader *et al.*, 2016) for crop production, and the pervasive effects that land-use change has on pollinator populations (Garibaldi *et al.*, 2011; Dainese *et al.*, 2019). However, with 87 pollinator-dependent crops produced worldwide (Klein *et al.*, 2007), we are far from a comprehensive view of how pollination services change across crops and their most important varieties, regions, environmental contexts and through time. For example, we know that only a fraction of worldwide pollinators are important crop pollination service providers (Kleijn *et al.*, 2015), but the turnover of important pollinators through time and space, even for the same crop, has just started to be explored (Winfree *et al.*, 2018). Similarly, despite clear evidence that crop production can be enhanced by pollinators in both experimental (studies underlying Klein *et al.*, 2007 Appendix 2) and natural (Garibaldi *et al.*, 2013) conditions, pollination levels have rarely been included in predictive models of crop yield (Garibaldi *et al.*, 2020).

One of the main barriers preventing developments in our understanding of global change impacts on NCPs in general, and on crop pollination in particular, is the lack of standardized datasets that relate the abundance of NCP providers, and their final contribution through space and time. In the absence of standardized monitoring programs, compiling comparable datasets collected by different researchers in a decentralized way can allow answering global questions in an efficient way (Bartomeus and Dicks, 2019). Hence, only by compiling the relevant data at the right scales we will be able to advance this field of research by developing predictive models and scenarios for the loss of biodiversity and associated NCPs. This is especially relevant as both the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Convention on Biological Diversity (CBD) have called for a better assessment of NCPs that are directly relevant for policy-making.

Developing predictive models largely hinges on data management practices which facilitate the detection, evaluation and iterative forecasting of changes in ecosystem structure and function (Dietze *et al.*, 2018; White *et al.*, 2018; Yenni *et al.*, 2019). To regularly update models and evaluate forecasts in an open and reproducible fashion, data should be collected frequently and released as quickly as possible under open licenses (Dietze *et al.*, 2018; White *et al.*, 2018). Furthermore, to support reproducibility and ensure that data can be used easily by a variety of researchers and in multiple modelling approaches, best practices in data structure should be employed for managing and storing collected data (Dietze *et al.*, 2018; White *et al.*, 2018; Yenni *et al.*, 2019). Such practices include the use of open licenses, standard data formats, accompanying metadata, version control, and performing quality control tests, among others

(White *et al.*, 2013; Wilson *et al.*, 2014; Hampton et. al 2015). Yenni *et al.* (2019) and White *et al.* (2018) provide accessible examples of modern workflows for regularly updated data and near-term iterative forecasting systems, featuring version control (using git and Github), automated data management, and quality control checks (using the testthat R package; Wickham, 2011).

These modern approaches to data management can accelerate ecological research and improve our ability to detect and even predict changes in natural ecosystems instrumental for decision-making, such as their ability to provide NCPs like crop pollination. Thus, we have compiled CropPol, a dynamic and open database of crop pollination data. The dataset comprises data recorded within 189 different studies on crop pollination: 143 of which were collated through previous meta-analyses (Garibaldi *et al.*, 2015; Kleijn *et al.*, 2015; Garibaldi *et al.*, 2016; Rader *et al.*, 2016; Dainese *et al.*, 2019, Reilly *et al.*, 2020), whereas 30 studies contain unpublished information. In this dataset, we provide data for 3,216 field observations, 2,421 yield measurements, and 46,262 insect records across 49 commercial crops, distributed throughout the globe (see figures 1-5). Furthermore, CropPol comprises 32 of the 87 leading global crops and commodities in Klein *et al.* (2007) that benefit from pollination (see figure 6). The sampled locations span over 32 countries distributed among European (70 studies), Northern America (59), Latin America and the Caribbean (27), Asia (22), Oceania (10), and Africa (7) (figures 1-5). Data collection occurred from 1990 to 2020. CropPol represents a major effort to compile open and standardized measures of the effect of pollinators on crop production, across different environmental scenarios, and over three decades. Finally, as more data is added to the database in the future, CropPol will provide new avenues to develop iterative forecasting on the effects of managed and wild pollinators on crop yield that can be relevant for society and decision-making.

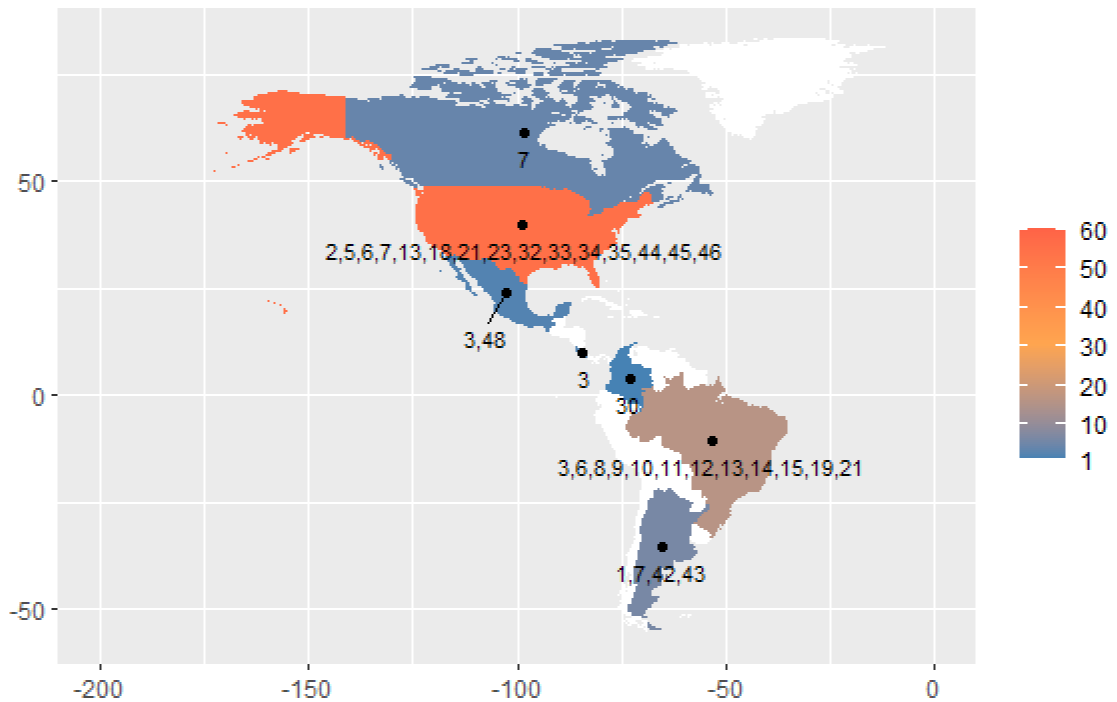

Figure 1. Distribution of the number of studies and types of crops in CropPol for Americas and the Caribbean. Crop ID's are as follows: *Rubus idaeus* (1), *Fragaria x ananassa* (2), *Coffea arabica* (3), *Coffea canephora* (4), *Prunus dulcis* (5), *Brassica napus* (6), *Vaccinium corymbosum* (7), *Passiflora edulis* (8), *Anacardium occidentale* (9), *Annona muricata* (10), *Annona squamosa* (11), *Bixa orellana* (12), *Gossypium hirsutum* (13), *Malpighia emarginata* (14), *Mangifera indica* (15), *Persea americana* (16), *Macadamia integrifolia* (17), *Prunus avium* (18), *Phaseolus vulgaris L.* (19), *Allium porrum* (20), *Malus domestica* (21), *Pyrus communis* (22), *Vaccinium macrocarpon* (23), *Abelmoschus esculentus* (24), *Cucumis sativus* (25), *Lagenaria siceraria* (26), *Luffa acutangula* (27), *Momordica charantia* (28), *Brassica rapa* (29), *Vaccinium meridionale* (30), *Fagopyrum esculentum* (31), *Citrullus lanatus* (32), *Cucurbita pepo* (33), *Malus pumila* (34), *Prunus cerasus* (35), *Trifolium pratense* (36), *Helianthus annuus* (37), *Vicia faba* (38), *Psidium guajava* (39), *Actinidia deliciosa* (40), *Cajanus cajan* (41), *Citrus limon* (42), *Citrus paradisi* (43), *Capsicum annuum* (44), *Cucumis melo* (45), *Solanum*

lycopersicum (46), *Annona squamosa atemoya* (47), *Coffea arabica/robusta* (48), and *Actinidia chinensis* (49). The dots represent the centroids of the respective countries (in the case of USA, its dot locate the geographic center of the contiguous United States).**

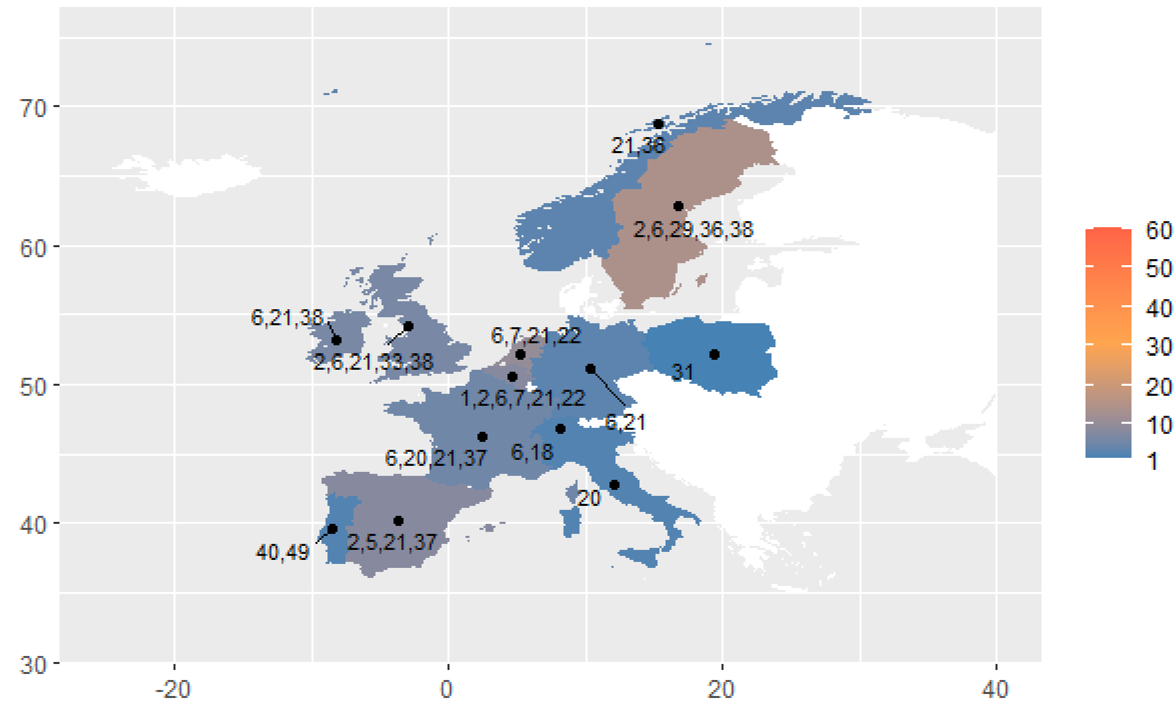

Figure 2. Distribution of the number of studies and types of crops in CropPol for Europe. Crop ID's are those in figure 1. The dots represent the centroids of the respective countries.

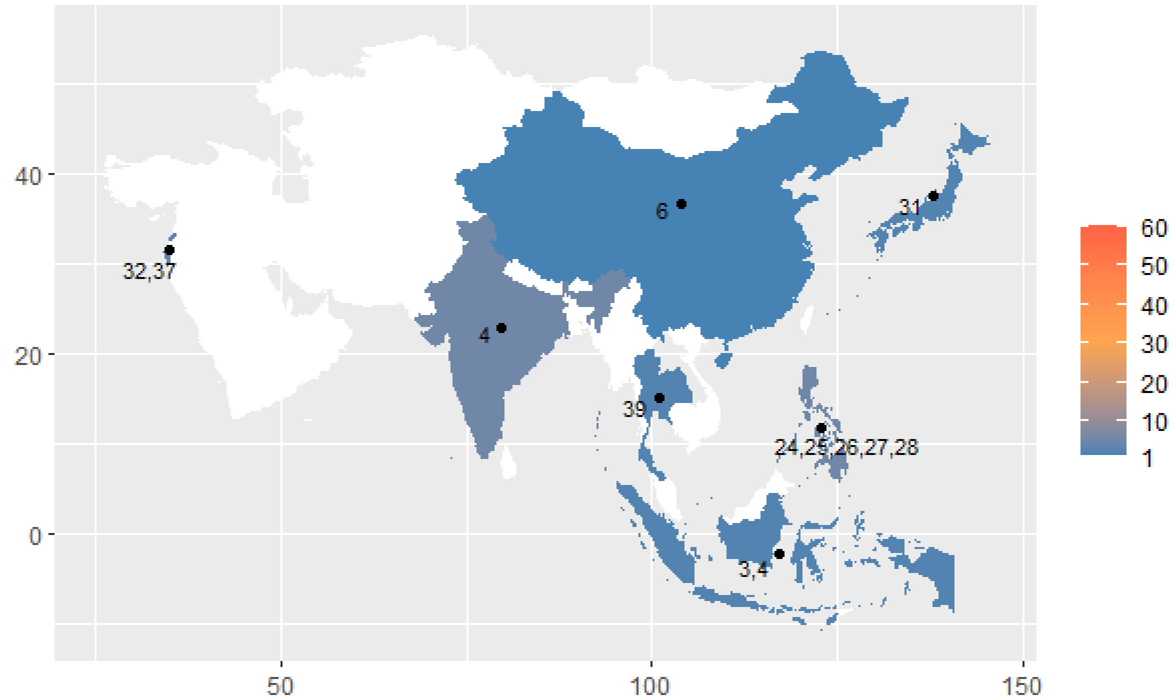

Figure 3. Distribution of the number of studies and types of crops in CropPol for Asia. Crop ID's are those in figure 1. The dots represent the centroids of the respective countries.

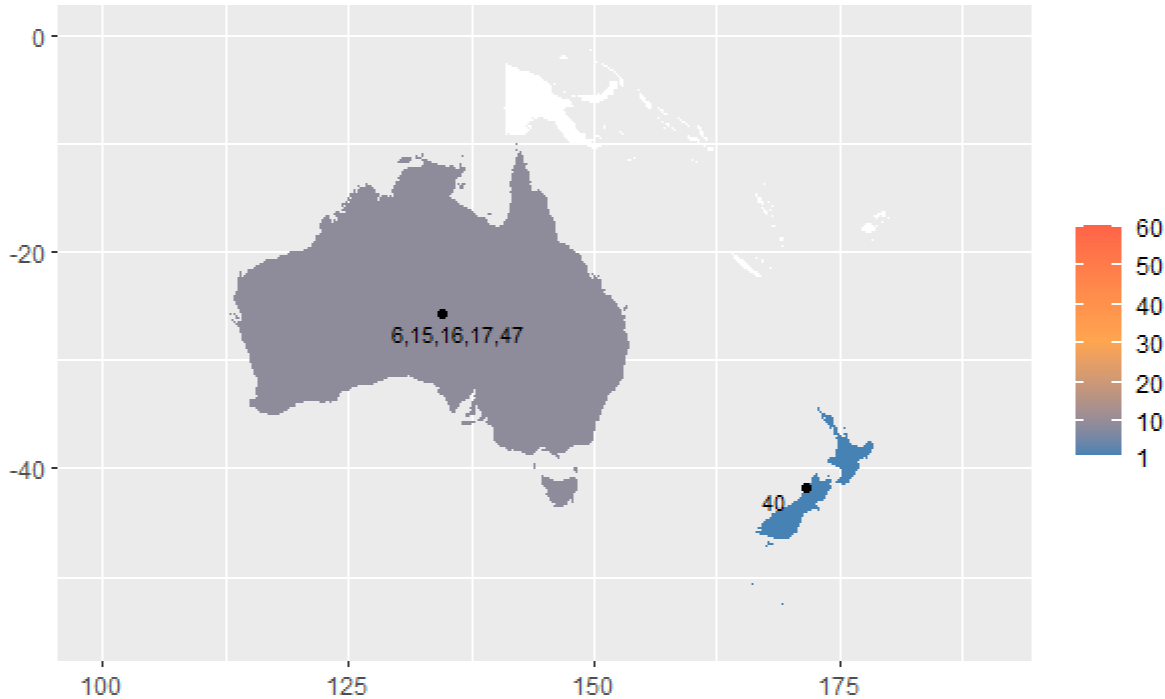

Figure 4. Distribution of the number of studies and types of crops in CropPol for Oceania. Crop ID's are those in figure 1. The dots represent the centroids of the respective countries.

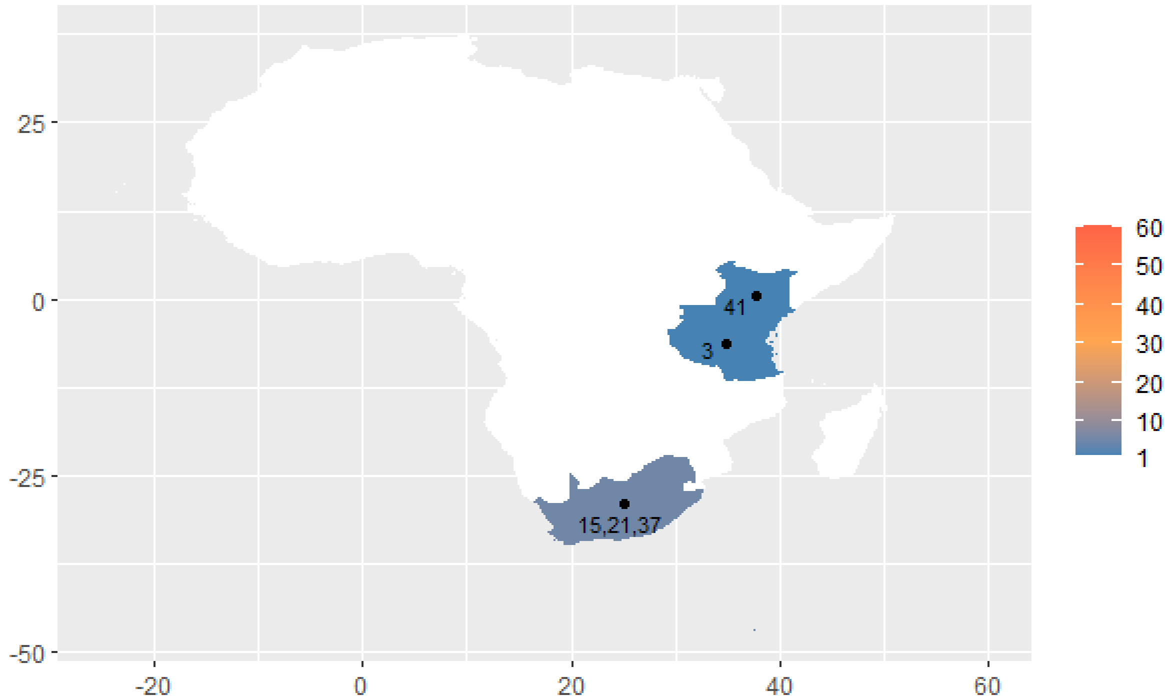

Figure 5. Distribution of the number of studies and types of crops in CropPol for Africa. Crop ID's are those in figure 1. The dots represent the centroids of the respective countries.

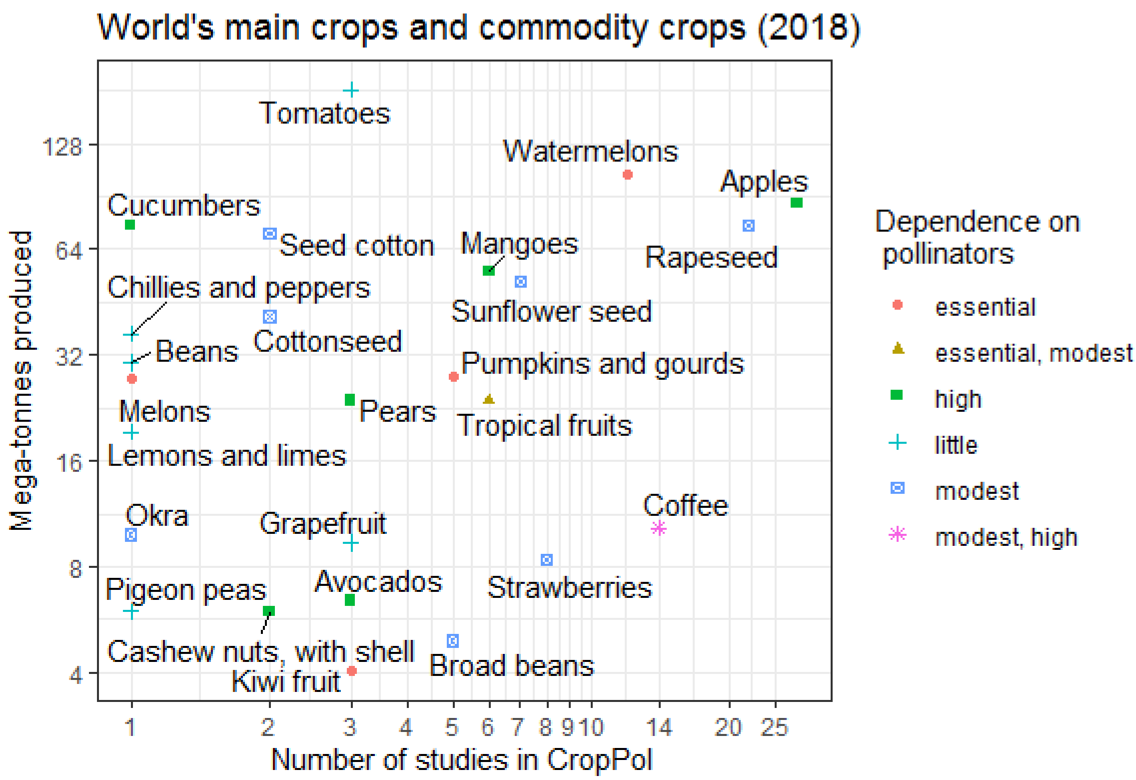

Figure 6. Number of studies included in CropPol on crops used for human food with an annual production of at least 4,000,000 Metric tonnes (Mt). The production data was collected from the FAO crop production list for the year 2018 (FAOSTAT 2018). The markers represent the impact of pollinators on increasing production according to Klein *et al.* (2007), namely: essential, high, modest, and little (see their characterization in section I.E., Description). In the case of coffee and tropical fruits, the markers summarize the degree of dependence of the following crops: Coffea arabica (modest), Coffea canephora (high), Annona spp. (essential) and Psidium guajava (modest).

We aim to maintain and update this database and researchers are encouraged to add more datasets as explained below.

METADATA

Class I. Data set descriptors

I.A. Data set identity

CropPol, a dynamic and open global database on crop pollination

I.B. Data set identification codes

CropPol_field_level_data.csv

CropPol_sampling_data.csv

CropPol_data_ownership.csv

I.C. Data set description

I.C.1. Principal investigators

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I.C.2. Abstract

Seventy five percent of fruit production of the major global crops benefit from insect pollination. Hence, there has been increased interest in how global change drivers impact this critical ecosystem service. Because standardized data on crop pollination are rarely available, we are limited in our capacity to understand the variation in pollination benefits to crop yield, as well as to anticipate changes in this service, develop predictions, and inform management actions. Here, we present CropPol, a dynamic, open and global database on crop pollination. It contains measurements recorded from 189 crop studies, covering 3,216 field observations, 2,421 yield measurements (i.e. berry weight, number of fruits and kg per hectare, among others), and 46,262 insect records from 49 commercial crops distributed around the globe. CropPol comprises

32 of the 87 leading global crops and commodities that are pollinator dependent. *Malus domestica* is the most represented crop (25 studies), followed by *Brassica napus* (22 studies), *Vaccinium corymbosum* (13 studies), and *Citrullus lanatus* (12 studies). The most abundant pollinator guilds recorded are honey bees (33.12% counts), bumblebees (18.65%), flies other than Syrphidae and Bombyliidae (13.76%), other wild bees (13.51%), beetles (11.47%), Syrphidae (4.86%), and Bombyliidae (0.06%). Locations comprise 32 countries distributed among European (70 studies), Northern America (59), Latin America and the Caribbean (27), Asia (22), Oceania (10), and Africa (7). Sampling spans three decades and is concentrated on 2001-05 (21 studies), 2006-10 (38), 2011-15 (87), 2016-20 (40). This is the most comprehensive open global data set on measurements of crop flower visitors, crop pollinators and pollination to date and we encourage researchers to add more datasets to this database in the future. No copyright restrictions are associated with the use of this dataset. Please cite this data paper when the data are used in publications and cite individual studies when appropriate.

D. Key words

Pollination, crop production, agricultural management, pollinator biodiversity, bees, flower visiting insects

E. Description

CropPol incorporates data from 189 crop pollination studies on 49 commercial crops, collected at 3,216 sites between 1990 and 2020, and distributed throughout the globe (figures 1-5). All the sites represent agricultural landscapes that are highly modified habitats for food production. CropPol includes data on crop yield across 2,421 sites (75.28%), pollinator abundance for different pollinator species across 2,109 sites (65.58%) and visitation rates to crops by different pollinator species across 1,992 sites (61.94%) (see figure 7).

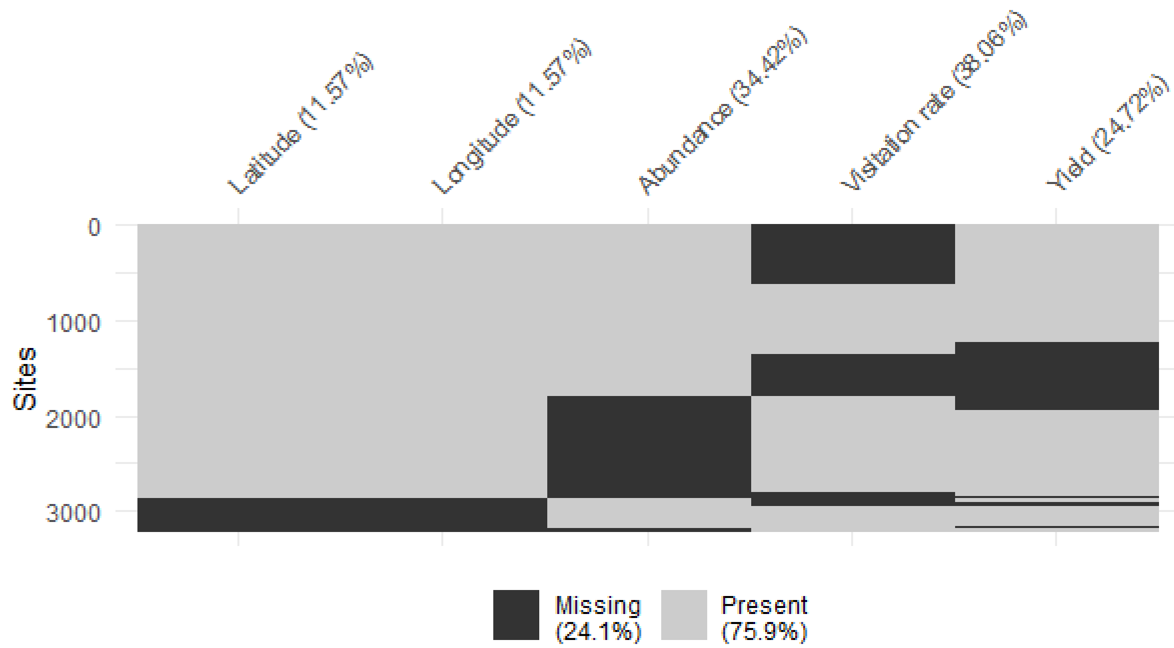

Figure 7. Missing information for the following variables in CropPol_field_level_data.csv: Latitude, longitude, abundance (i.e. number of pollinator individuals observed), visitation rate (i.e. number of visits recorded per 100 flowers and hour, unless the variable "visitation_rate_units" in CropPol_field_level_data.csv redefines such units), and yield.

Most of the crops included are pollinator-dependent crops used for human consumption and for which annual production is at least 4 x 10^6 Metric tonnes (i.e., they are leading global crops and commodities; 74.60% of studies and 65.31% of crops considered) (see figure 6). CropPol also includes raw pollinator data for 161 of the studies included (85.19%), which represents 46,262 records of visitors (see CropPol_sampling_data.csv).

In our compilation, according to Klein *et al.* (2007) the impact of pollinators on increasing production is *essential* in 24 studies (i.e., production reduction by 90% or more without pollinator activity), *high* in 84 (40 to less than 90% reduction), *modest* in 55 (10 to less than 40%), *little* in 10 (greater than 0 to less than 10%), and *unknown* (dependence on pollination is known but the contribution of pollinators to crop production is not) in 16. The most represented crop is *Malus domestica* (25 studies), followed by *Brassica napus* (22), *Vaccinium corymbosum* (13), and *Citrullus lanatus* (12).

Overall, 59 studies (31.21%) recorded only bees, whereas 130 studies also targeted additional flower visitors (68.78%). Honey bees were the most abundant pollinator recorded (33.12% of the counts or flower visits in CropPol_sampling_data.csv), followed by bumblebees (18.65%), flies other than Syrphidae and Bombyliidae (13.76%), other wild bees (13.51%), beetles (11.47%), Syrphidae (5.11%), non bee Hymenoptera (3.21%), Lepidoptera (0.40%), and Bombyliidae (0.06%). Most of the flower visitors recorded have been identified to the species or morphospecies levels (78.49% and 7.70%, respectively). The taxonomic resolution of the remaining visitors is distributed as follows: "family/subfamily/superfamily" (4.94%), "genus/subgenus/tribe" (4.76%), "order/suborder" (3.90%), and "other/unknown" (0.02%). In each global sub-region, the number of sampled records varies greatly. The largest number of flower visitation and count records comes from Western Europe (212,440), followed by Northern Europe (106,652), Southern Europe (98,090), Latin America and the Caribbean (36,645), Northern America (31,200), Eastern Asia (16,649), Australia and New Zealand (16,116), Sub-Saharan Africa (12,875), Southern Asia (10,426), South-eastern Asia (5,370), Eastern Europe (2,230), and Western Asia (656). Although the guild composition of each region varies, bees are the most sampled organisms worldwide, except in Northern Europe (see figure 8): Western Europe (67.7%), Northern Europe (25.7%), Southern Europe (80.3%), Latin America and the Caribbean (90.4%), Northern America (91.2%), Eastern Asia (73.1%), Australia and New Zealand (47.0%), Sub-Saharan Africa (87.9%), Southern Asia (91.3%), South-eastern Asia (94.7%), Eastern Europe (91.6%), and Western Asia (100%). In Northern Europe the main guild of flower visitors was flies other than Syrphidae and Bombyliidae (61.5%), but this effect is strongly influenced by two studies out of 29 (the percentage of bees and other flies without those studies is 72.7% and 14.5%, respectively).

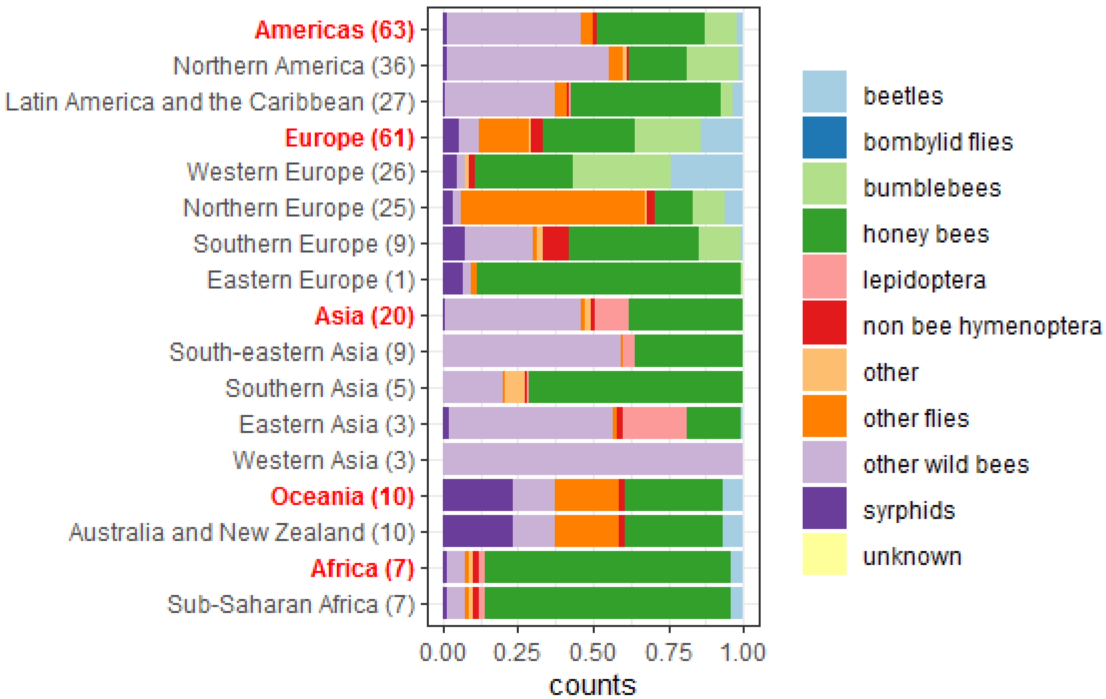

Figure 8. Proportion of recorded counts in CropPol_sampling_data.csv per guild and geographic area, namely: global region (red) and sub-region (black). The total number of studies by geographic area is shown in brackets.

Finally, in figure 9 we show the spatiotemporal coverage of CropPol. As can be observed, the sampling spans over two decades and concentrates around 2001-05 (15 studies), 2006-10 (29), 2011-15 (72), 2016-20 (40).

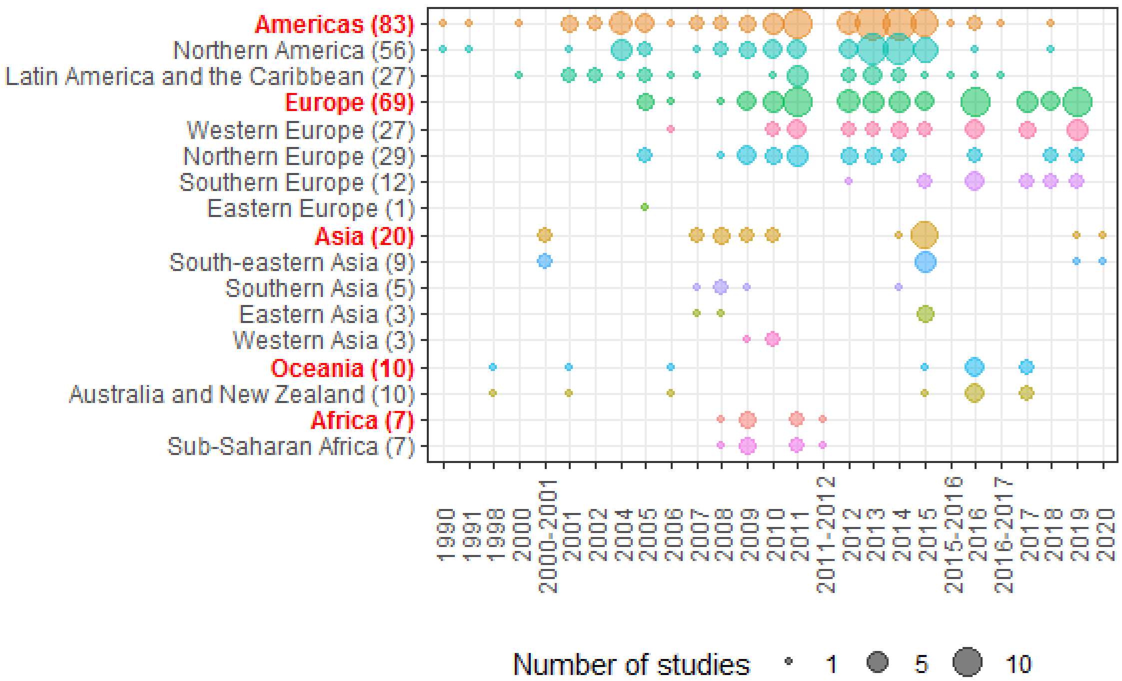

Figure 9. Number of studies by year and geographic area, namely: global region (red) and sub-region (black). Circle radii are proportional to the number of studies. The total number of studies by geographic area is shown in brackets.

Class II. Research origin descriptors

II.A. Overall project description

II.A.1 Identity

CropPol, a dynamic and open global database on crop pollination

II.A.2 Originators

Same as above.

II.A.3 Period of Study

Data collection reported in studies occurred from 1990 to 2020. This period of study results from the data collated, after making a general requests for data, and a specific call to the authors of previous meta-analyses on crop pollination (Garibaldi *et al.*, 2015; Kleijn *et al.*, 2015; Garibaldi *et al.*, 2016; Rader *et al.*, 2016; Dainese *et al.*, 2019, Reilly *et al.*, 2020).

II.A.4 Objectives

Our objectives for compiling these data were to summarize open and standardized measures of (i) crop yield, (ii) pollinator abundance for different pollinator species, and (iii) pollinator visitation rates to crops by different pollinator groups or species, across different environmental scenarios; and to identify gaps in geography, crops and varieties.

II.A.5 Abstract

Same as above.

II.A.6 Source (s) of funding

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14-01-008); B.G.H. was supported through the programme Bee Minus to Bee Plus and Beyond: Higher Yields from Smarter, Growth-focused Pollination Systems C11X1309. F.J. was supported by the Deutsche Bundesstiftung Umwelt (DBU). M.N. was supported by Mercator Research Program of the World Food System Centre at ETH Zurich. H.C. was supported by RENATURE - "Programa Operacional Regional do Centro 2014-2020 (Centro2020) - CENTRO-01-0145-FEDER-000007. H.G. was supported by Operational group I9Kiwi – Developing strategies for the sustainability of kiwifruit production through creation of an added value product, funded by PDR2020. S.C. was supported by CULTIVAR project (CENTRO-01-0145-FEDER-000020), co-financed by Centro 2020, Portugal 2020 and European Union, through ERDF. N.C. was supported by CONICET/FUNDACION PROYUNGAS, CONICET/FUNDACION PROYUNGAS, FUNDACION ANTORCHAS; J.F.C. and R.V. were supported by the South African National Biodiversity Institute & GEF. F.O.S. was supported by MCT/CNPq/CT-AGRO Nº 24/2009 Pollinators Research Networks - Process: 556050/2009-6; /CAPES/GEF/FAO/UNEP/FUNBIO; FAPESP/CNPQ/PRONEX Nº 020/2009. J.G.E.C. was supported by MCT/CNPq/CT-AGRO Nº 24/2009 Pollinators Research Networks - Process: 556050/2009-6; /CAPES/GEF/FAO/UNEP/FUNBIO; FAPESP/CNPQ/PRONEX Nº 020/2009. L.S., M.A., P.J. were supported by EU FP7. C.H.V. was supported by a grant from Mexico's Environmental Ministry (SEMARNAT-CONACyT2002-C01-0194) to CV. E.H.B. was supported by USDA NIFA Grant #1003539. J.E. was supported by FORMAS grant nr. 2014:00254. A.T. was supported by the Spanish Ministry of Economy and Competitiveness project FLORMAS (CGL2012-33801) and by the Biodiversa-FACCE project ECODEAL (PCIN-2014-048). AT was supported by a Severo-Ochoa predoctoral fellowship (SVP-2013-067592) and by the Super-B COST Action (FA1307:18100). JMH was supported by the Spanish

Ministry of Education and Science through a postdoctoral fellowship ‘Juan de la Cierva’ (FPDI-2013-16335), and by the Portuguese national funding agency for science, research and technology (FCT) (IF/00001/2015). A.C. was financially supported by the GermanResearch Foundation (DFG) within the Research Unit FOR1246. A.M.C. was supported by Food from Thought: Agricultural Systems for a Healthy Planet Initiative (Canada First Research Excellence Fund, grant 000054) and a North American Pollinator Protection Campaign grant 2018. M.O. was supported by a PhD Scholarship from the Felix Trust, UK - 2006 – 2010. N.E.R. was supported by Food from Thought: Agricultural Systems for a Healthy Planet Initiative (Canada First Research Excellence Fund, grant 000054), Ontario Ministry for Agriculture, Food and Rural Affairs (grant 2018-3307), Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (2015-06783) and as the Rebanks Family Chair in Pollinator Conservation by the Weston Family Foundation. S.C. and S.J. were supported by Texas Parks and Wildlife Department, the Army Research Office, and the National Science Foundation. F.J.C.G. and G.N.P were supported by the Food and Agriculture Organization of the United Nations from the Norwegian Environment Agency for a project on “Building Capacity in the Science-Policy Interface of Pollination Services”. J.K. was supported by the Agriculture and Horticulture Development Board [CP118]. J.O. was supported by the European Union FEDER INTERREG SUDOE VB program (Project SOE1/P5/E0129). J.A.G. was supported by the European Union FEDER INTERREG SUDOE VB program (Project SOE1/P5/E0129). J.L.O. and R.F.S. were supported by the Natural Environment Research Council UK [NE/J014680/1]. V.H. was supported by the European Union FEDER INTERREG SUDOE VB program (Project SOE1/P5/E0129). H.S. and M.W. were supported by EU FP7: GOCE-CT-2003-506675 ALARM. B.I.S. was supported by the Royal Commission for the Exhibition of 1851 Research

Fellowship. K.H. was supported by SCIENCE grants: Henrik Tofte Jacobsen's Grant = 15000 DKK; William Demant Fonden = 8500 DKK and Knud Højgaards Fond, 13000 DKK. A.D.O.R. was supported by the Science Foundation Ireland. N.J.V, T.W. and N.L. received financial support from the Walloon Region through a research grant delivered by the Direction générale opérationnelle de l’Agriculture, des Ressources naturelles et de l’Environnement (DGO3) for the “Modèle permaculturel” project on biodiversity in micro-farms, as well as from the FNRS/FWO joint pro- gramme “EOS — Excellence Of Science” for the project “CliPS: Climate change and its impact on Pollination Services (project 30947854)”. A.S. was supported by the Global Environment Fund, United Nations Environment Program, United Nations Food and Agriculture Organization (GEF/UNEP/FAO) Global Pollination Project, with additional support to the Food and Agriculture Organization of the United Nations from the Norwegian Environment Agency for a project on “Building Capacity in the Science-Policy Interface of Pollination Services”, and from the International Fund for Agricultural Development for the development of the sampling protocol. A.-M.K. was funded by the Alexander von Humboldt Foundation with a Feodor Lynen Fellowship and by the German Science foundation (DFG, KL 1849/4-1). Her project was funded by the DFG (Germany Science Fundation) and by the DAAD (German Academic Exchange Programme) to support A.-M.K. C.K. was funded by the Hellmann foundation. B.I.S. was supported by a Royal Commission for the Exhibition of 1851 Research Fellowship. B.M.F - thanks the Project "Conservation and Management of Pollinators for Sustainable Agriculture, through an Ecosystem Approach", which is supported by the Global Environmental Facility Bank (GEF), coordinated by the Food andAgriculture Organization of the United Nations (FAO) with implementation support from the United Nations Environment Programme (UNEP) and supported in Brazil by the Ministry of Environment (MMA) and Brazilian Biodiversity Fund

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II.B. Specific subproject description

II.B.1 Site description

CropPol comprises data collected across 12 global subregions, namely: Northern America (56 studies), Northern Europe (29), Western Europe (27), Latin America and the Caribbean (27), Southern Europe (12), Australia and New Zealand (10), South-eastern Asia (9), Sub-Saharan Africa (7), Southern Asia (5), Western Asia (3), Eastern Asia (3), and Eastern Europe (1). We provide latitude and longitude coordinates (in World Geodetic System 1984 datum or WGS 84) for 2,844 out of 3,216 field records (see figure 7). Hence, the context can be extracted for those sites. Locations for other fields were not originally recorded or are protected for privacy reasons. For specific uses they can be obtained upon request to the corresponding data-holder.

Sites are variable, but share the common feature of being highly modified habitats for food production. Management information was provided for 62.1% of the sites, and most of the crops grew under conventional practices of agricultural intensification (79.2%), followed by organic practices (14.5%), integrated pest management (4.9%) and unmanaged (1.4%). Hence, most of the sites may correspond to monocultures of high-yield varieties, cultivated in medium to large arable fields with medium to high input of mineral fertilizers and pesticides (Tscharntke et. al, 2005). Detailed characteristics of the habitats sampled can be accessed for 82.7% of the sites in the corresponding original papers (see variable “Publication” in Table 2, and available DOIs in Table 4).

IIII.B.2 Experimental or sampling design

All studies measure pollinator abundances or visitation rates to crop plant species within at least five different crop fields (17.02 ∓ 22.10). Crop field size ranges from 3 x 10^{-4} to 84,573 (624.80 ∓ 4,633.58) hectares with total area sampled within these crop fields ranging from 0.15 to 19,800 m^2 (632.33 ∓ 1,147.92 m^2). Within each crop field pollinators were measured using a variety of techniques (see Research Methods) for a time period ranging from 6 to 2,880 minutes (175.51 ∓ 196.36 minutes). Flowers sampled per census at each site ranged from 17 to 199,822 flowers (7,568.12 ∓ 19,667.44 flowers).

In addition, 67.02% of the 189 studies included a measure of crop production or yield, such as kg per hectare or weight per fruit, among others (see variable “yield_units” in Table 2). Furthermore, a subset of such studies also include measures of yield or production within crop plants subject to different treatments: 20.63% of the studies report results for pollinator exclusion, whereas 13.76% of them provide values for pollen supplementation.

Detailed characteristics of the sampling design (such as data collection frequency, number of sampling rounds, etc.) are available for 75.13% of the studies in the corresponding original papers (see variable “Publication” in Table 2, and available DOIs in Table 4).

II.B.3 Research methods

CropPol includes 189 studies that assess the effect of flower visitors on crop yield for different crop species collected around the world. The file CropPol_field_level_data.csv includes data on crop yield, pollinator abundance and visitation rates to crops by different pollinator species for 67.20%, 83.60% and 48.68% of the studies, respectively. When available, for each study we mentioned the digital object information (DOI) of the original paper/s (see variable "Publication" in Table 2, and Table 4). Thus, the complete research methodology used in those studies can be accessed. Furthermore, in the case of the studies that provided their sampling raw data (161 studies in CropPol_sampling_data.csv), a brief description of the overall sampling methodology (variable "description") and the method/s that were used to survey a given site (variable "sampling_method") were included (91.30% and 98.75%, respectively). Studies predominantly used one sampling method (136 studies), few of them reported 2 methods (23), and 2 studies used three methods. 55 studies collected pollinator data using "sweep netting", 54 followed "transect counts", 50 used "focal observations", 20 used "pan trap, bee bowl, blue vane trap or pitfall traps", and 5 used "other" methods.

We provide some metrics already calculated in CropPol by using some general heuristics. Regarding the estimation of richness and abundance in each site, on the one hand, pan-trap data were not taken into account to estimate their values, respectively, if other sampling methods were available. Despite their popularity, pan-traps have a suite of flaws that make them poorly equipped to monitor bees (Portman *et al.*, 2020). On the other hand, the values of richness, abundance and visitation rates for a given site were obtained by aggregating the records of insects observed during the total sampling time. Consequently, in this database richness, abundance and visitation rates do not reflect the mean value of the respective surveys or rounds in each site, but the total one. When possible, visitation rates were only derived from timed observations to a given number of flowers, and their units were set to [visits per 100 flowers and hour]. Richness data were not calculated in a given study if the percentage of identified species (or morphospecies) was lower than or equal to 75%, or when the data was obtained by using pan-traps. However, other assumptions or metrics can be calculated using CropPol, as the raw data is also available in the database.

To compare the sampling effort among studies and sites, on the one hand, we included two variables in CropPol_field_level_data.csv: “total_samped_area” and “total_sampled_time” (see Table 2). Their values are reported for 53.44% and 60.85% of the 189 studies, respectively. On the other hand, in CropPol_sampling_data.csv the following variables were included to account for sampling effort: “total_samped_area”, “total_sampled_time”, and “total_samped_flowers” (see Table 1). Their values are reported for 62.11%, 66.46%, and 21.74% of the 161 studies, respectively (see their values above, in “II.B.2 Experimental or sampling design”).

Taxonomic resolution for pollinators was collected from the raw data, when information was available (as is the case of the studies in (Dainese *et al.*, 2019)). Otherwise, we tried to estimate the taxonomic rank of the organisms by using the package taxize in R (Chamberlain *et al.*, 2020) and searching in the Integrated Taxonomic Information System (ITIS) and the NCBI Taxonomy databases. Species taxonomy is provided “as is” by the original data-holders.

The data workflow used to compile CropPol comprised the following stages: 1) Initial data gathering using a common template; 2) data processing; 3) author validation of scripts and data; and 4) final publication (see figure 10). Data gathering stage began in January 2020, after making a general requests for data, and a specific call to the authors of previous meta-analyses on crop pollination (Garibaldi *et al.*, 2015; Kleijn *et al.*, 2015; Garibaldi *et al.*, 2016; Rader *et al.*, 2016; Dainese *et al.*, 2019, Reilly *et al.*, 2020). The general information on this initiative, data requirements, frequently asked questions, as well as the forms we used to collect the data can be accessed in: https://www.beeproject.science/croppollination.html

Raw datasets were processed as soon as we received them. For that reason, data gathering and processing stages overlapped. We transposed raw data to CropPol templates by using R-scripts (R Core Team, 2020) under a version control protocol (i.e. git, https://git-scm.com/). During that stage, we fixed transcription and format errors, homogenized information, and prepared automated reports on the transposed datasets (see section III.A.4. Data verification for further detail).

The validation of scripts and data stage began in July 2020 and extended to November 2020. We contacted the corresponding author of each dataset and shared with him/her all the materials collected and produced during the previous stages, along with specific queries. The feedback and corrections we received were used to update and fix the raw materials, R-scripts to process them, and the data in CropPol templates, when needed.

Finally, to compile CropPol we merged those studies that were verified and corrected by the corresponding author, and after performing additional quality checks, published in this data paper. All the process is reproducible and can be tracked at: https://github.com/ibartomeus/OBservData

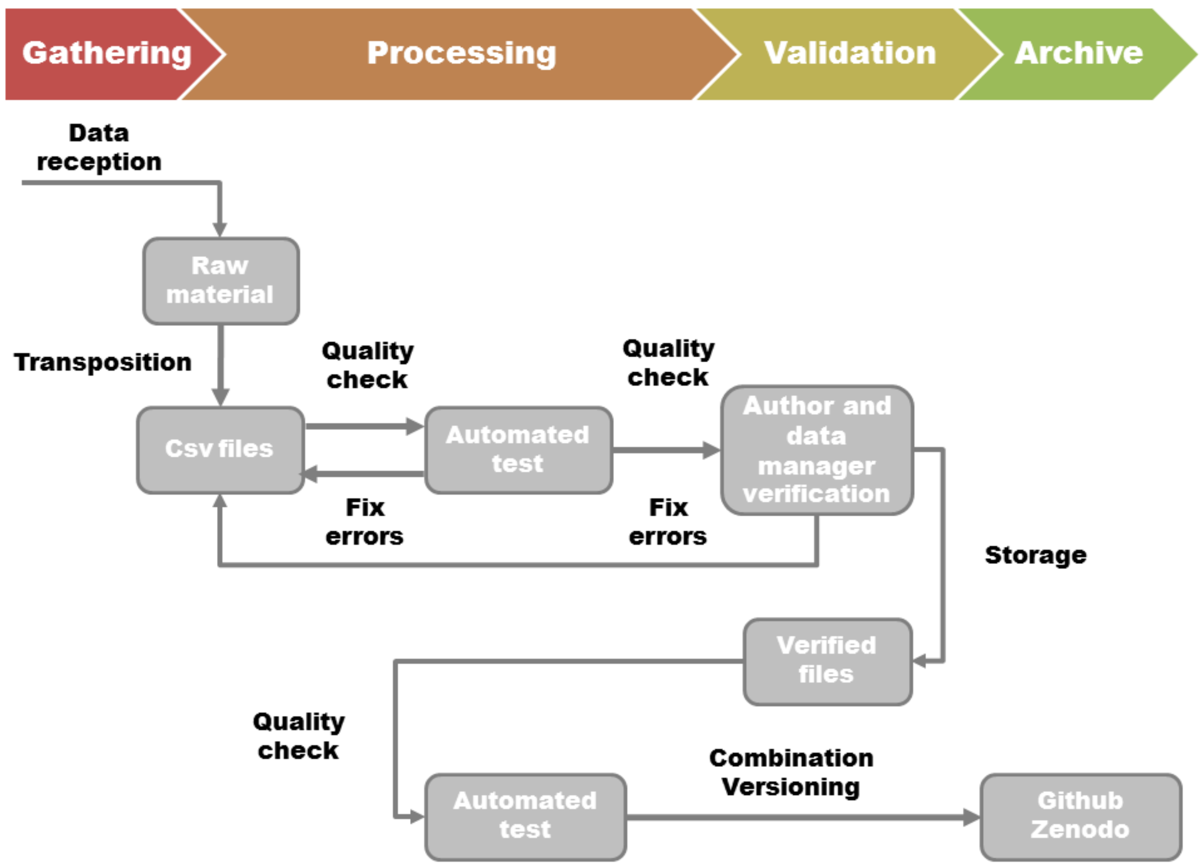

Figure 10. Data workflow in CropPol. After collecting the raw data, the information is transposed to CropPol templates and checked by using R scripts. The materials gathered during the previous stages are shared with the corresponding authors, along with specific queries. The author's feedback and corrections are used to fix errors. Finally, the verified templates are merged into the main database and the version number is updated.

II.C. Data Limitations and Potential Enhancements

As any compilation of data assembled from independent data sources with slightly different protocols and objectives, CropPol requires a careful evaluation of which sources are appropriate to answer different questions. For example, sampling effort measures are not available in 46.56% of the studies, and those studies might not be suitable for answering detailed questions.

In addition, the majority of data arises from North America and Western Europe. Therefore, large geographical and crop gaps are found especially in the Southern hemisphere and Africa and Asia in particular. Besides, information on crop varieties is available only on 55.56% of studies (46.05% of sites). Hence, crop variety gaps are also present. We plan to maintain CropPol as a live dataset where more data will be contributed as it becomes available.

Currently, taxonomy in CropPol_sampling_data.csv (variable "pollinator") is as provided by the authors. We plan to develop additional tests to curate such data. Besides, if any researcher identifies data issues that affect this or other variables, he/she can contact the main investigators by opening GitHub issues and/or via email. The CropPol team will fix the dataset and expand the tested requirements and metadata information, accordingly.

To contribute new datasets, we implemented a modern workflow in CropPol's GitHub repository (https://github.com/ibartomeus/OBservData). On the one hand, those users that are familiar with GitHub can follow the workflow A in figure 11, namely: (i) clone the repository; (ii) access the template in the "Template" folder; (iii) fill out the information and save the file in "Your_study_folder" with the name "<author's name>_"<crop>"_<country>_<year>" (e.g. "John_Doe_Malus_domestica_USA_2020.ods"); (iv) run the R-script "importing_single_file" (if any test fail, a report will be created and the data should be fixed); and (v) pull a request to merge the new data, only once the dataset pass all the automated tests. On the other hand, for non-GitHub users, we proposed an alternative workflow to contribute new studies (see workflow B in figure 11): (i) access the repository site and download the template in the "Template" folder, (ii) fill out the information and name the file as "<author's

name>_“<crop>”_<country>_<year>”, (iii) open an issue in GitHub to let us know where we can access the filled template; (iv) we will test the template and, if any test fail, we will send an email to the corresponding author, asking him/her to fix his/her data. Once we receive a pull request (workflow A) or data that passes all our tests (workflow B), we will rebuild the database and release a new version of CropPol. Major releases will be deposited permanently at Zenodo (accessible using the same DOI)

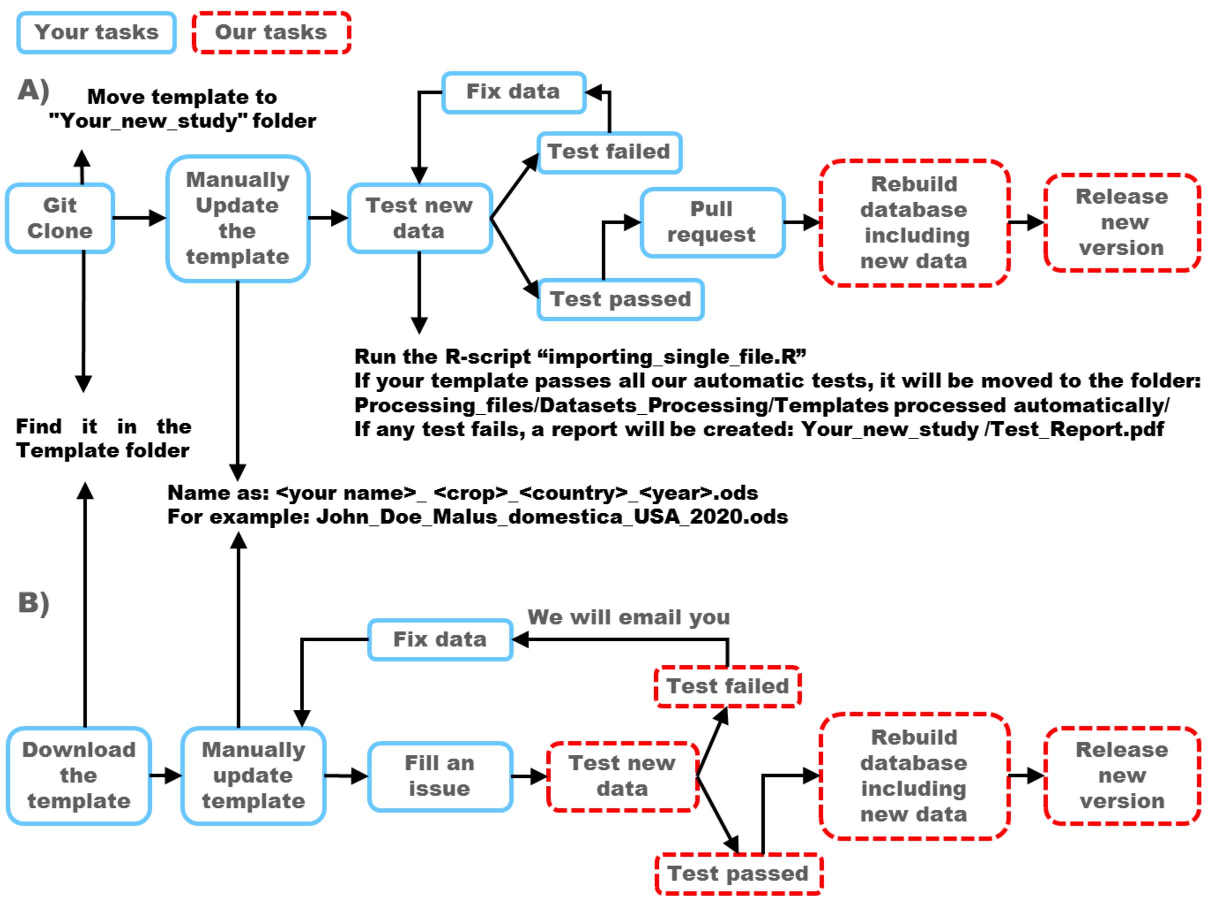

Figure 11. Data workflow for collecting new datasets. Workflow A is intended for GitHub users, whereas workflow B is for non-GitHub users. See main text for details on each workflow.

CLASS III. DATA SET STATUS AND ACCESSIBILITY

III.A. Status

III.A.1. Latest update

December 2020

III.A.2. Latest archive date

December 2020

III.A.3. Metadata status

Last update 11 December 2020, version submitted

III.A.4. Data verification

Raw data (collected from different sources) was transposed to CropPol templates by using R-scripts (R Core Team, 2020). During that stage, we corrected any transcription errors and homogenized information. Then we checked the format and values of the different variables by using Testthat (Wickham, 2011). For example, if the data holders provided the latitude and longitude of their orchards/fields/plots, we verified that such locations were in the country that they reported. Then, automated reports on the transposed datasets and their test were prepared with R. In order to check the correctness of the results obtained during the processing stage, we shared with the corresponding authors of each dataset (i) the raw data we received, (ii) the R-scripts (where all the transformations performed on the raw data were recorded), (iii) the resulting files (along with a metadata file that contained the description of the variables), and (iv) the report and some queries. The feedback and corrections we received from the corresponding authors was used to update and fix (i) the raw materials, (ii) R-scripts to process them, and (iii) the data in CropPol templates, when needed. Finally, to compile CropPol we only merged those studies that were verified and corrected by the corresponding author. All the process is reproducible and can be tracked at: https://github.com/ibartomeus/OBservData

III.B. Accessibility

III.B.1 Storage location and medium

The original dataset (v1.0) of the CropPol database can be accessed from the ECOLOGY repository. Updated versions of these datasets can be accessed at https://github.com/ibartomeus/OBservData Main upgrades will be versioned and deposited in Zenodo (doi: 10.5281/zenodo.4311291).

III.B.2. Contact person

Ignasi Bartomeus[1] (nacho.bartomeus@gmail.com) and Alfonso Allen-Perkins[1] (alfonso.allen.perkins@gmail.com)

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III.B.3. Copyright restrictions

III.B.4. Proprietary restrictions

Please cite this data paper when using the data in bulk, but prioritize citing the original datasets when appropriate (see Table 4).

Citation: Allen-Perkins A., A. Magrach, M. Dainese, L. A. Garibaldi, D. Kleijn, R. Rader, J. R. Reilly, R. Winfree, O. Lundin, C. M. McGrady, C. Brittain, D. Biddinger, D. R. Artz, E. Elle, G. Hoffman, J. D. Ellis, J. Daniels, J. Gibbs, J. W. Campbell, J. Brokaw, J. K. Wilson, K. Mason, K. L. Ward, K. B. Gundersen, K. Bobiwash, L. Gut, L. Rowe, N. K. Boyle, N. M. Williams, N. Joshi, N. Rothwell, R. L. Gillespie, R. Isaacs, S. J. Fleischer, S. S. Peterson,

S. Rao, T. L. Pitts-Singer, T. Fijen, V. Boreux, M. Rundlöf, B. Felipe Viana, A.-M. Klein, H. G. Smith, R. Bommarco, L. G. Carvalheiro, T. H. Ricketts, J. Ghazoul, S. Krishnan, F. E. Benjamin, J. Loureiro, S. Castro, G. A. (Arjen) de Groot, F. G. Horgan, J. Hipólito, S. G. Potts, C. Kremen, D. García, M. Miñarro, D. Crowder, G. Pisanty, Y. Mandelik, N. J. Vereecken, N. Leclercq, T. Weekers, S. M. Lindstrom, D. A. Stanley, C. C. Nicholson, J. Scheper, C. Rad, E. A. N. Marks, L. Mota, B. Danforth, M. Park, A. D. de Melo Bezerra, B. M. Freitas, R. Mallinger, F. Oliveira da Silva, B. Willcox, D. L. Ramos, F. D. da Silva e Silva, A. Lázaro, D. Alomar, M. A. González-Estévez, H. Taki, D. P. Cariveau, M. P. D. Garratt, R. I. A. Stewart, E. Lichtenberg, C. Schüepp, F. Herzog, M H. Entling, C. D. Michener, G. C. Daily, P. R. Ehrlich, K. L.W. Burns, A. Robson, B. Howlett, F. Jauker, F. Schwarzbach, M. Nesper, T. Diekötter, V. Wolters, H. Castro, H. Gaspar, B. A. Nault, C. Zaragoza-Trello, I. Badenhausser, J. D. Petersen, T. Tscharntke, V. Bretagnolle, N. Chacoff, G. K. S. Andersson, S. Jha, J. F. Colville, R. Veldtman, J. G. da Encarnação Coutinho, F. J. J. A. Bianchi, L. Sutter, M. Albrecht, P. Jeanneret, Y. Zou, A. L. Averill, K. E. Mackenzie, A. Saez, A. Sciligo, C. H. Vergara, E. H. Bloom, E. I. Badano, G. Loeb, H. Grab, J. Ekroos, V. Gagic, S. A. Cunningham, J. Åström, P. Cavigliasso, A. Trillo, A. Classen, A. L. Mauchline, A. Montero-Castaño, A. Wilby, B. A. Woodcock, C. Sheena Sidhu, I. Steffan-Dewenter, I. N. Vogiatzakis, J. M. Herrera, M. Otieno, M. W. Gikungu, M. Vilà, N. E. Raine, S. Cusser, T. Nauss, L. Nilsson, S. S. Greenleaf, J. Knapp, J. Ortega, J. A. González, J. L.Osborne, R. Blanche, R. F. Shaw, V. Hevia, J. Stout, A. D. Arthur, B. Blochtein, H. Szentgyorgyi, J. Li, M. M. Mayfield, M. Woyciechowski, P. Nunes-Silva, R. Halinski de Oliveira, S. Henry, B. I. Simmons, B. Dalsgaard, K. Hansen, T. Sritongchuay, A. D. O'Reilly, F. J. Chamorro García, G. Nates Parra, C. Magalhães Pigozo, I. Bartomeus. CropPol: a dynamic, open and global database on crop pollination. Ecology (volume, issue, year, reference number).

III.B.5. Costs

None.

CLASS IV. DATA STRUCTURAL DESCRIPTORS

IV.A. Data Set File

IV.A.1. Identity

(1) CropPol_field_level_data.csv

(2) CropPol_sampling_data.csv

(3) CropPol_data_ownership.csv

IV.A.2. Size

(1) CropPol_field_level_data.csv: 3,216 sites sampled; 1,763 KB

(2) CropPol_sampling_data.csv: 46,262 floral visitors records; 15,325 KB

(3) CropPol_data_ownership.csv: 1,109 records; 234 KB

IV.A.3. Format and storage mode

Data tables formatted as comma-separated values (*.csv)

IV.A.4. Header information

See column descriptions in section IV.B.

IV.A.5. Alphanumeric attributes

Mixed.

IV.A.6. Special characters/fields

Both files CropPol_sampling_data.csv and CropPol_field_level_data.csv contain a column that provides clarifications or comments on the values of other variables (see variable "notes" in Tables 1 and 2).

IV.A.7. Authentication procedures

Same as above (III.A.4. Data verification).

IV.B. Variable information

1) Site level information
2) Insect sampling information
3) Data ownership/data holders

IV.C. Data anomalies

If no information is available for a given record, this is indicated as 'NA'. Besides, both files CropPol_sampling_data.csv and CropPol_field_level_data.csv contain a column that provides clarifications or comments on the values of other variables (see variable “notes” in Tables 1 and 2).

CLASS V. SUPPLEMENTAL DESCRIPTORS

V.A. Data acquisition

The current data template that we use for data acquisition can be downloaded from (i) the project site (https://www.beeproject.science/croppollination.html), (ii) the CropPoll GitHub repository (see folder “Template” in https://github.com/ibartomeus/OBservData (folder “Template”), and (iii) the CropPoll Zenodo permanent repository (https://zenodo.org/record/4311292#.X8-eN1VKjIU).

Examples of the completed data forms can be accessed in the GitHub repository: https://github.com/ibartomeus/OBservData/Datasets_Processing/

Currently the procedures employed to verify that a data set is error free consist of (i) human review, (ii) automatic data verification as indicated above (III.A.4. Data verification). The datasets collected from now on will be automatically verified as indicated at the end of section II.C. Data Limitations and Potential Enhancements (see the workflow for GitHub and non-GitHub users in Fig. 11).

V.B. Related materials

See Table 4 for a list of publications related with the raw data.

V.C. Computer programs and data-processing algorithms

The algorithms used in deriving, processing , or transforming data can be accessed in the GitHub repository: https://github.com/ibartomeus/OBservData/

V.D. Archiving

The data is archived for long-term storage and access in Zenodo (https://zenodo.org/record/4311292#.X9MZDFVKjIU). As redundant archival sites, data is also available in the GitHub repository: https://github.com/ibartomeus/OBservData/Final_Data/

ACKNOWLEDGMENTS

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AUTHOR CONTRIBUTIONS

I.B. and A.A.-P. conceived the idea. A.A.-P. compiled and cleaned the data. M.D., L.A.G., D.K., R.R. and J.R.R. invited the co-authors of their respective meta-analyses to participate in the project and provided the original datasets of those data holders who accepted the invitation. The rest of the authors contributed data. All corresponding authors checked the cleaned data, verified its correctness, and provided corrections, when needed. A.A.-P, I.B. and A.M. wrote the manuscript draft. All the authors discussed and revised earlier versions of the manuscript.

Tables

Table 1. Site level information. Description of the fields related with the site level information – file (1) CropPol_field_level_data.csv

Field	Description	Level or range	Example
study_id	identification code for a given study: Author's name+crop name+country+year	Agustin_Saez_Rubus_idaeus_Argentina_2014 … Yi_Zou_Brassica_napus_China_2015 (n=161)	Thijs_Fijen_Allium_porrum_Italy_2016
site_id	identification code for a site within a study	1 … Zaltbommel_P2	Arroyo Claro

		(n=1,676)	
pollinator	name of the organism recorded	(Dialictus) sp. D … Zygoptera_sp. (n=2,824)	Eristalis arbustorum
guild	guild of the pollinator	honeybees bumblebees other_wild_bees syrphids humbleflies other_flies beetles non_bee_hymenoptera lepidoptera other	honeybees
identified_to	taxonomic resolution of the pollinator (whether identification is at the level of species, morphospecies, genera, etc).	class … Unknow (n=37)	species

sampling_method	method to survey organisms. If multiple methods were used per organism, one independent row is added for each method.	10 censuses of 15 minutes observation to a flowering branch … transects (n=88)	sweepnet
abundance	number of individuals observed/collected. In the case of performing several censuses (transect walks/plant observations), this field reflects the sum of the individuals collected. When specified in "description", the values may refer to visitation rates.	4.58435e-05 … 9808 (n=1,705)	1
total_sampled_area	area sampled during each census at each of the sites (e.g. area covered by one transect) in [square meters]. In the cases in	0.15 … 19800 (n=158)	480

	which there was more than one sampling area within a site, this variable reflects the sum of their respective areas.		
total_sampled_time	time spent sampling [minutes] each field. In the case in which sites were surveyed multiple times, this variable reflects the sum of their respective durations.	0 … 161280 (n=137)	60
total_sampled_flowers	number of flowers surveyed at each census (e.g., transect) per site. In the cases in which several censuses were performed, this variable reflects the sum of the respective counts.	17 … 199822.20 (n=273)	225

description	free text to describe the overall methodology, including the number of temporal replicates per site and what a spatial replicate means in the corresponding study.	10 flowers times 30 min . A group of two to three flowers (rarely one or four) were filmed for 30 min at each site, on three different days during bloom, and resulting in recordings of approx. 225 flower-minutes per site. Exact number of flowers filmed given in field level data file and now used to calculate visitation rates, average under total_sampled_flowers … within one crop field, 3 plots for crop measurements and 12 inventory transects were randomly located. 2 inventory rounds per transect (1x morning, 1x afternoon) (n=360)	3 sampling rounds in one season; one 150m observation transect per plot

notes	free text to add comments on the taxa resolution or any other variables	According to the corresponding author, if there are several pan-trap records for a given species at a given site, it means that such record was identified to a morphospecies level. … It was set to NA previously (n=11)	inlcudes muscids and drosophila

Table 2. Insect sampling information. Description of the fields related with the insect sampling information – file (2) CropPol_sampling_data.csv

Field	**Description**	**Level or range**	**Example**
study_id	identification code for a given study: Author's name+crop name+country+year	Alejandro_Trillo_Fragaria_ananassa_Spain_2016 … Yi_Zou_Brassica_napus_China_2015 (n=189)	Bryony_Willcox_Mangifera_indica_Australia_2016

site_id	identification code for a site within a study	1 … Zaltbommel_P2 (n=2,146)	Arroyo Claro
crop	crop latin name	Abelmoschus esculentus … Vicia faba (n=49)	Helianthus annuus
variety	crop variety name	741 … Yellow passion fruit (n=186)	Koipesol NAPOLI
management	management system implemented in the field: (1) Organic Agriculture, (2) Integrated pest management, and (3) Other Conventional Practices (4) unmanaged	organic IPM conventional unmanaged NA	conventional
country	country where the crop field is located	Argentina… USA (n=32)	Thailand

latitude	latitude (WGS84) of a given field expressed in degrees [°]	-42.12767 … 59.86528 (n=1,833)	43.44760
longitude	longitude (WGS84) of a given field expressed in degrees [°]	-123.1979 … 176.3204 (n=1,822)	8.7155910
X_UTM	Easting planar coordinate of a given field expressed in meters	-4,069,306 … 4,326,346 (n=346)	677,230
Y_UTM	Northing planar coordinate of a given field expressed in meters	142,490 … 9,757,262 (n=346)	8,526,182
zone_UTM	the UTM zone number of a given field.	10 .. SAD 69 24S (n=14)	32
sampling_start_month	month of the year at the beginning of the	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	2

	sampling period (for example, 1 for January, 2 for February and so on)		
sampling_end_month	month of the year at the end of the sampling period (see description for sampling_start_month)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	2
sampling_year	year in which the sampling was carried out	1990 … 2020 (n=27)	2011-2012
field size	area of the field [hectare]	0.000375 … 84,573 (n=501)	7.5
yield	yield value of a given field	-1.770894 … 1,500,000 (n=2,105)	72.548722

yield_units	yield units	average fruit set per 100 flowers … z-score Seeds produced (n=46)	tonnes per hectare
yield2	secondary yield value	-1.414558 … 10,386.6 (n=1,454)	213.5790
yield2_units	secondary yield units	%pods produced_pod weight … z-score Seed set (%) (n=27)	Fruit number on fixed branch length per tree
yield_treatments_no_pollinators	if the results for yield involve exclosures (e.g., bags, etc.), we fill this column with such results (measured as the first unit)	-2.22144444 … 1,272.60000000 (n=788)	40.00829587
yield_treatments_pollen_supplement	if the results for yield were obtained by using an additional treatment	-1.380536 … 74,780.40300	30

	(e.g., hand-pollination, etc.), we fill this column with such results measured as the first unit)	(n=656)	
yield_treatments_no_pollinators2	if the results for secondary yield involve exclosures (e.g., bags, etc.), we fill this column with such results (second yield unit)	-8.577778 ... 258.62 (n=631)	27.9781746
yield_treatments_pollen_supplement2	if the results for yield were obtained by using an additional treatment (e.g., hand-pollination, etc.), we fill this column with such results. (second yield unit)	-3.38888889 … 215.29100 (n=546)	87.30599647
fruits_per_plant	average number of fruits per plant [count per plant]	0.96 … 12,927.55 (n=199)	774.75685
fruit_weight	average fruit weight	0.02930331	1.6675

	[grams per fruit]	… 8,668.006 (n=710)	
plant_density	amount of crop plants per unit area of crop field [individuals per square meter]	0.006222222 … 4,485 (n=150)	2.35
seeds_per_fruit	average number of seeds per fruit [count per fruit]	0 … 308.5 (n=167)	8.2
seeds_per_plant	average number of seeds per plant or pod [count per plant]	10.5 … 1,427.24 (n=87)	545.48
seed_weight	average seed weight [grams per 100 seeds]	0.0031 … 81.064 (n=107)	3.985
sampling_richness	method/s to survey organisms that is/are used to estimate	"focal observations" … "transects + pan trap, bee	"transects + focal observations"

	richness.	bowl, blue vane trap, pitfall" (n=11)	
observed_pollinator_richness	number of different pollinator species observed [counts]	0 … 49 (n=63)	17
other_pollinator_richness	estimated number of different species [counts]	0 … 164.4062 (n=758)	46.93600
other_richness_estimator_method	method used for estimating “other_pollinator_richness”, preferably Chao1.	Chao 1 Chao NA (n=3)	Chao 1
richness_restriction	free text to describe constraints on richness/abundance measurements, such as “only bees”, “only non-managed bees”, etc.	all visitors considered … only bees (non-managed bees) (n=14)	bees and hoverflies

sampling_abundance	method/s to survey organisms that is/are used to estimate abundance.	"focal observations" … "transects" (n=9)	"sweep net"
abundance	total amount of counts along transect lines [counts]. In the case of performing several transect walks, we indicate the sum of the individuals collected.	0 … 6,001 (n=528)	1,961
ab_honeybee	total amount of transect counts for honey bees [counts]	0 … 1,750 (n=381)	237
ab_bombus	total amount of transect counts for bumble bees [counts]	0 … 1,906 (n=189)	171
ab_wildbees	total amount of transect counts for other wild bees [counts]	0 … 2,697.3	415

		(n=188)	
ab_syrphids	total amount of transect counts for syrphids [counts]	0 … 1,782 (n=98)	10
ab_humbleflies	total amount of transect counts for bombyliidae [counts]	0 … 2 (n=4)	1
ab_other_flies	total amount of transect counts for non syrphid or bombilida diptera [counts]	0 … 666 (n=84)	56
ab_beetles	total amount of transect counts for coleoptera [counts]	0 … 4,861 (n=65)	20
ab_lepidoptera	total amount of transect counts for lepidoptera (butterflies and moths) [counts]	0 … 452 (n=35)	7

ab_nonbee_hymenoptera	total amount of transect counts for nonbee hymenoptera (sawflies, wasps, ants, etc.) [counts]	0 … 1,147 (n=59)	59
ab_others	total amount of transect counts that were not included in the previous categories [counts]	0 … 263 (n=56)	3
total_sampled_area	area sampled during each census at each of the sites (e.g. area covered by one transect) in [square meters]. In the cases in which there was more than one sampling area within a site, this variable reflects the sum of their respective areas.	0.15 … 19,800 (n=163)	600
total_sampled_time	time spent sampling [minutes] each field. In the case in which sites	6 … 2,880	180

	were surveyed multiple times, this variable reflects the sum of their respective durations.	(n=160)	
sampling_visitation	method/s to survey organisms that is/are used to estimate visitation rates.	"focal observations" … "transects" (n=5)	"other"
visitation_rate_units	number of legitimate visits (i.e. contacting reproductive structures) to crop units (flowers, branches,etc.), per unit time. Preferred units: [visits per 100 flowers during one hour].	(average number of) visits per 100 flowers and hour … visits per unit of time (n=21)	visits per tree and hour
visitation_rate	total visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 ... 10,451.77 (n=1,452)	46.4473684
visit_honeybee	guild (honey bees) visitation rate to crop units (flowers,	0 … 7,574.678	20.11935000

	branches,etc.) [in the visitation_rate_units].	(n=1,254)	
visit_bombus	guild (bumble bees) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 492 (n=582)	4.319706000
visit_wildbees	guild (other wild bees) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 4,251.755 (n=877)	2.374101
visit_syrphids	guild (syrphids) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 1,980.458 (n=458)	0.394736842
visit_humbleflies	guild (bombyliidae) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 593.7041 (n=26)	0.0007105048

visit_other_flies	guild (non syrphid or bombilida diptera) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 607.631 (n=301)	2.0314250839
visit_beetles	guild (coleoptera) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 200 (n=130)	0.7117437722
visit_lepidoptera	guild (lepidoptera: butterflies and moths) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 229.7873 (n=132)	3.1496062992
visit_nonbee_hymenoptera	guild (nonbee hymenoptera: sawflies, wasps, ants, etc.) visitation rate to crop units (flowers, branches,etc.) [in the	0 … 1,332.724 (n=136)	2.1007727741

	visitation_rate_units].		
visit_others	guild (other) visitation rate to crop units (flowers, branches,etc.) [in the visitation_rate_units].	0 … 113.5246 (n=108)	0.7812500000
Publication	If published, DOI of the publication (preferred) or article reference, if DOI is not available.	10.1111/1365-2664.12977 … yield data unpublished (n=83)	10.1098/rspb.2013.2686
Credit	list with all authors who need to be given credit	Agustin Saez/CONICET (Universidad Nacional del Comahue) … Yi Zou and Felix J. J. A. Bianchi (n=88)	Christof Schüepps, Felix Herzog and Martin H. Entling
Email_contact	email for contacting purposes.	agustinsaez@live.com.ar … yi.zou.1@hotmail.com (n=75)	entling@uni-landau.de

notes	comments or clarifications on the values of a given variable	"At each site, the data collector walked through the orchard, collecting all non-Apis bees visiting apple flowers with a net. One data collection day was conducted per orchard." … "total_sampled_area: 20 almond individuals; 5-10 meters separation between individuals" (n=11)	"total_sampled_area: 800 m2 for honeybees and bumblebees, otherwise 400 m2"

Table 3. Data holders information. Description of the fields related with the data ownership information – file (3) CropPol_data_ownership.csv

Field	**Description**	**Level or range**	**Example**
study_id	identification code for a given study: Author's name+crop name+country+year	Alejandro_Trillo_Fragaria_ananassa_Spain_2016 … Yi_Zou_Brassica_napus	Bryony_Willcox_Mangifera_indica_Australia_2016

		_China_2015 (n=189)	
name	name of the co-author. Co-authors could be people directly involved in collecting the data. The main/corresponding author decides who his/her co-authors are. Please, use one line per co-author.	Agustin Saez … Yi Zou (n=176)	Charlie C. Nicholson
affiliation	Co-author affiliation. If a given co-author has several affiliations, please, use one line per affiliation.	[deceased] … Wageningen Environmental Research, Alterra (n=123)	School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland
email	email address of the co-author	[deceased] … yi.zou.1@hotmail.com (n=125)	freitas@ufc.br

role	One of the following role categories: (1) Lead author/Corresponding author, (2) Co-author/Co-owner	Lead author/Corresponding author Co-author/Co-owner	Co-author/Co-owner
funding	Funding sources (grants, scholarships, projects, etc.) that supported the co-author	"2013 2014 BiodivERsA FACCEJPIjoint call for research proposals (project ECODEAL)" … "Wisconsin Dept of agriculture, trade, and consumer protection" (n=63)	This study was financially supported by the GermanResearch Foundation (DFG) within the Research Unit FOR1246

Table 4. List of publications related with the raw data.

Publication (DOI)	Study identifier (study_id)
10.1126/science.aac7287	Agustin_Saez_Rubus_idaeus_Argentina_2014, Breno_M_Freitas_Anacardium_occidentale_Brazil_2011, Guiomar_Nates_Parra_Vaccinium_meridionale_Colombia_2013, Jens_Astrom_Malus_domestica_Norway_2013, Jens_Astrom_Trifolium_pratense_Norway_2013,

	Jens_Astrom_Trifolium_pratense_Norway_2014, Ruan_Veldtman_Helianthus_annuus_South_Africa_2011
10.1016/j.baae.2018.05.008	Alejandro_Trillo_Fragaria_ananassa_Spain_2016
10.1098/rspb.2002.2306	Alexandra_Maria_Klein_Coffea_arabica_Indonesia_2000_2001
10.1046/j.1365-2664.2003.00847.x	Alexandra_Maria_Klein_Coffea_canephora_Indonesia_2000_2001
10.1111/j.1365-2664.2012.02144.x	Alexandra_Maria_Klein_Prunus_dulcis_USA_2008
10.1038/ncomms8414	Alexandra_Maria_Klein_Prunus_dulcis_USA_2009, David_Kleijn_Allium_porrum_Italy_2012, Mia_Park_Malus_domestica_USA_2009, Mia_Park_Malus_domestica_USA_2010, Mia_Park_Malus_domestica_USA_2011, Rachael_Winfree_Malus_Domestica_USA_2004, Ruan_Veldtman_Malus_domestica_South_Africa_2011
10.1098/rspb.2013.3148, 10.5281/zenodo.12540	Alice_Classen_Coffea_arabica_Tanzania_2011_2012
10.1016/j.agee.2018.05.004, 10.1016/j.agee.2019.02.009	Amparo_Lazaro_Prunus_dulcis_Spain_2015, Amparo_Lazaro_Prunus_dulcis_Spain_2016
10.1590/1519-6984.02213	Betina_Blochtein_Brassica_napus_Brazil_2011
10.1111/j.1461-0248.2011.01669.x	Blande_Viana_Passiflora_edulis_Brazil_2005
10.1126/science.1230200	Breno_M_Freitas_Anacardium_occidentale_Brazil_2012,

	Breno_M_Freitas_Gossypium_hirsutum_Brazil_2011
10.1073/pnas.1517092112	Breno_M_Freitas_Annona_squamosa_Brazil_2013, Breno_M_Freitas_Malpighia_emarginata_Brazil_2011
10.1126/sciadv.aax0121	Breno_M_Freitas_Bixa_orellana_Brazil_2007
10.1038/s41598-019-49535-w	Bryony_Willcox_Mangifera_indica_Australia_2016
10.1038/s41598-019-49535-w, yield data unpublished	Bryony_Willcox_Persea_americana_Australia_2015, Bryony_Willcox_Persea_americana_Australia_2016, Bryony_Willcox_Macadamia_integrifolia_Australia_2016, Bryony_Willcox_Mangifera_indica_Australia_2016_2, Bryony_Willcox_Persea_americana_Australia_2017
10.1016/j.agee.2008.08.001	Carlos_H_Vergara_Coffea_arabica_Mexico_2004
10.1016/j.agee.2018.10.018, 10.1016/j.agee.2017.08.030	Charlie_Nicholson_Vaccinium_corymbosum_USA_2014, Charlie_Nicholson_Vaccinium_corymbosum_USA_2015, Charlie_Nicholson_Vaccinium_corymbosum_USA_2013
10.1098/rspb.2013.2667	Christof_Schuepps_Prunus_avium_Switzerland_2011
10.1111/1365-2664.12060	Dara_Stanley_Brassica_napus_Ireland_2009
10.1007/s10841-013-9599-z, 10.1007/s11258-014-0301-7	Dara_Stanley_Brassica_napus_Ireland_2010
10.1371/journal.pone.0204460	Davi_L_Ramos_Phaseolus_vulgaris L_Brazil_2015_2016
10.1093/aesa/88.3.334	David_Kleijn_Vaccinium_macrocarpon_USA_1990,

	David_Kleijn_Vaccinium_macrocarpon_USA_1991
10.1126/science.aac7287, 10.26786/1920-7603%282014%2926	Fabiana_Oliveira_da_Silva_Malus_domestica_Brazil_2010, Fabiana_Oliveira_da_Silva_Malus_domestica_Brazil_2011, Fabiana_Oliveira_da_Silva_Malus_domestica_Brazil_2012
10.1007/s10980-009-9331-2	Frank_Jauker_Brassica_napus_Germany_2006
10.1371/journal.pone.0031599	Georg_Andersson_Fragaria_ananassa_Sweden_2009
10.1016/j.agee.2009.05.001	Hajnalka_Szentgyorgyi_Fagopyrum_esculentum_Poland_2005, Simon_Potts_Vicia_faba_UK_2005
10.1016/j.agee.2015.05.004	Heather_Lee_Grab_Fragaria_ananassa_USA_2012
10.1111/j.1744-7348.2009.00326.x, 10.1016/j.baae.2010.08.004	Hisatomo_Taki_Fagopyrum_esculentum_Japan_2007, Hisatomo_Taki_Fagopyrum_esculentum_Japan_2008
10.1016/j.baae.2015.07.004	Ignasi_Bartomeus_Brassica_napus_Sweden_2013
10.1098/rspb.2020.0922	James_Reilly_Citrullus_lanatus_USA_2013, James_Reilly_Citrullus_lanatus_USA_2014, James_Reilly_Citrullus_lanatus_USA_2015, James_Reilly_Cucurbita_pepo_USA_2013, James_Reilly_Cucurbita_pepo_USA_2015, James_Reilly_Cucurbita_pepo_USA_2014, James_Reilly_Malus_pumila_USA_2013, James_Reilly_Malus_pumila_USA_2014, James_Reilly_Malus_pumila_USA_2015,

	James_Reilly_Prunus_avium_USA_2013, James_Reilly_Prunus_avium_USA_2014, James_Reilly_Prunus_cerasus_USA_2013, James_Reilly_Prunus_cerasus_USA_2014, James_Reilly_Prunus_cerasus_USA_2015, James_Reilly_Prunus_dulcis_USA_2013, James_Reilly_Prunus_dulcis_USA_2014, James_Reilly_Vaccinium_corymbosum_USA_2015, James_Reilly_Vaccinium_corymbosum_USA_2014, James_Reilly_Vaccinium_corymbosum_USA_2013
10.1111/1365-2664.12287	Jessica_D_Petersen_Cucurbita_pepo_USA_2011
10.1016/j.baae.2018.09.003	Jessica_Knapp_Cucurbita_pepo_UK_2016
10.1016/j.agee.2017.09.038	Juliana_Hipolito_Coffea_arabica_Brazil_2013, Juliana_Hipolito_Coffea_arabica_Brazil_2014
10.4257/oeco.2010.1401.09	Juliana_Hipolito_Mangifera_indica_Brazil_2005
<U+FEFF>10.3390/d12060259	Katrine_Hansen_Psidium_guajava_Thailand_2019, Katrine_Hansen_Psidium_guajava_Thailand_2020
10.1111/1365-2664.12977	Louis_Sutter_Brassica_napus_Switzerland_2014
10.1111/j.1461-0248.2010.01579.x	Luisa_G_Carvalheiro_Helianthus_annuus_South_Africa_2009
10.1111/j.1365-2664.2010.01829.x	Luisa_G_Carvalheiro_Mangifera_indica_South_Africa_2008
10.1111/j.1365-2664.2012.02217.x	Luisa_G_Carvalheiro_Mangifera_indica_South_Africa_2009

10.1007/s13592-018-0600-4	Marcos_Minarro_Malus_domestica_Spain_2015, Marcos_Minarro_Malus_domestica_Spain_2016
10.1017/CBO9780511754821	Margaret_Mayfield_Actinidia_deliciosa_New_Zealand_NA
10.1007/s10841-015-9788-z	Mark_Otieno_Cajanus_cajan_Kenya_2009
unpublished, 10.1016/j.biocon.2013.11.001	Michael_Garratt_Brassica_napus_UK_2012
unpublished, 10.1111/2041-210X.13292	Michael_Garratt_Fragaria_ananassa_UK_2011
unpublished, 10.1371/journal.pone.0153889, 10.26786/1920-7603(2014)8,10.1111/2041-210X.13292	Michael_Garratt_Malus_domestica_UK_2011
unpublished, 10.1016/j.biocon.2013.11.001, 10.1111/2041-210X.13292	Michael_Garratt_Vicia_faba_UK_2011
10.1111/j.1365-2664.2005.01116.x, 10.1098/rspb.2007.1547	Natacha_Chacoff_Citrus_paradisi_Argentina_2000, Natacha_Chacoff_Citrus_paradisi_Argentina_2001, Natacha_Chacoff_Citrus_paradisi_Argentina_2002
10.1111/j.1365-2664.2007.01418.x	Rachael_Winfree_Capsicum_annuum_USA_2004, Rachael_Winfree_Cucumis_melo_USA_2004,

	Rachael_Winfree_Solanum_lycopersicum_USA_2004, Rachael_Winfree_Solanum_lycopersicum_USA_2005
10.1111/j.1461-0248.2007.01110.x	Rachael_Winfree_Citrullus_lanatus_USA_2004, Rachael_Winfree_Citrullus_lanatus_USA_2005, Rachael_Winfree_Citrullus_lanatus_USA_2007, Rachael_Winfree_Citrullus_lanatus_USA_2008, Rachael_Winfree_Citrullus_lanatus_USA_2010, Rachael_Winfree_Citrullus_lanatus_USA_2011, Rachael_Winfree_Citrullus_lanatus_USA_2012
10.1111/1365-2664.12198	Rachael_Winfree_Vaccinium_corymbosum_USA_2010, Rachael_Winfree_Vaccinium_corymbosum_USA_2011
10.1111/ele.12126	Rachael_Winfree_Vaccinium_macrocarpon_USA_2009, Rachael_Winfree_Vaccinium_macrocarpon_USA_2010
10.1111/1365-2664.12377	Rachel_Mallinger_Malus_domestica_USA_2012, Rachel_Mallinger_Malus_domestica_USA_2013
10.1016/j.baae.2016.09.006	Rebecca_Steward_Fragaria_ananassa_Sweden_2014
10.1007/s00442-012-2271-6	Riccardo_Bommarco_Brassica_napus_Sweden_2005
10.1098/rspb.2011.0647	Riccardo_Bommarco_Trifolium_pratense_Sweden_2008, Riccardo_Bommarco_Trifolium_pratense_Sweden_2009, Riccardo_Bommarco_Trifolium_pratense_Sweden_2010
10.1007/s00442-015-3517-x	Sandra_Lindstrom_Brassica_napus_Sweden_2011,

	Sandra_Lindstrom_Brassica_napus_Sweden_2012
10.1016/j.agee.2016.04.020	Sarah_Cusser_Gossypium_hirsutum_USA_2014
10.1016/j.biocon.2006.05.025	Sarah_S_Greenleaf_Solanum_lycopersicum_USA_2001
10.1603/0022-0493-98.4.1193	Saul_A_Cunningham_Annona_squamosa atemoya_Australia_2001
10.1016/j.baae.2010.05.001	Saul_A_Cunningham_Brassica_napus_Australia_2006
10.1111/j.1600-0706.2009.17523.x	Shalene_Jha_Coffea_arabica_robusta_Mexico_2006
10.1016/j.baae.2012.03.007	Smitha_Krishnan_Coffea_canephora_India_2007, Smitha_Krishnan_Coffea_canephora_India_2008, Smitha_Krishnan_Coffea_canephora_India_2009
10.1073/pnas.0405147101, 10.1111/j.1523-1739.2004.00227.x	Taylor_Ricketts_Coffea_arabica_Costa_Rica_2001, Taylor_Ricketts_Coffea_arabica_Costa_Rica_2002
10.1111/ele.13150	Thijs_Fijen_Allium_porrum_France_2016, Thijs_Fijen_Allium_porrum_Italy_2016
10.1007/s13593-016-0377-7, 10.1016/j.agee.2012.05.003, 10.1073/pnas.1210590110	Virginie_Boreux_Coffea_canephora_India_2008
10.1890/14-0910.1	Yael_Mandelik_Citrullus_lanatus_Israel_2009, Yael_Mandelik_Citrullus_lanatus_Israel_2010
10.1007/s13592-013-0242-5	Yael_Mandelik_Helianthus_annuus_Israel_2010

10.1186/s12898-017-0116-1	Yi_Zou_Brassica_napus_China_2015

LITERATURE CITED IN METADATA

Bartomeus, I., and L. V. Dicks. 2019. The need for coordinated transdisciplinary research infrastructures for pollinator conservation and crop pollination resilience. Environmental Research Letters, 14(4), 045017. https://doi.org/10.1088/1748-9326/ab0cb5

Dainese, M., E. A. Martin, M. A. Aizen, M. Albrecht, I. Bartomeus, R. Bommarco, L. G. Carvalheiro, R. Chaplin-Kramer, V. Gagic, L. A. Garibaldi, J. Ghazoul, H. Grab, M. Jonsson, D. S. Karp, C. M. Kennedy, D. Kleijn, C. Kremen, D. A. Landis, D. K. Letourneau, … I. Steffan-Dewenter. 2019. A global synthesis reveals biodiversity-mediated benefits for crop production. Science Advances, 5(10), eaax0121. https://doi.org/10.1126/sciadv.aax0121

Díaz, S., U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, K. M. A. Chan, I. A. Baste, K. A. Brauman, S. Polasky, A. Church, M. Lonsdale., A. Larigauderie, P. W. Leadley, A. P. E. van Oudenhoven, F. van der Plaat, M. Schröter, S. Lavorel, … Y. Shirayama. 2018. Assessing nature's contributions to people. Science, 359(6373), 270–272. https://doi.org/10.1126/science.aap8826

FAOSTAT data. 2018. Data available at http://www.fao.org/faostat/en/#data/QC Last accessed in November 2020.

Garibaldi, L. A., I. Steffan-Dewenter, C. Kremen, J. M. Morales, R. Bommarco, S. A. Cunningham, L. G. Carvalheiro, N. P. Chacoff, J. H. Dudenhöffer, S. S. Greenleaf, A. Holzschuh, R. Isaacs, K. Krewenka, Y. Mandelik, M. M. Mayfield, L. A. Morandin, S. G. Potts, T. H. Ricketts, H. Szentgyörgyi, … A.-M. Klein. 2011. Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecology Letters, 14(10), 1062–1072. https://doi.org/10.1111/j.1461-0248.2011.01669.x

Garibaldi, L. A., I. Steffan-Dewenter, R. Winfree, M. A. Aizen, R. Bommarco, S. A. Cunningham, C. Kremen, L. G. Carvalheiro, L. D. Harder, O. Afik, I. Bartomeus, F. Benjamin, V. Boreux, D. Cariveau, N. P. Chacoff, J. H. Dudenhoffer, B. M. Freitas, J. Ghazoul, S. Greenleaf, … A.-M. Klein. 2013. Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance. Science, 339(6127), 1608–1611. https://doi.org/10.1126/science.1230200

Garibaldi, L. A., I. Bartomeus, R. Bommarco, A.-M. Klein, S. A. Cunningham, M. A. Aizen, V. Boreux, M. P. D. Garratt, L. G. Carvalheiro, C. Kremen, C. L. Morales, C. Schüepp, N. P. Chacoff, B. M. Freitas, V. Gagic, A. Holzschuh, B. K. Klatt, K. M. Krewenka, S. Krishnan, … M. Woyciechowski. 2015. EDITOR’S CHOICE: REVIEW: Trait matching of flower visitors and crops predicts fruit set better than trait diversity. Journal of Applied Ecology, 52(6), 1436–1444. https://doi.org/10.1111/1365-2664.12530

Garibaldi, L. A., L. G. Carvalheiro, B. E. Vaissiere, B. Gemmill-Herren, J. Hipolito, B. M. Freitas, H. T. Ngo, N. Azzu, A. Saez, J. Astrom, J. An, B. Blochtein, D. Buchori, F. J. C.

Garcia, F. Oliveira da Silva, K. Devkota, M. d. F. Ribeiro, L. Freitas, M. C. Gaglianone, … H. Zhang. 2016. Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. Science, 351(6271), 388–391. https://doi.org/10.1126/science.aac7287

Garibaldi, L. A., A. Sáez, M. A. Aizen, T. Fijen, and I. Bartomeus. 2020. Crop pollination management needs flower-visitor monitoring and target values. Journal of Applied Ecology, 57(4), 664–670. https://doi.org/10.1111/1365-2664.13574

Hampton, S. E., S. S. Anderson, S. C. Bagby, C. Gries, X. Han, E. M. Hart, M. B. Jones, W. C. Lenhardt, A. MacDonald, W. K. Michener, J. Mudge, A. Pourmokhtarian, M. P. Schildhauer, K. H. Woo, and N. Zimmerman. 2015. The Tao of open science for ecology. Ecosphere, 6(7), art120. https://doi.org/10.1890/es14-00402.1

Retrieved [11/06/2020], from the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES. 2016. Assessment Report on Pollinators, Pollination and Food Production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 552 pages. Zenodo. https://doi.org/10.5281/ZENODO.3402856

Kleijn, D., R. Winfree, I. Bartomeus, L. G. Carvalheiro, M. Henry, R. Isaacs, A.-M. Klein, C. Kremen, L. K. M'Gonigle, R. Rader, T. H. Ricketts, N. M. Williams, N. Lee Adamson, J. S. Ascher, A. Báldi, P. Batáry, F. Benjamin, J. C. Biesmeijer, E. J. Blitzer, … S. G. Potts. 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature Communications, 6(1). https://doi.org/10.1038/ncomms8414

Klein, A.-M., B. E. Vaissière, J. H. Cane, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, and T. Tscharntke. 2006. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences, 274(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721

Klein Goldewijk, K., A. Beusen, J. Doelman, and E. Stehfest. 2017. Anthropogenic land use estimates for the Holocene – HYDE 3.2. Earth System Science Data, 9(2), 927–953. https://doi.org/10.5194/essd-9-927-2017

Millenium Ecosystem Assessment (MEA). 2005. Ecosystems and human well being: synthesis. Island Press, Washington, D.C., USA. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Portman, Z. M., B. Bruninga-Socolar, and D. P. Cariveau. 2020. The State of Bee Monitoring in the United States: A Call to Refocus Away From Bowl Traps and Towards More Effective Methods. Annals of the Entomological Society of America, 113(5), 337–342. https://doi.org/10.1093/aesa/saaa010

Rader, R., I. Bartomeus, L. A. Garibaldi, M. P. D. Garratt, B. G. Howlett, R. Winfree, S. A.Cunningham, M. M. Mayfield, A. D. Arthur, G. K. S. Andersson, R. Bommarco, C. Brittain, L. G. Carvalheiro, N. P. Chacoff, M. H. Entling, B. Foully, B. M. Freitas, B. Gemmill-Herren, J. Ghazoul, … M. Woyciechowski. 2015. Non-bee insects are important contributors to global crop pollination. Proceedings of the National Academy of Sciences, 113(1), 146–151. https://doi.org/10.1073/pnas.1517092112

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Reilly, J. R., D. R. Artz, D. Biddinger, K. Bobiwash, N. K. Boyle, C. Brittain, J. Brokaw, J. W. Campbell, J. Daniels, E. Elle, J. D. Ellis, S. J. Fleischer, J. Gibbs, R. L. Gillespie, K. B. Gundersen, L. Gut, G. Hoffman, N. Joshi, O. Lundin, … R. Winfree. 2020. Crop production in the USA is frequently limited by a lack of pollinators. Proceedings of the Royal Society B: Biological Sciences, 287(1931), 20200922. https://doi.org/10.1098/rspb.2020.0922

Chamberlain, S., E. Szoecs, Z. Foster, Z. Arendsee, C. Boettiger, K. Ram, I. Bartomeus, J. Baumgartner, J. O'Donnell, J. Oksanen, B. Greshake Tzovaras, P. Marchand, V. Tran, M. Salmon, G. Li, and Grenié. 2020. *taxize: Taxonomic information from around the web*. R package version 0.9.98 https://github.com/ropensci/taxize.

Tscharntke, T., A.-M. Klein, A. Kruess, I. Steffan-Dewenter, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity - ecosystem service management. Ecology Letters, 8(8), 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

Venter, O., E. W. Sanderson, A. Magrach, J. R. Allan, J. Beher, K. R. Jones, H. P. Possingham, W. F. Laurance, P. Wood, B. M. Fekete, M. A. Levy, and J. E. M. Watson. 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nature Communications, 7(1). https://doi.org/10.1038/ncomms12558

White, E., E. Baldridge, Z. Brym, K. Locey, D. McGlinn, and S. Supp. 2013. Nine simple ways to make it easier to (re)use your data. Ideas in Ecology and Evolution, 6(2). https://doi.org/10.4033/iee.2013.6b.6.f

Wickham, H. 2011. Testthat: Get started with testing. The R Journal, 3, 5–10. Retrieved from: http://journal.r-project.org/archive/2011-1/RJournal_2011-1_Wickham.pdf

Winfree, R., J. R. Reilly, I. Bartomeus, D. P. Cariveau, N. M. Williams, and J. Gibbs. 2018. Species turnover promotes the importance of bee diversity for crop pollination at regional scales. Science, 359(6377), 791–793. https://doi.org/10.1126/science.aao2117