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# Delivery of crop pollination services is an insufficient argument for wild pollinator conservation

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There is compelling evidence that more diverse ecosystems deliver greater benefits to people, and these ecosystem services have become a key argument for biodiversity conservation. However, it is unclear how much biodiversity is needed to deliver ecosystem services in a cost-effective way. Here we show that, while the contribution of wild bees to crop production is significant, service delivery is restricted to a limited subset of all known bee species. Across crops, years and biogeographical regions, crop-visiting wild bee communities are dominated by a small number of common species, and threatened species are rarely observed on crops. Dominant crop pollinators persist under agricultural expansion and many are easily enhanced by simple conservation measures, suggesting that cost-effective management strategies to promote crop pollination should target a different set of species than management strategies to promote threatened bees. Conserving the biological diversity of bees therefore requires more than just ecosystem-service-based arguments.

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Worldwide, biodiversity is declining at unprecedented rates, threatening species persistence as well as the benefits humans gain from ecosystems<sup>1–3</sup>. These benefits, known as ecosystem services, have become an increasingly important argument for biodiversity conservation<sup>4–8</sup>. The economic and other benefits from ecosystems can motivate conservation action, and are more and more being used in payment for ecosystem service schemes. Once an economic value of the service has been determined, it can be captured in commercial markets or quantified in terms comparable with economic services and manufactured capital<sup>9</sup>. These economic values can then potentially be used to support biodiversity conservation within policies.

The use of ecosystem services arguments for justifying biodiversity conservation is, however, not without risk or controversy. Many experimental studies show that biodiversity increases the magnitude and/or stability of ecosystem functioning (of which ecosystem services are the subset that benefit people), and that most species contribute to ecosystem functioning in some way<sup>10–13</sup>. However, such studies do not consider the costs of maintaining or promoting biodiversity, even though costs are generally a limiting factor for implementing real-world conservation policies<sup>14</sup>. When the economic pay-off from ecosystem services is the main factor motivating conservation, the cost-effective action is to conserve the subset of species that provide the greatest return at relatively short timescales. Because real-world communities are almost invariably dominated by a small number of species<sup>15,16</sup> that often respond readily to conservation management<sup>17</sup>, we hypothesize that in real-world landscapes (1) the majority of the services is provided by a relatively small number of species; (2) that these species are generally common, and that threatened species rarely contribute to present ecosystem service delivery; and (3) that the most important ecosystem-service-providing species can be easily enhanced by simple management actions that are insufficient to support threatened species. Support for these hypotheses would suggest that delivery of ecosystem services is insufficient as a general argument for biodiversity conservation<sup>18–21</sup>.

Here we test these hypotheses using data from 90 studies and 1,394 crop fields on crop-visiting bee communities from five continents. Pollination is an important ecosystem service. The economic contribution of pollinators to crop production is significant<sup>22</sup>, and bees are generally considered the most important pollinators of crops<sup>23</sup>. We find that wild bee communities contribute on average over \$3,000 ha<sup>-1</sup> to the production of insect-pollinated crops. However, a limited subset of all known bee species provides the majority of pollination services because, across different crops, years and large biogeographical regions, crop-visiting bee communities are dominated by a small number of common species and rarely contain regionally threatened species. Dominant crop pollinators are furthermore able to persist under agricultural expansion and many are relatively easily enhanced by simple conservation measures. Focusing conservation on the services delivered by pollinators may therefore lead to management strategies that predominantly benefit the limited set of species currently providing the majority of crop pollination. Consequently, conservation of the biological diversity of bees should be motivated not only by immediate benefits from ecosystem services but also by the full richness of arguments for conservation.

## Results

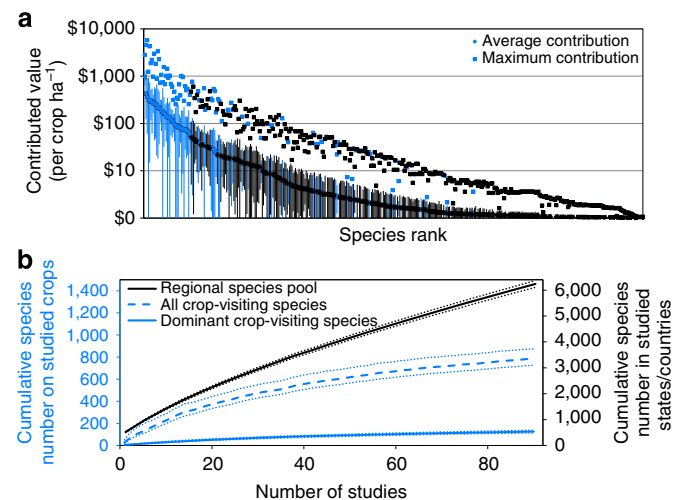
**The crop production value of wild bees.** On average, wild bee communities contributed \$3,251 ha<sup>-1</sup> to production of the

examined crops (s.e. = \$547, range \$7–14,252), about the same as the contribution of managed honey bees (mean ± s.e. = \$2,913 ± 574, range \$0–18,679). Individual wild bee species contribute substantially to crop production value with contributions up to \$963 per crop ha<sup>-1</sup> per species (mean across studies; Fig. 1a). Twenty-five species have a mean contribution higher than \$100 ha<sup>-1</sup> and 93 species have a maximum contribution higher than \$100 ha<sup>-1</sup> (Supplementary Table 2). The maximum contributions were 16.0 (± 0.34) times higher than the mean contributions, suggesting that for most species large contributions to pollination are limited to specific years, crops and/or sites.

## The proportion of bee species contributing to pollination.

Figure 1a also suggests that a small number of species dominate the contribution of wild bees to crop production value. Across the 90 studies, we collected a total of 73,649 individual bees of 785 species visiting crop flowers. Although this is an impressive number, it represents only 12.6% of the currently known number of species occurring in the states or countries where our studies took place (Fig. 1b). When we consider only bee species that contribute 5% or more to the relative visitation rate of any single study (hereafter, dominant crop-visiting species), the percentage drops to 2.0% of the species in the regional species pool (Fig. 1b). Yet these 2% of species account for almost 80% of all crop visits (Supplementary Fig. 2). The gentle slope of the species accumulation curve in Fig. 1b suggests that there is little turnover in dominant crop-visiting species between years, crops and locations, mainly because within biogeographical regions, a small number of species tend to dominate the crop-visiting bee communities everywhere (Supplementary Table 2).

**The commonness of crop-visiting bee species.** To test the hypothesis that the species providing the majority of the pollination services are generally regionally common species, we use two lines of enquiry. First, we examined the contribution of



**Figure 1 | The relative contribution of individual species in wild bee communities to crop pollination.** (a) The rank distribution of the contribution of wild bee species to crop production value in their biogeographical area. Dominant species, contributing at least 5% of all visits within a given study, are indicated in blue. Bars indicate 95% confidence intervals. (b) The cumulative number of bee species known to exist in the countries in which the studies were done, compared with an asymptotic estimate of the number of species that visit the flowers of the studied crops (Chao1 estimator), and the number of dominant crop-visiting wild bee species. Lightly dashed lines indicate estimates ± s.e.

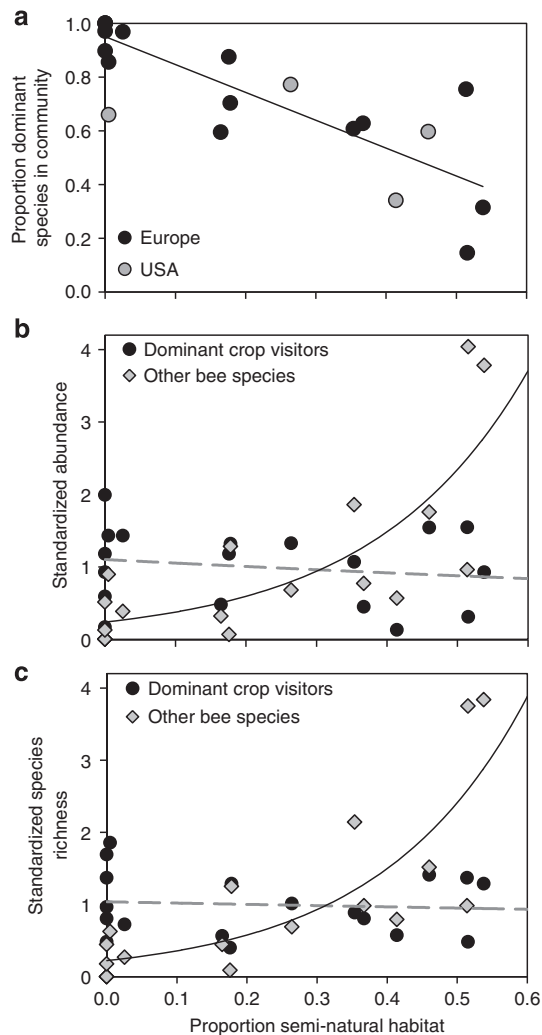
threatened bee species to the set of bee species found on crops. Four of the countries we studied have compiled Red Data books for bees, which we used to objectively identify threatened species. In these countries, on average 44% of the bee species are threatened, but in the 19 studies carried out in these countries only 12 threatened species were found accounting for 0.3% (s.e. 0.1%) of the individual bees observed on crops. Second, we determined whether the dominant crop-visiting bee species are common in agricultural landscapes generally, using an independent data set of bee communities in 264 sites in agricultural landscapes in Europe and North America (see Methods section). These studies compared bee communities in agricultural habitats such as arable fields (but not flowering, bee-pollinated crops), grasslands, old fields and hedgerows with bee communities in nearby sites that are actively managed for biodiversity enhancement (for example, agri-environment schemes and wildflower plantings) (Supplementary Fig. 1; refs 17,24). We used only the agricultural habitat controls to evaluate the frequency of dominant crop-visiting bee species (listed in Supplementary Table 3) in these 'background' agricultural habitats.

The dominant crop-visiting bee species dominate bee communities in agricultural landscapes generally, constituting  $75.4 \pm 6.9\%$  of individuals in these habitats in Europe and  $59.2 \pm 10.5\%$  in North America. This suggests that the species that are the dominant crop pollinators are the most widespread and abundant species in agricultural landscapes in general. Furthermore, the proportion of all bees on crops that belong to the dominant crop-visiting species was inversely related to the proportion of semi-natural habitats around study sites (Fig. 2a), and declined from  $\sim 92\%$  in landscapes almost completely devoid of semi-natural habitats to 40% in landscapes with half of the area covered by semi-natural habitats. This occurred because the pooled number and species richness of dominant crop-visiting bees were not related to semi-natural habitat cover, whereas the pooled number and species richness of all other bee species declined with decreasing cover of semi-natural habitat (Fig. 2b,c).

**Mitigating loss of dominant crop-visiting bee species.** To test whether dominant crop-visiting species can easily be enhanced (hypothesis 3), we compared their abundance on sites with biodiversity-enhancing management with that in 'background' agricultural habitats (as defined above). Across all studies, biodiversity management raised the abundance of dominant crop-visiting bees by a factor of 3.2. Organic farming, planting wildflowers and establishing grass margin strips significantly enhanced dominant crop-visiting bees in arable landscapes (Fig. 3). On grasslands, restricting the use of agro-chemicals and delaying the annual onset of agricultural activities (Hungary, Switzerland and the Netherlands; Fig. 3) did not result in increased densities of dominant crop pollinators.

## Discussion

Here we show that wild bee pollinators provide important pollination services to crops around the globe (Fig. 1a), with the economic value of this ecosystem service being on par with that provided by managed honey bees. Knowledge of the economic contribution of wild pollinators to farm income points out the potential for win-win situations, as it allows for the identification of cost-effective measures that raise both crop yields and promote wild pollinator populations<sup>25</sup>. However, our results also clearly highlight the limitations of the ecosystem services argument for biodiversity conservation, because we found that only a small minority of common bee species provides most of the crop pollination services.

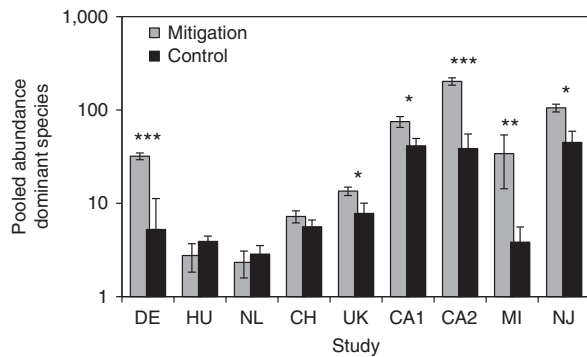


**Figure 2 | The relation between dominant crop-visiting bee species and cover of semi-natural habitats in agricultural landscapes.** (a) The

proportion of dominant crop-visiting bee species in bee communities in habitats other than flowering crops is negatively related to the proportion of semi-natural habitat within a 1,000-m radius ( $F_{1,14} = 14.47$ ,  $P = 0.002$ ).

(b) The relation between the proportion of semi-natural habitat in agricultural landscapes and bee abundance differs between dominant crop-visiting species and all other bee species (interaction type of bee and cover semi-natural habitat:  $\chi^2_{1,31} = 8.20$ ,  $P = 0.004$ ). Lines indicate back-transformed model predictions for dominant (dashed) and all other bee species (solid). (c) The relation between the proportion of semi-natural habitat in agricultural landscapes and the bee species richness differs between dominant crop-visiting species and all other species (interaction type of bee and cover semi-natural habitat:  $\chi^2_{1,31} = 7.84$ ,  $P = 0.005$ ). Lines indicate back-transformed model predictions for dominant (dashed) and all other bee species (solid).

Our data sets supported all three of our hypotheses about the disconnect between the ecosystem services approach to conservation and the protection of biodiversity at large. First, few species are needed to provide ecosystem services, with almost 80% of the crop pollination provided by only 2% of bee species. Second, the species currently contributing most to pollination service delivery are generally regionally common species, whereas threatened species contribute little, particularly in the most agriculturally productive areas. Thus, a strictly ecosystem-service-based approach to conservation would not necessitate the conservation



**Figure 3 | The effect of measures mitigating biodiversity loss on dominant crop-visiting bee species.** Bars indicate mean pooled abundance ( $\pm$  s.e.) of dominant crop-visiting bee species on sites with management measures mitigating biodiversity loss compared with control sites in nine different studies. Abbreviations and test statistics: DE—Germany,  $F_{1,40} = 12.69$ ,  $P < 0.001$ ; HU—Hungary,  $F_{1,38} = 1.13$ ,  $P = 0.295$ ; NL—Netherlands,  $F_{1,39} = 0.36$ ,  $P = 0.553$ ; CH—Switzerland,  $F_{1,39} = 1.29$ ,  $P = 0.263$ ; UK—United Kingdom,  $F_{1,39} = 4.97$ ,  $P = 0.032$ ; CA1—California study 1,  $F_{1,37} = 6.97$ ,  $P = 0.012$ ; CA2—California study 2,  $F_{1,9} = 29.83$ ,  $P < 0.001$ ; MI—Michigan,  $F_{1,5,6} = 15.10$ ,  $P = 0.009$ ; NJ—New Jersey;  $F_{1,10} = 10.06$ ,  $P = 0.010$ . \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

of threatened species. Third, the most important ecosystem-service-providing species are relatively robust to agricultural intensification, and furthermore can be readily enhanced in those systems by simple management actions. This suggests that the rarer species, which are already absent from such systems, would benefit less from ecosystem-service-based actions than they would from traditional biodiversity conservation that targets threatened species in the areas where they are found.

The first two points have been raised before in opinion and perspective papers as arguments for why the usefulness of ecosystem service provision as an argument to conserve biodiversity may be limited<sup>18–20</sup>. The contribution of this study is that we bring large data sets to this question for the first time. Specifically, for hundreds of bee species, we quantify both the economic value of the ecosystem services they provide as well as their conservation status. Such empirical testing in real-world landscapes is essential, given that, at present, the conclusion that ecosystem functioning strongly benefits from increased biodiversity rests primarily on data from small-scale experiments<sup>12</sup>. At the same time, the ecosystem services argument for conservation is gaining considerable traction as a dominant paradigm in real-world conservation<sup>6–8</sup>.

At first sight, our findings contrast with results of earlier studies, several of which were part of this study<sup>26–29</sup>, that demonstrated the benefits to crop production of pollinator biodiversity. The observed positive relations between pollinator species richness and seed or fruit set indicate that, at the plant or field scale, more diverse pollinator communities generally provide better pollination services (summarized in ref. 30). Our finding that relatively few species dominate pollination service delivery is largely the result of the larger spatial scale and the consideration of species identity in this study. Accounting for the identity of species shows that pollinator communities in different farm fields across large areas basically consist of variations of the same core set of species that prefer to forage on crops and that are augmented with the occasional new species. So while there is little doubt that a reduction in the local diversity of crop-visiting bee species may have negative consequences for the pollination services they deliver<sup>26,27</sup>, here we show that even the cumulative number of species across species-poor and species-rich fields

represents only a small proportion of all bees and are dominated by an even smaller subset of species that occur on most fields (Fig. 1b).

One benefit of biodiversity to ecosystem services is that it may provide insurance effects that stabilize services over time or space<sup>31</sup>. Our results are in line with this because for most bee species large contributions to pollination were limited to specific years, crops and/or sites (Fig. 1a). It could therefore be argued that in order to maintain stable pollination services, one would need to conserve a much wider set of bee species than those that are currently numerous on crops. Species that are now rarely observed may, after all, become important in the future. While this may be true, this line of reasoning only applies to bee species that can actually use crop plants for forage. Bee species, even generalists, have distinct preferences for host plants<sup>32</sup> and may be incapable of raising offspring on resources from non-preferred plants such as agricultural crops (cf. ref. 33). Species preferring non-crop plant families show more negative population trends than species specializing on members of crop plant families<sup>34,35</sup>, thereby confirming that many bee species fail to make use of this abundant resource supply. Thus, many of the bee species that are currently absent from crop flowers are unlikely to be important for spatial or temporal insurance effects of pollinator biodiversity on crop pollination, simply because they will not utilize crops even if conditions change.

Many previous studies have found that species richness of bee communities in agricultural landscapes declines with decreasing proportion of semi-natural habitats<sup>36,37</sup>. Our findings present a novel and more nuanced interpretation: while most bee species decline in abundance with expansion of agriculture, the species currently providing most of the pollination services to crops persist (Fig. 2b). Previous studies on plants have likewise demonstrated that with increasing land use intensity subdominant species are the first to decline, whereas dominant species are little affected<sup>38,39</sup>. Whether bee communities consisting of only the dominant pollinators are capable of providing sufficient pollination is unclear, but this pattern suggests that land use change will affect crop pollination less than it affects biodiversity<sup>12</sup>.

Measures to mitigate loss of pollination services are most cost effective in relatively intensively farmed landscapes because here measures have the highest impact<sup>40</sup>, ecosystem service delivery is likely to be reduced owing to the intensive farming practices, and returns on investments are greater owing to higher yields in intensively farmed areas<sup>39</sup>. Our results show that pollinator habitat creation in intensively farmed landscapes can successfully enhance the dominant crop-visiting bee species (Fig. 3), but are unlikely to benefit threatened species because of lack of source populations<sup>17</sup>. Species are classified as threatened when their numbers have experienced significant declines or their geographical distributions have contracted. Agricultural intensification is an important driver of species decline<sup>1</sup>. It is therefore perhaps not surprising that, in agricultural landscapes, threatened species contribute little to ecosystem service delivery, and benefit little from general conservation measures<sup>17</sup>. However, in the past, many of the species that are now threatened occurred widespread and contributed to pollination services on more extensively managed farmland<sup>41</sup>. Threatened species may also still dominate bee communities in restricted parts of their former distributional range<sup>42</sup>. Effective conservation measures for threatened species should therefore be targeted towards these bee species and their habitats, and not the crops to be pollinated<sup>39,43</sup>.

Highlighting the economic benefits people might obtain from biodiversity can be an effective instrument to motivate people or institutions to support biodiversity conservation. However, too much focus on the services delivered by pollinators may lead to

adoption of practices that will not benefit species that could potentially contribute under changing agricultural conditions nor species that will never contribute to crop pollination. Benefits of biodiversity should therefore not be used as the sole rationale for biodiversity conservation as, for example, is currently done in the new strategy of the Convention on Biological Diversity<sup>7</sup> and in the EU biodiversity strategy to 2020 (ref. 8). Moral arguments remain pivotal to supporting conservation of the larger portion of biodiversity including threatened species that currently contribute little to ecosystem service delivery. Such arguments are powerful and define many human actions, from taking care of the elderly to preserving historical buildings or art<sup>44</sup>. Ecologists and conservationists need to make these distinctions clear if we expect policy makers or land owners to defend species with no clearly defined economic value to humans.

## Methods

**Data sets to study crop visitation by bees.** Our data sets record the relative visitation rate of bees to crop flowers, which is a good proxy for the relative contribution to pollination service delivery (see next section). We used data from 90 studies and 1,394 crop fields around the world that used standardized protocols to examine the abundance and identity of wild bees visiting flowers of 20 different crops that depend on bee pollinators for maximum yield (Supplementary Fig. 1 and Supplementary Table 1). We determined species abundance distributions of wild bee communities on insect-pollinated crops by pooling data within studies, that is, from fields sampled in the same year, region and crop species. We only included studies that directly observed individual bees on crop flowers, identified all individuals to species level and that were based on data from at least four fields that were 1 km or more apart. This yielded a total of 90 studies with an average of 15.7 fields per study that were on average 41.7 km apart.

### Flower visitation frequency as a proxy for crop pollination service delivery.

Pollination is a function of both pollinator visitation frequency to flowers and per-visit pollen deposition (or efficiency)<sup>45</sup>. Because the differences in per-visit pollen deposition among species are generally outweighed by the differences in flower visitation among species<sup>46</sup>, visitation frequency is considered to be a good proxy for total pollination per species<sup>47</sup>. However, previous analyses of the suitability of visitation as proxy for pollination are mostly based on non-crop species (only 3 out of 22 species analysed by ref. 47 are crops, namely *Citrullus lanatus*, *Helianthus annuus* and *Phaseolus coccineus*). We therefore additionally analyse the relationship between visitation frequency (measured as the number of individual bees collected from crop flowers), per-visit pollen deposition (measured as the number of conspecific pollen grains deposited during a single visit<sup>45–47</sup>) and total pollination (calculated as the product of these two terms) using four of our best-resolved crop-pollinator data sets. The crops included are watermelon (5 years), tomato (2 years), cranberry (2 years) and blueberry (2 years), such that overall we analysed 11 crop-year combinations. Each annual data set was treated separately because different sites were studied in different years, and also because pollinator populations can fluctuate considerably among years. Each crop data set included extensive data on single-visit pollen deposition, a common metric used to assess per-interaction efficiency<sup>46</sup> (watermelon 302 single-visit pollen deposition experiments conducted with virgin flowers, cranberry 176 experiments, blueberry 100 experiments and tomato 66 experiments; for methods details see refs 48–50). Because our data on per-visit pollen deposition were resolved only to the level of species groups, we combined our visitation data into the same groups to avoid biasing our analyses with respect to the variance contributed by the visitation as compared with the pollen deposition factors (see below). At least one known nectar robber (*Xylocopa virginica*) was included in several of our data sets. This would tend to increase the importance of per-visit deposition, and decrease the importance of visitation, in driving total pollination, which is a bias against the assumption tested here.

We calculated total pollination as visitation multiplied by per-visit pollen deposition, as is generally done in the literature<sup>47</sup>, and then examined the Pearson correlations between each of these three values. Values of Pearson's  $r$  between visitation and total pollination were high (mean = 0.87; Supplementary Table 4). Although our methodology for estimating total pollination as the product of visitation and per-visit deposition makes such a correlation likely, it does not constrain it to be the case. The same expectation applies to per-visit deposition, which was not strongly correlated with total pollination (mean  $r = 0.11$ ; Supplementary Table 4). Furthermore, visitation and per-visit deposition were not correlated (Supplementary Table 4). Interestingly, our crop data sets reveal the same mechanism found by ref. 47 using data sets on predominantly native plant species: the high correlation arises because visitation has a much larger variance than does per-visit deposition; thus, visitation drives the variance in total pollination (Supplementary Table 4). In conclusion, there is strong empirical evidence that visitation is a good proxy for pollination in our data sets.

**Determining species abundance distributions.** To be able to determine species abundance distributions, we only used studies that identified all bee individuals to species level. However, this was not possible for a small number of species complexes. On mainland Europe, *Bombus terrestris* and *B. lucorum* workers and queens are extremely difficult to separate without careful microscopic examination or molecular techniques, and so are nearly always grouped together in field studies<sup>51</sup>. In this study, they were therefore considered as a single taxon. In the eastern United States, *Ceratina calcarata*, *C. dupla* and *C. mikmaqi* were grouped for similar reasons, as were *Lasioglossum leucocomum* and *L. pilosum*. The western honey bee (*Apis mellifera*), was only considered to be non-managed in South Africa because here the species is native and wild populations still exist (although managed honey bees are also used to enhance pollination of some crops, such as apples). In Indonesia, the Asian honey bee (*A. cerana*) is occasionally kept by local people and so was considered to be a managed pollinator. In all other countries, honey bees were considered to be managed pollinators and therefore irrelevant for ecosystem service provisioning. However, honey bee abundance was incorporated in the calculations of the contribution of bees to crop production value. On average, western honey bees had similar flower visitation rates as wild bees (proportional contribution:  $0.51 \pm \text{s.e. } 0.036$ ), although this varied among crops (Supplementary Table 1). Across all studies, species abundance distributions were based on 754 individuals.

**The economic contribution of bees to crop production.** For 53 studies, the data allowed us to calculate the economic contribution of wild bees to crop production using the production value method<sup>22</sup>. The financial contribution of individual pollinators to crop production was estimated using national Food and Agriculture Organization of the United Nations statistics for each crop<sup>52</sup>, year and country combination, and the production value method<sup>53</sup>:  $V_{\Delta\text{pollination}} = P \cdot Y \cdot D \cdot \rho$ . Here  $V_{\Delta\text{pollination}}$  is the value of pollination ( $\$ \text{ ha}^{-1}$ ),  $P$  is the price ( $\$ \text{ tonne}^{-1}$ ),  $Y$  is the yield ( $\text{tonne ha}^{-1}$ ),  $D$  is the proportional reduction in crop yield without pollination<sup>54</sup> and  $\rho$  is the proportion of the visits to crop flowers made by a particular bee species (including honey bees).

**Identifying dominant crop-visiting bee species.** Bee species were characterized as being dominant within a study when their relative abundance on crop flowers was 5% or higher. This threshold corresponds to the cumulative set of species that collectively provide 80% of the crop flower visits (Supplementary Fig. 2). Sensitivity analysis on this choice of threshold showed that results were robust to the choice of threshold so long as the definition of 'dominant' did not fall below including species that contributed only 2% of total crop flower visits (Supplementary Fig. 3). Furthermore, our results regarding the dominant crop-visiting species were robust to various study designs and methodological differences among studies, including the spatial extent of sampling and sampling effort (Supplementary Fig. 4). Last, as is often the case for studies of bees for which identification keys do not exist for many parts of the world, there were some unidentified specimens in our studies. These difficult-to-identify taxa were generally rare, however (when pooled, still <5% of the specimens in a given data set), and thus would have minimal impact on our main analyses.

**Crop-visiting bee species relative to regional species pool.** Conservation policy objectives are often formulated at national or even continental levels. We therefore also explored how the number of bee species encountered in our studies compared with the total number of unique bee species existing in the political territories in which the studies were performed (that is, the regional species pool). We used a database compiled from published and unpublished sources by J.S.A. of all described bee species currently known to exist in each country, state or province (that is, at the lowest territorial level for which such lists could be obtained). We obtained these data for the German federal states of Hessen<sup>55</sup>, Lower Saxony<sup>56</sup> and Bavaria<sup>57</sup>, and for the European countries of France, Great Britain, Hungary, Israel, Italy, Netherlands and Sweden (from ref. 58). In North America, species lists were obtained from ref. 58, for the US states California (CA), Massachusetts, New Jersey (NJ), New York, Pennsylvania and Virginia, and the Canadian province of British Columbia. Elsewhere in the world, species lists were used from ref. 58 for Chiapas (Mexico), Costa Rica, Minas Gerais (Brazil), New Zealand, South Africa and Sulawesi (Indonesia). We subsequently calculated straight-forward sample-based species accumulation curves using EstimateS software<sup>59</sup>, treating each territorial species list as a sample. Because each species list is not an ecological sample but is based on collections, revisions, faunal surveys and national inventories, we refrained from calculating a true species richness estimator.

To examine what proportion of the regional bee species pool visited crop flowers, and what proportion of them was dominant in at least one study, we similarly generated species accumulation curves for (dominant) crop-visiting bee species. Using the full data set of all observed bee species on crop flowers in our data set, we computed the nonparametric, asymptotic true species richness estimator Chao1 with log-linear 95% confidence intervals<sup>60</sup>, which corrects for unseen species based on the number of species in each study that were observed once (singletons) or twice (doubletons). For dominant species, which included no singletons or doubletons, and further are unlikely to include missing species, we calculated straight-forward species accumulation curves.

**The contribution of threatened species to crop visitation.** To examine what proportion of the bee communities observed on crops had a recognized threat status, we used Red Data Books. Red Data Books were only available for four of the countries from which we had data of crop-visiting bee species: Germany<sup>61</sup>, Netherlands<sup>62</sup>, Sweden<sup>63</sup> and United Kingdom<sup>64</sup>. In total, 19 separate studies had been carried out in these countries for which we calculated the per study mean pooled proportion of individuals from threatened species.

**Data sets to study commonness and effects of conservation.** To address the hypotheses that dominant crop-visiting bee species are generally common species and that these species can be easily enhanced by simple management actions, we used data from a number of European and North American studies examining the effects of measures to promote biodiversity in agricultural areas. These studies used paired designs and standardized protocols to compare bee community composition on sites with biodiversity-enhancing management with that on control sites (sites that were as similar as possible to the treatment sites but were not exposed to biodiversity management). Full details of the study locations and methodologies of the European studies collected in the EU-funded EASY project are given in refs 17,65. In summary, these sites were sampled in Germany, Hungary, Switzerland, the Netherlands and the United Kingdom in 2003. In each country, three regions were selected with contrasting landscape structure with each region containing seven field pairs. Biodiversity-enhancing management involved delaying the first seasonal cut of grasslands, restricting agro-chemical usage, and/or restricting cattle stocking rates (Hungary, Switzerland and The Netherlands), organic arable farming (Germany) and establishing 6-m-wide grass field margin strips along arable fields (the United Kingdom); all interventions were in the framework of existing agri-environment schemes. In each field, all samples were taken along two 95-m-long transects: one along the field edge and another, parallel to the first one, 50 m from the edge in the grassland interior. We sampled bees using sweep nets (60 sweeps per transect per round) and transect surveys (15 min sampling per transect per round) in the edge and interior of the fields three times (May, June and July) in 2003. For analyses, all data per field were pooled.

In the United States, unpublished 2012 data were used from two studies in CA, one in NJ and one in Michigan (MI). Biodiversity-enhancing management involved establishment of hedgerows of native perennial plants (study CA1) or establishment of wildflower plantings (studies CA2, NJ, MI). In contrast to the European studies, experimental sites in the United States were generally located adjacent to agricultural fields on pre-existing field edges or old fields. For the CA1 study, 20 field edges were selected containing native plant restorations (all at least 5 years old), which were paired with 20 non-restored control sites. Restorations were ~350 m long and 3–6 m wide and contained a mix of native perennial shrubs and trees<sup>24</sup>. Control sites were selected to roughly match conditions surrounding paired restoration sites; for each restoration site, a control site was selected adjacent to the same crop type (row crop, orchard, pasture or vineyard) within the same landscape context (that is, within 1–3 km of the restoration site), but at least 1 km from all other study sites. Control sites were generally weedy field edges and they reflected a variety of unmanaged crop field edges found in the region. Bee communities were sampled at each restoration and control site four times (except one pair of sites sampled only three times). Bees were netted along a 350-m transect for 1 h, stopping the timer while handling specimens. All native bees were collected and identified in the laboratory. The other three studies (CA2, NJ and MI) used the same general approach; each had six site pairs consisting of a wildflower plot established at least 2 years before sampling, using diverse (at least 10 species) mixes of native wildflowers that provided resources for bees throughout the growing season, paired with a control plot that was unrestored. Sampling sites within each pair were separated by 100–800 m. In NJ, four 40 m transects were established within each plot and sampled once in the morning and once in the afternoon, for 10 min each (net sampling time). In MI and CA2, eight 23-m-long transects were established in each plot and were sampled once in the morning and once in the afternoon for 5 min. All bees visiting flowers within 1 m of the transect were collected. In all three studies, each site was sampled four times throughout the summer. Again, for analyses, all data per site were pooled.

**Analysing commonness in relation to semi-natural habitat.** To examine whether dominant crop-visiting bee species are common species in agricultural landscapes, generally (hypothesis 2) only data from the control sites were used because they were situated in agricultural habitats such as arable fields (but not flowering, bee-pollinated crops), grasslands, old fields and hedgerows. The proportion of the bee communities consisting of individuals from bee species dominating crop visitation rates (Supplementary Table 3) were then calculated. The units of analysis were averages of multiple fields, as sample size per site was too low to yield reliable estimates of the relative contribution of dominant species to the bee community. In Europe, averages per region within each country ( $n = 7$ ) were used, whereas in the United States the average per study was used. For the studies MI, NJ and CA2, sample size was six, whereas for CA1 sample size was nine, since land cover data (see below) for all 20 site pairs were not available. To explain differences in the proportional contribution of dominant species between studies, this variable was tested against a number of variables known to affect bee species community composition: the percentage of semi-natural habitat in the vicinity of sampling sites, latitude and continent<sup>26</sup>. The percentage of semi-natural habitat (for example,

extensive grasslands, forests, heathlands and wetlands) was calculated in a radius of 1,000 m around each site, an approximate mean range at which different species groups of bees have been shown to respond to semi-natural habitat in studies on different continents<sup>48,66</sup>. For the European sites, we used CORINE Land Cover 2006 data sets<sup>67</sup> (all land use classes with codes starting with 3 or 4) which, although less accurate than national data sets, provide spatially consistent land cover classifications across all countries. In NJ, land cover data sets provided by the State Department of Environmental Protection were used (<http://www.nj.gov/dep/gis/lulc07cshp.html>). In MI, land cover was manually digitized from 2012 National Agriculture Imagery Program orthoimagery at the 1:2,000 scale (United States Department of Agriculture Geospatial Data Gateway, <http://datagateway.nrcs.usda.gov/>). The other two US studies used the National Agricultural Statistics Service crop data file (<http://nassgeodata.gmu.edu/CropScape/>).

We used standard multiple linear regression models to relate the proportion of individuals from dominant crop-visiting species in bee communities to the proportion of semi-natural habitat, thereby correcting for latitude and continent. Plotting residuals versus fitted values confirmed that model assumptions were met satisfactorily. The often used arcsine transformation of proportional data or binomial regression increased heteroscedasticity, and we therefore present the results of untransformed data. To subsequently explain the patterns in the proportional data, we calculated standardized abundances of dominant crop-visiting bees and, separately, for all other bees for each of the European study regions by dividing the per region bee abundance by the mean abundance across all 15 regions. Since the study in each region had used exactly the same survey protocol, a standardized bee abundance >1 indicates above-average bee abundance compared with the cross-study mean, and a value <1 indicates a below-average bee abundance. We similarly calculated standardized abundances of dominant crop-visiting bees and, separately, all other bees for the three US studies that used the same survey protocol (study CA1 used a different survey protocol and was excluded from this particular analysis). The same approach was used to calculate per study standardized species richness. This allowed us to use the European and US data sets in a joint analysis. We used log-linear models assuming a Poisson distribution with standardized abundance or species richness as response variables, and the proportion semi-natural habitat, bee type (dominant crop-visiting bees versus all other bees) and their interaction as main explanatory variables of interest. A significant interaction would indicate that dominant crop-visiting bees and all other bees are differently related to semi-natural habitat. Latitude was again included as a correcting variable. Continent was not included because we had standardized the response variables between the studies on each continent.

**Analysing effects of measures mitigating biodiversity loss.** We used site-level count data as the statistical unit and used generalized linear mixed models assuming Poisson error distribution and using a log-link function<sup>68</sup>. The initial models used treatment pair as a random term and study, mitigation measure (yes and no) and their interaction as fixed terms. This revealed a significant interaction between the effects of mitigation measures and study ( $F_{8,267} = 3.94, P < 0.001$ ). We therefore chose to perform separate analyses for each study with treatment pair as a random factor and mitigation measure as a fixed factor. We chose not to correct for multiple testing, as correction reduces type I error, but tends to inflate type II error<sup>69</sup>. Instead, we critically interpret statistical outcomes of analyses comparing treatment means. Model outcomes were checked by plotting residuals versus fitted values, confirming that assumptions were met satisfactorily.

All models were fitted using standard facilities in Genstat<sup>70</sup>.

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## Author contributions

D.K., R.W. and I.B. compiled and analysed data; D.K., R.W., L.G.C., M.H., R.I., A.-M.K., C.K., L.K.M., R.R., T.R., N.M.W. and S.G.P. discussed and revised earlier versions of the manuscript. The authors named from N.L.A. to C.W. are listed alphabetically, as they contributed equally in gathering field data, providing several important corrections to subsequent manuscript drafts and discussing ideas.

## Additional information

**Supplementary Information** accompanies this paper at <http://www.nature.com/naturecommunications>

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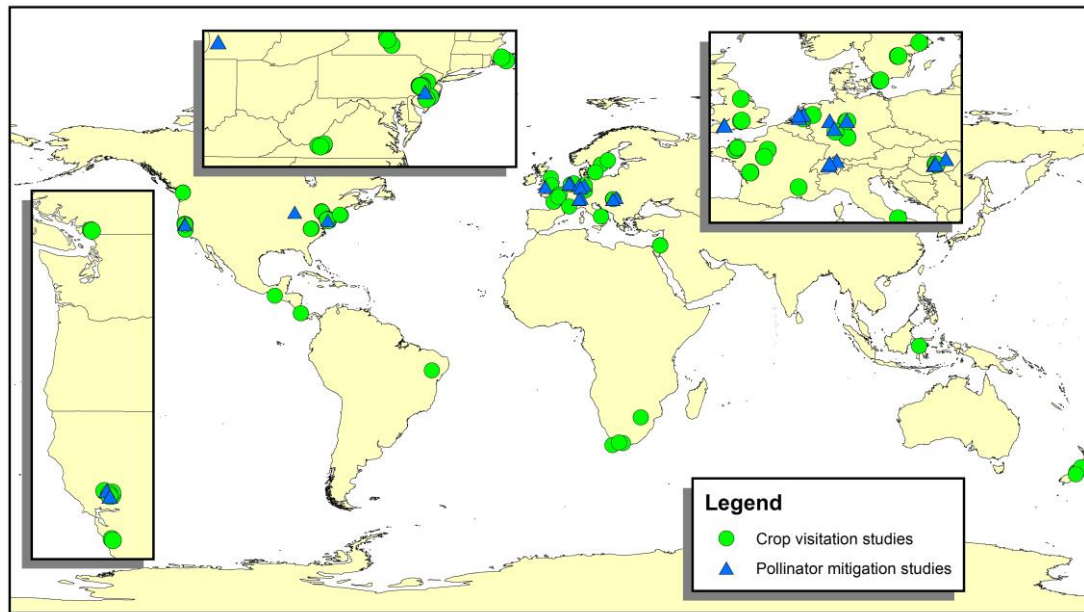
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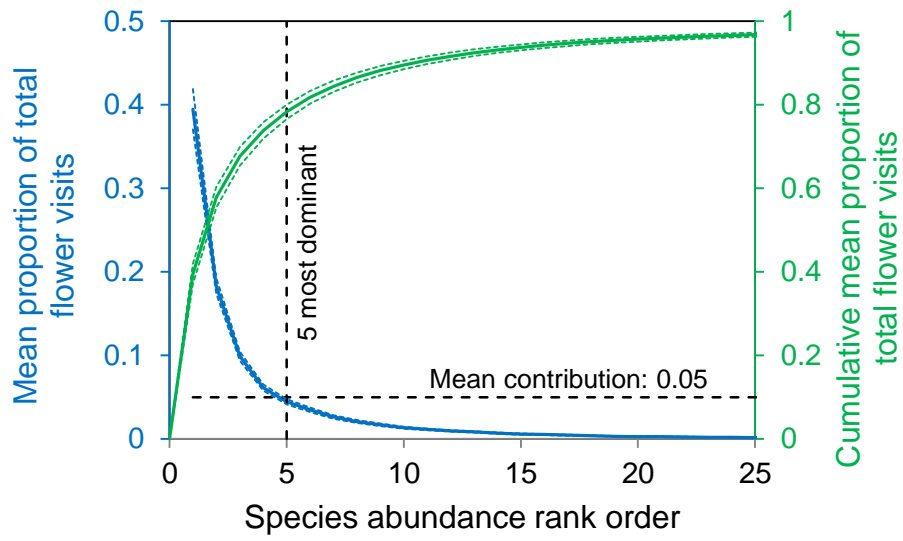


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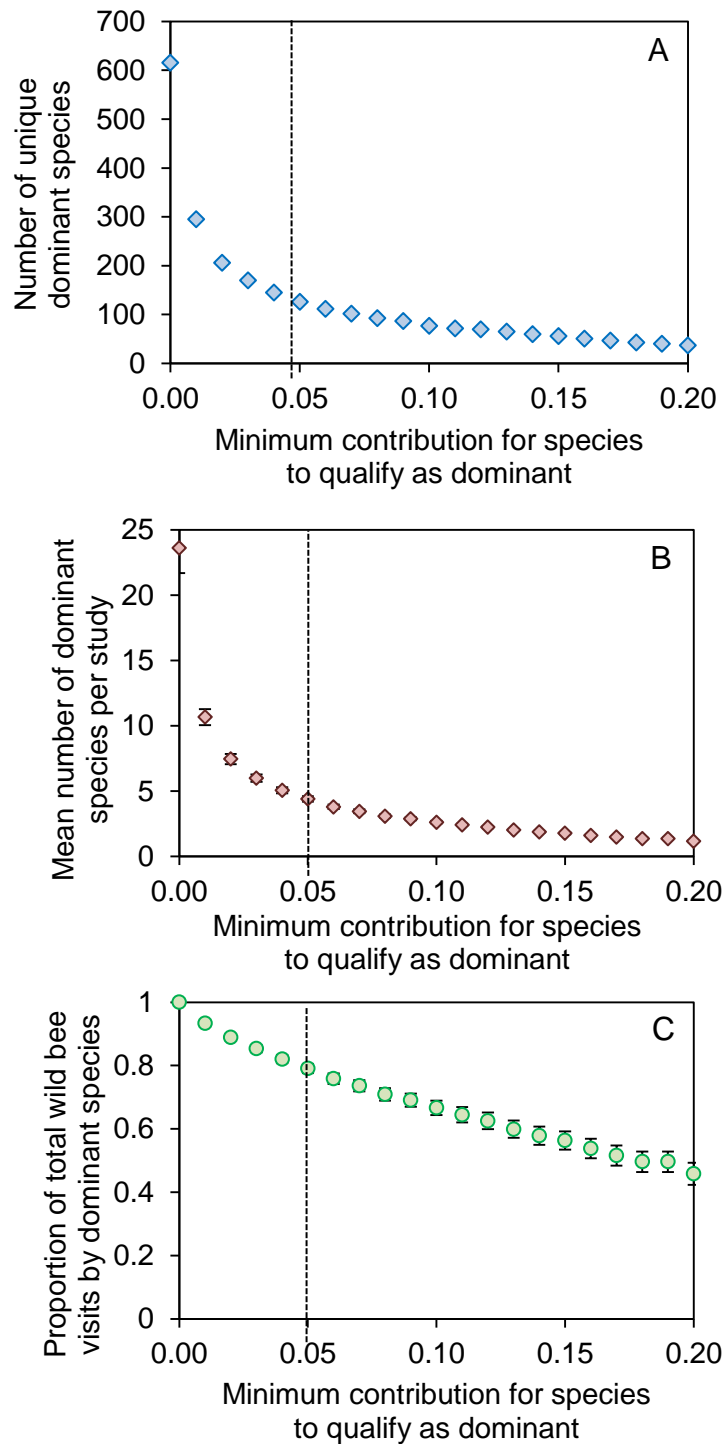




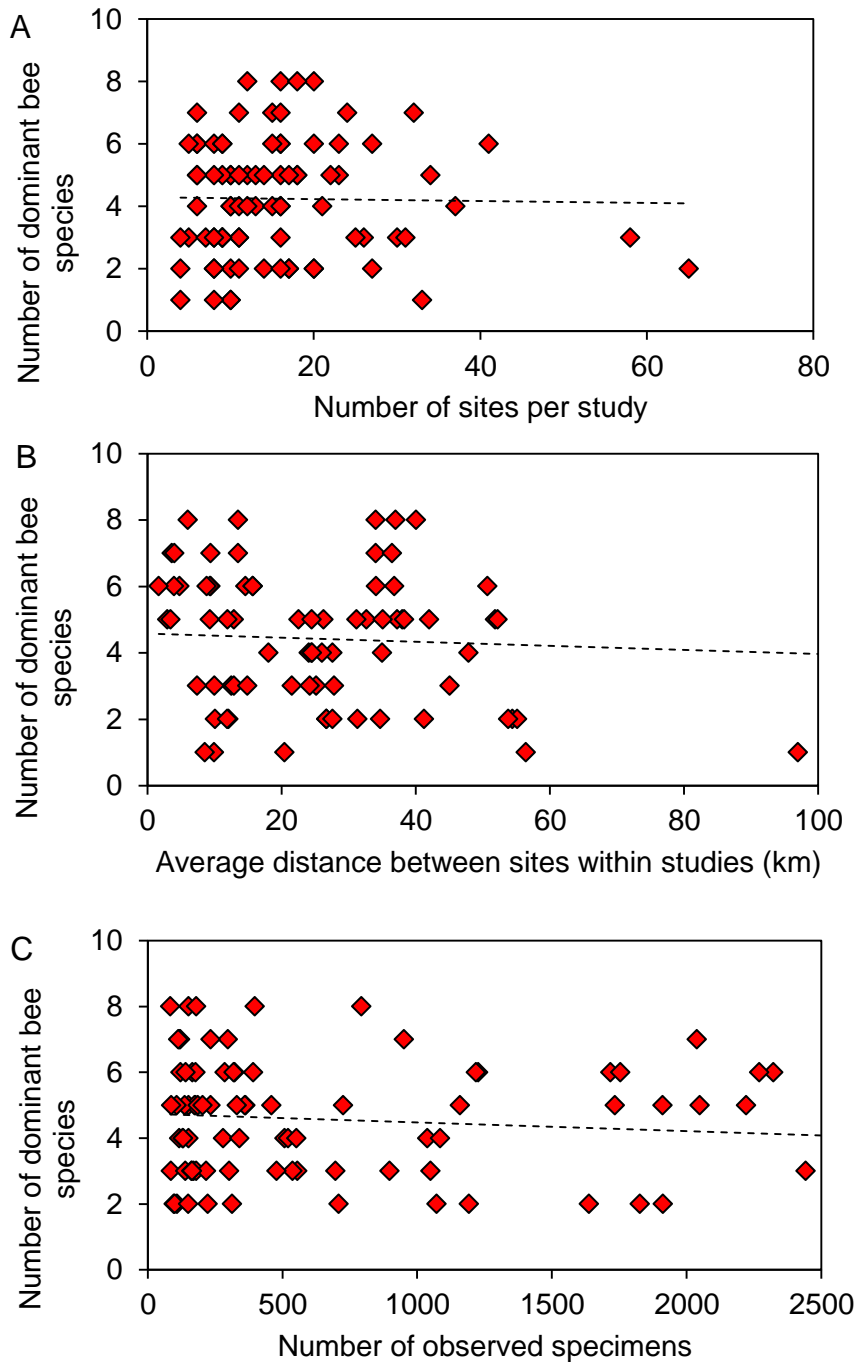
**Supplementary Figure 1 | An overview of the study site locations.** Note that some of the symbols are overlapping where a study had temporal (yearly) replicates. Further details of studies are given in Supplementary Table 1.



**Supplementary Figure 2 | The relationships between the species abundance rank order and the mean (cumulative) proportional contribution of species to the total crop-visitation by wild bee species.** Depicted are means ( $\pm$ s.e. indicated by dashed lines) of 90 studies.



**Supplementary Figure 3 | The relationship between threshold level for identifying dominant crop-visiting bee species and the proportion of the total wild bee visits made by dominant bee species.** Dominance patterns are relatively robust to changes in the dominance criterion. Changing the threshold value from the 5% value used in this study to characterise dominant species (vertical dashed line), results in only modest changes in: **a**, the total number of unique dominant bee species across all studies; **b**, the mean ( $\pm$  se,  $n = 90$ ) number of dominant species per study; and, **c**, the mean ( $\pm$  se,  $n = 90$ ) contribution by dominant species to the total bee flower visits. Only when the dominance criterion drops below 2%, do changes become marked.



**Supplementary Figure 4 | The relationships between the number of identified dominant bee species visiting crop flowers and a number of key characteristics of the studies. a,** The number of dominant species was not related to the number of sites sampled in a study (simple regression analysis;  $F_{1,83} = 0.03$ ,  $P = 0.875$ ) and was constant at about ~4.2 species across the entire range of 4-65 sites sampled per study. **b,** The number of dominant species was not related to the average distance between the sites that had been sampled in each study ( $F_{1,80} = 2.77$ ,  $P = 0.100$ ). Within studies, sites were at least 1 km apart. Studies with average between site distances larger than 100 km (21-23, 76-79, 86; see Extended Data Table 1) are not shown for clarity. **c,** The number of dominant species was not related to the number of observed individuals ( $F_{1,83} = 2.13$ ,  $P = 0.148$ ). South African studies were excluded from this

particular analysis as in South Africa it is impossible to distinguish wild from managed honey bees. Studies with more than 3,000 individuals are not shown (studies 9, 23; Supplementary Table 1). Dominant species contributed more than 5% to the total number of individuals of the bee community on crop flowers in each study. For all three analyses, regression on the full dataset revealed heteroscedasticity. This variability was caused by a small number of outliers (i.e. studies with very high between site distances). Transformations of the response variable, or analyses assuming binomial or Poisson error distributions, did not produce homoscedastic datasets. Analyses without these studies produced constant error variance. The results of these analyses were similar to those of analyses using the full dataset, and so in this figure, we therefore present the results using the full dataset. For illustrative purposes only, the non-significant relationships are depicted by means of a dashed trend-line based on these analyses.

**Supplementary Table 1 | A summary of the studies providing the data on bee species visiting flowers of insect pollinated crops.** Unpublished datasets are identified by the name of the first author. Yield and price statistics based on FAO data<sup>25</sup>. N.a.: not available.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**1<sup>1</sup> Red Clover (*Trifolium pratense*); Sweden, Östergötland; 2008; n.a.; n.a.; 14; 1637; 0.80**

**2<sup>1</sup> Red Clover (*Trifolium pratense*); Sweden, Skåne; 2009; n.a.; n.a.; 20; 1826; 0.62**

**3<sup>1</sup> Red Clover (*Trifolium pratense*); Sweden, Östergötland; 2009; n.a.; n.a.; 17; 1912; 0.74**

**4<sup>1</sup> Red Clover (*Trifolium pratense*); Sweden, Skåne; 2010; n.a.; n.a.; 11; 555; 0.53**

**5<sup>1</sup> Red Clover (*Trifolium pratense*); Sweden, Östergötland; 2010; n.a.; n.a.; 17; 1071; 0.53**

**Method:** Bee abundances were recorded in arable fields of flowering red clover cultivated for seed production. In 2008, 2009 and 2010, flower visiting insects were collected along 1 m wide and 50 m long transects in the flowering red clover seed fields. In 2008, surveys in each field were based on four transects located 4 and 12 m from the field edge. In 2009 and 2010, surveys in each field were based on two transects located 8 and 100 m from the field edge (or for smaller fields in the field centre). Each site was visited two times in 2008 and three to five times in 2009 and 2010. Sampling was conducted only on days with warm, sunny and calm weather between 25 June and 29 July, 2008, 26 June and 20 August, 2009, and 5 July and 10 August, 2010. The collected bees were identified to species level. Of the bumble bee (*Bombus*) individuals, 2.8% were only identified to genus level because field workers did not catch them. As *Bombus* is a well-known genus with most individuals identified to species level, for these studies the unidentified specimens were assigned to species based on the proportions of actual species level identifications within each study.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**6<sup>2</sup> Oil Seed Rape (*Brassica napus*); Sweden, Uppsala; 2005; 2.41; 271.5; 10; 96; 0.06**

**Method:** Bees were surveyed in ten oilseed rape fields. In each field, surveys were conducted in a 150 m long and 4 m wide transect line at the center of the field or, for large fields, between the center of the field and one of its margins. Flower visiting bees were sampled with an aerial net for 30 minutes identifying specimens to species level. In each field, transects were monitored four times during the main flowering period from 27 June to 21 July in 2005, between 9.00 and 17.00, and only on days with temperature  $\geq 15^{\circ}\text{C}$ , no precipitation, dry vegetation, and low wind speeds ( $< 40 \text{ km.h}^{-1}$ ). Of the bumble bee (*Bombus*) individuals, 26% were only identified to genus level because field workers did not catch them. As *Bombus* is a well-known genus with most individuals identified to species level the unidentified specimens were assigned to species based on the proportions of actual species level identifications within each study.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**7<sup>3</sup> Oil Seed Rape (*Brassica napus*); Germany, Lower Saxony; 2007; 3.44; 392.0; 34; 362; 0.25**

**Method:** In 2007 bee densities were assessed on 34 flowering oilseed rape fields in Germany. Bees were recorded along 100 m transects with 1 m width in the field centre and at the field edge for 15 min per transect on two occasions during oilseed rape flowering in April and May. The edge transect was located 1 m into the oilseed rape field along the field edge; the centre transect started 10 m from the field edge and followed a lane toward the field centre. Sites were sampled between 10.00 and 17.00 h at temperatures above  $15^{\circ}\text{C}$  on days with no rain, low or non-existent cloud cover and low wind speeds. All bees that could not be identified in the field were collected for subsequent identification in the laboratory.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**8<sup>V. Riedinger</sup> Oil Seed Rape (*Brassica napus*); Germany, Bavaria; 2011; 2.91; 619.4; 16; 150; 0.29**

**Method:** In 2011 bee densities were assessed on 16 flowering oilseed rape fields in Germany. In each field, bees were surveyed twice between 18 April and 10 May, 2011, in two 150 m long and 1 m wide transects, one located along the edge of the field and the other in the centre of the field. In each

survey, each transect was surveyed for 15 minutes by slowly walking its length. Surveys were conducted between 09:00 and 18:00 at temperatures above 15 °C on days with no rain, low or non-existent cloud cover and low wind speeds. Honey bees and bumble bees were identified to species in the field, all other bees were collected for identification in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**9<sup>4</sup> Sunflower (*Helianthus annuus*); Germany, Bavaria; 2011; 1.98; n.a.; 16; 7747; 0.39**

**Method:** In 2011 bee densities were assessed on 16 flowering sunflower fields. In each field, bees were surveyed between 4 July and 6 August, 2011, in two 150 m long and 1 m wide transects; one located along the edge of the field and the other in the centre of the field. Surveys were conducted between 09:00 and 18:00 at temperatures above 16 °C on days with no rain, low or non-existent cloud cover and low wind speeds. On two fields, edge and centre transects were surveyed four times. On three more fields, edge transects were surveyed three times but center transects only two times. All other fields were surveyed completely three times, each time for 15 minutes, while slowly walking along the transect and recording only pollinators on sunflower heads. Honey bees and bumble bees were identified to species in the field, all other bees were collected for identification in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**10<sup>5</sup> Oil Seed Rape (*Brassica napus*); Germany, Hesse; 2006; 3.73; 292.6; 23; 177; 0.54**

**Methods:** In June and July, 2006 bees were surveyed in 23 oilseed rape fields. Bees were surveyed in up to three sampling points within each field (depending on the field size). Each survey lasted ten minutes and took place between 10:00 and 17:00 on sunny days with little wind. Each sampling point was surveyed up to three times, depending on flowering phenology. Surveys were carried out by two experienced ecologists. Bees were either identified in the field or collected for identification in the laboratory.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**11<sup>6</sup> Strawberry (*Fragaria x ananassa*); Germany, Lower Saxony; 2005; 10.90; 3351.1; 10; 507; 0.16**

**Methods:** Bees were surveyed using standardized transect walks in 10 strawberry fields. Surveys were carried out from 27 April until 16 June, 2005 under good weather conditions with temperatures at least 15°C, no precipitation and a wind speed below 40 km.h<sup>-1</sup>. Bees were surveyed for 30 min in a 150 m transect line identifying visiting insects at species level and catching unidentified species within a 4 m wide corridor. Each field was surveyed four times during the main flowering period of the crop. Collected specimens were pinned, labeled, and subsequently identified to species.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**12<sup>7</sup> Field Bean (*Vicia faba*); UK, Reading; 2005; 3.83; 149.5; 10; 1037; 0.86**

**Methods:** Bees were surveyed using standardized transect walks in 10 field bean fields. Surveys were carried out between 09:00 and 17:00 from May to August, 2005 under good weather conditions with temperatures at least 15°C, no precipitation and a wind speed below 40 km.h<sup>-1</sup>. Bees were surveyed for 30 min in a 150 m transect line identifying visiting insects at species level and catching unidentified species within a 4 m wide corridor. Each field was surveyed four times during the main flowering period of the crop. Collected specimens were pinned, labeled, and subsequently identified to species. 62.5% of the bumble bee (*Bombus*) individuals were only identified to genus level because field workers did not catch them. For these studies, as *Bombus* is a well-known genus with most individuals identified to species level, the unidentified specimens were assigned to species based on the proportions of actual species level identifications within each study.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**13<sup>M. Garratt</sup> Strawberry (*Fragaria x ananassa*), UK, West Yorkshire; 2011; 22.16; 3859.0; 8; 1192; 0.55**  
**14<sup>M. Garratt</sup> Field Bean (*Vicia faba*); UK, Berkshire; 2011; 3.35; 274.0; 8; 537; 0.88**

**Methods:** In 2011, bee visitation to field beans and strawberry fields was surveyed. For each crop, 8 fields were selected and 2\*150m transects were walked between rows. For recording purposes, the transects were sub-divided into 3\*50m transects, each of which was walked for 10 minutes. Any pollinators observed carrying out floral visits (legitimate only for beans) were recorded, if the pollinator could not be identified in the field, it was collected and identified in the laboratory. Three rounds of bean surveys were carried out at each field between the 10th and 25th of May and 3 rounds of strawberry surveys between the 18th of May and the 14th of June. All surveys were conducted only when temperatures exceeded 15 °C and when wind was light or non-existent. 12.8 % of the bumble bee (*Bombus*) individuals were only identified to genus level because field workers did not catch them. For these studies, as *Bombus* is a well-known genus with most individuals identified to species level, the unidentified specimens were assigned to species based on the proportions of actual species level identifications within each study.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**15<sup>8</sup> Apple (*Malus domestica*); Netherlands, Gelderland; 2010; 38.47; 576.0; 6; 165; 0.42**

**16<sup>8</sup> Apple (*Malus domestica*); Netherlands, Gelderland; 2011; 50.57; 745.2; 6; 297; 0.24**

**17<sup>8</sup> Pear (*Pyrus communis*); Netherlands, Gelderland; 2010; 34.27; 750.7; 6; 150; 0.85**

**18<sup>8</sup> Pear (*Pyrus communis*); Netherlands, Gelderland; 2011; 40.96; 678.4; 6; 285; 0.78**

**Methods:** In 2010 and 2011 bee visitation rate on crop flowers was examined in 6 apple and 6 pear orchards. The same apple and pear orchards were used in both years. Each orchard was surveyed twice per year, once in the morning and once in the afternoon with at least three and at most seven days separating surveys. Surveying was conducted by four experienced entomologists between 23 April and 6 May, 2010 and between 8 and 20 April, 2011 under sunny conditions or scattered clouds. Temperatures ranged between 15 °C and 20 °C with calm wind to moderate breeze. Bees were surveyed using a single transect between two rows of trees along the length of each orchard with the transect subdivided into 25 m long plots (mean number of plots per orchard ± s.e.: 8.5±1.0 for apple and 9.7±0.5 for pear). In each plot all bees observed on apple or pear flowers during a 10 minute-period were identified to species. Easily recognizable species were generally identified in the field; all other species were collected and identified in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**19<sup>J. Schepers</sup> Oil Seed Rape (*Brassica napus*); Netherlands, Overijssel; 2011; 3.44; 501.5; 8; 312; 0.42**

**Methods:** In 2011, bees were surveyed in 8 oilseed rape fields. One field was surveyed only once on 30 April, while all others were surveyed twice between 30 April and 30 May, once in the morning and once in the afternoon. In each field, bees were surveyed in two 1 x150 m transects located at the edge and in the interior of the field (>25 m from field edge). Transects were subdivided into three 1 m x 50 m plots. In each plot, bees visiting crop flowers were collected during a period of 5 minutes. Easily recognizable species were generally identified in the field; all other species were collected and identified in the lab. Surveys were carried out under dry weather conditions, with low to moderate wind speeds and temperatures above 15 °C.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**20<sup>D. Kleijn</sup> Leek (*Allium porrum*); Italy, Foggia; 2012; n.a.; n.a.; 10; 173; 0.74**

**Methods:** In 2012, bees were surveyed at 10 leek fields in the province of Foggia, Italy. Each field was surveyed once between 19 and 21 June, 2012 under sunny weather conditions with temperatures above 20 °C and light or non-existent winds. In each field, bees were surveyed in a single 5 m long transect between two crop rows. During a period of 10 minutes (net observation time), all bees visiting leek umbels were noted. Easily recognizable species were generally identified in the field; all other species were collected and identified in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**21<sup>9</sup> Alfalfa (*Medicago sativa*); Hungary; 1954; n.a.; n.a.; 8; 2321; n.a.**

**22<sup>9</sup> Alfalfa (*Medicago sativa*); Hungary; 1955; n.a.; n.a.; 9; 2441; n.a.**



**23<sup>9</sup> Alfalfa (*Medicago sativa*); Hungary; 1956; n.a.; n.a.; 11; 3464; n.a.**

**Methods:** Data were extracted from reference (63). Bees were surveyed on presumably 8 alfalfa fields in 8 different areas between 21 June and 22 August, 1954. Surveys were repeated from 11 July and 9 September, 1955 in the same 8 areas along with one additional area, presumably on 9 alfalfa fields. Finally, a total of 11 fields in the same 9 areas were surveyed between 5 July and 21 August, 1956. The study areas were scattered across Hungary and in each area and year bees were surveyed during approximately 10 days. Total number of survey days per year were 67 in 1954 and 80 in 1955. In 1956, bees were surveyed for a total of 127 hours. Wild bees were collected with nets from alfalfa flowers. Individual surveys lasted 30 minutes and were conducted both in the morning and in the afternoon.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**24<sup>10</sup> Alfalfa (*Medicago sativa*); Hungary; 2004; n.a.; n.a.; >10; 1910; n.a.**

**25<sup>10</sup> Alfalfa (*Medicago sativa*); Hungary; 2005; n.a.; n.a.; >10; 950; n.a.**

**26<sup>10</sup> Alfalfa (*Medicago sativa*); Hungary; 2006; n.a.; n.a.; >10; 1158; n.a.**

**27<sup>10</sup> Alfalfa (*Medicago sativa*); Hungary; 2007; n.a.; n.a.; >10; 1717; n.a.**

**Methods:** Data were extracted from reference (64). In the years 2004 through 2007, bees on alfalfa fields were surveyed throughout Hungary. Each year 120-160 surveys were made near 80 settlements in 5-19 different counties. This study represents a replication of the surveys conducted in studies 21-23.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**28<sup>11</sup> Sunflower (*Helianthus annuus*); France, Poitou-Charentes; 2010; 2.36; 563.9; 30; 85; 0.07**

**29<sup>11</sup> Alfalfa (*Medicago sativa*); France, Poitou-Charentes; 2010; n.a.; n.a.; 18; 136; 0.31**

**30<sup>11</sup> Oilseed rape (*Brassica napus*); France, Poitou-Charentes; 2011; 3.45; 569.7; 58; 139; 0.19**

**31<sup>11</sup> Sunflower (*Helianthus annuus*); France, Poitou-Charentes; 2011; 2.54; 596.1; 65; 108; 0.02**

**32<sup>11</sup> Alfalfa (*Medicago sativa*); France, Poitou-Charentes; 2011; n.a.; n.a.; 41; 322; 0.11**

**Methods:** In 2010 and 2011, bees were surveyed on three different crops in a 500 km<sup>2</sup> intensively farmed area in Western France (LTER “Zone Atelier Plaine & Val de Sèvre”). A total of 217 sites were surveyed, located in 30 grid cells (10 per year) randomly drawn without replacement from a 3×3 km grid covering the whole study area. Sampling took place during the flowering periods of oilseed rape (April 1 - 13 in 2011) and sunflower (July 16 - 23 in 2010 and June 28 - July 12 in 2011) and alfalfa (July 18 - September 20 in 2010 and June 5 - August 29 in 2011). Temperatures ranged between 16°C and 35°C and wind speeds were below 15 km/h. Each site was surveyed once by capturing bees along a 50 m long and 1 m wide transect, within the main flowering crops, oilseed rape and sunflower and flowering alfalfa. All species (other than honey bees) were identified in the lab by specialists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**33<sup>12</sup> Oil Seed Rape (*Brassica napus*); France, Brittany; 2007; 2.90; 432.3; 20; 83; 0.76**

**34<sup>12</sup> Oil Seed Rape (*Brassica napus*); France, Centre; 2007; 2.90; 432.3; 10; 107; 0.83**

**35<sup>12</sup> Oil Seed Rape (*Brassica napus*); France, Brittany; 2008; 3.32; 495.4; 20; 318; 0.48**

**36<sup>12</sup> Oil Seed Rape (*Brassica napus*); France, Centre; 2008; 3.32; 495.4; 32; 116; 0.85**

**Methods:** In 2007 and 2008, bees were collected with sweepnets on oilseed rape flowers in two regions of France. Bees were always captured in the first meter of the fields, except in 2008 in Pleine-Fougères where bees were also captured in the middle of the fields. Each field was surveyed three times during the oilseed rape flowering period, with between 3 and 5 days separating surveys. Surveying was conducted under sunny conditions or with scattered clouds. Temperatures ranged between 15 °C and 20 °C with at most a moderate breeze. Depending on the field, a survey round comprised 3 to 12 points. On each point, 3 strikes of a sweepnet were used to catch bees on oilseed rape flowers. All bees were collected and identified in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

- 37<sup>13</sup> Sunflower (*Helianthus annuus*); Israel; 2009; 5.24; 1399.5; 10; 99; 0.05  
 38<sup>13</sup> Sunflower (*Helianthus annuus*); Israel; 2010; 5.32; 1603.5; 17; 222; 0.09  
 39<sup>14</sup> Watermelon (*Citrullus lanatus*); Israel; 2009; 11.12; 430.3; 15; 121; 0.12  
 40<sup>14</sup> Watermelon (*Citrullus lanatus*); Israel; 2010; 11.93; 385.6; 13; 301; 0.18

**Methods:** Bees were surveyed on sunflower and watermelon fields in the Judean Foothills in central Israel during crop bloom in May-June, 2009 and 2010. In 2009, 10 sunflower and 17 watermelon fields were surveyed and in 2010, 15 sunflower and 13 watermelon fields were surveyed. Study plots (25 × 25 m) were located at field edges; in some fields (sunflower-9, watermelon-12) an additional interior plot was located 100 m from the edge. Sampling sites were separated by at least 1 km from one another. Field work was conducted under standardized weather conditions (sunny to light overcast skies, temperatures >18 °C and mean wind velocity <5 m.s<sup>-1</sup>). Each plot was sampled between one and three times (mostly twice), each time on a separate day. In each sampling day, two sampling sessions (2-3 hours apart) were carried out. Each session included 10 min (or 15 min in sunflower in 2010) of bee netting (the stopwatches were stopped when handling bees that were caught). Bee sampling was conducted between 8:00 and 16:00 in the sunflower study, and between 7:00 and 11:00 in the watermelon study.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

- 41<sup>B.Vaissière</sup> Sunflower (*Helianthus annuus*); France, Rhone-Alpes; 2009; 2.37; 365.4; 5; 169; n.a.

**Methods:** Non-*Apis* bees were collected in five fields of sunflower for hybrid seed production on both male-fertile (MF) and male-sterile (MS) parental lines (each field had a different pair of parental lines). All fields were located within 20 km east of the town of Montélimar at an altitude ranging from 169 to 270 m. In each field, we established a study site 100 m long over 8 adjacent patterns of MF and MS rows and centered halfway between the center and the edge of the field. Bees were collected with a net over a 30 min interval (not counting handling time), split into 15 min over 100 m of row of MF plants and 15 min over 100 m of rows of MS plants. Bees were surveyed 4 to 8 times over the flowering period, with collections taking place in the morning and in the afternoon on alternate days. All collections took place between 13 and 30 July, 2009 under good weather conditions (vegetation dry, temperature at least 15°C and low to non-existent wind) and between 09:30 and 17:15 local time.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

- 42<sup>M.Park</sup> Apple (*Malus domestica*); USA, New York; 2009; 31.28; 509; 12; 1733; 0.76  
 43<sup>M.Park</sup> Apple (*Malus domestica*); USA, New York; 2010; 30.46; 556; 9; 724; 0.62  
 44<sup>M.Park</sup> Apple (*Malus domestica*); USA, New York; 2011; 31.95; 644; 22; 2220; 0.65

**Methods:** In late April and May from 2009 to 2011, bees visiting apple blossoms were surveyed. Twelve orchards were surveyed in 2009, nine in 2010 and in twenty-two in 2011. Each orchard was surveyed once or twice during the apple bloom, on days with temperature > 15°C between 10:00 and 15:30. We required that there be enough sun to cast a shadow. At each site, multiple transects of 15-minute aerial netting surveys were conducted along blooming tree rows. During each survey, collectors walked a steady pace along 50 m of each side of two-adjacent tree rows and netted all bees observed to be visiting apple blossoms. Transects were spaced, at least, 50 m apart and were placed where trees were in highest bloom, within 150 m from the orchard edge. Distance between orchards was at least 1.9km. The number of timed net collections per site varied according to farm size.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

- 45<sup>R.Winfree</sup> Apple (*Malus domestica*); USA, New Jersey; 2004; 30.36; 300; 16; 151; n.a.

**Methods:** In April 2004, bees were surveyed in 16 sites in 6-8 commercial apple orchards. 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.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**46<sup>15</sup> Tomato (*Solanum lycopersicum*); USA, New Jersey/Pennsylvania; 2004; 80.57; 825; 15; 119; 0.99**

**47<sup>15</sup> Tomato (*Solanum lycopersicum*); USA, New Jersey/Pennsylvania; 2005; 72.55; 917; 13; 86; 1.00**

**Methods:** In June and July, bees were surveyed in tomato fields on 15 study farms in 2004 and 13 study farms in 2005. Surveys used one 50 meter transect per farm within which all data were collected. All non-Apis bees visiting crop flowers were collected by hand net along the entire length of the transect. Total minutes of sampling effort varied across years but was always standardized across all farms within a given year. One sample day per farm was conducted per year. Honey bees were observed visiting flowers in timed samples, but not netted, so data used for honey bees include only observed visitors. Data collection was only conducted on days suitable for bee activity (sunny, partly cloudy or bright overcast; wind speeds  $<2.5 \text{ m.s}^{-1}$ ;  $>18 \text{ }^\circ\text{C}$ ). Bees were identified by professional taxomists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**48<sup>16</sup> Cranberry (*Vaccinium macrocarpon*); USA, New Jersey; 2009; 20.13; 937; 16; 1226; 0.2**

**49<sup>16</sup> Cranberry (*Vaccinium macrocarpon*); USA, New Jersey; 2010; 19.82; 948; 16; 1753; n.a.**

**Methods:** Bees were surveyed in 16 commercial cranberry bogs. Within each bog, two 60 m transects were located; one in the interior of the cranberry bog, one parallel to the edge next to forest. Two sample days per farm were conducted per year, and within each day data sampling was conducted once in the morning and once in the afternoon. All wild bees visiting cranberry flowers within the transect were collected for a total of 60 minutes per collection day. Data were collected from June to July, in each of 2009 and 2010. Honey bees were observed visiting flowers in timed samples, but not collected, so data used for honey bees include only observed visitors. Sampling was only conducted during weather suitable for bee activity ( $>15 \text{ }^\circ\text{C}$ , wind  $<3.5 \text{ meters.s}^{-1}$ , not dark overcast). Bees were identified by professional taxomists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**50<sup>15</sup> Musk melon (*Cucumis melo*); USA, New Jersey/Pennsylvania; 2004; 27.90; 324; 13; 116; 0.29**

**Methods:** In July, 2004, bees were surveyed for one day each in musk melon fields on 14 study farms. One 50 meter transect was used per farm within which all data were collected. All non-Apis bees visiting crop flowers were collected by hand net along the entire length of the transect for 20 minutes. Sampling was only conducted on days suitable for bee activity (sunny, partly cloudy or bright overcast; wind speeds  $<2.5 \text{ m/s}$ ;  $>18 \text{ }^\circ\text{C}$ ). Honey bees were observed visiting flowers in timed samples, but not collected, so honey bee data includes only observed visitors. Bees were identified by professional taxomists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**51<sup>17</sup> Highbush Blueberry (*Vaccinium corymbosum*); USA, New Jersey; 2010; 6.71; 3175; 16; 233; 0.09**

**52<sup>17</sup> Highbush Blueberry (*Vaccinium corymbosum*); USA, New Jersey; 2011; 6.85; 4057; 16; 396; 0.10**

**Methods:** Bees were surveyed in 16 sites in commercial blueberry fields using one 200 m transect per site. On each site-day, a transect was sampled three times, with 3 site-days per year organized into 3 collection rounds temporally stratified to span the period of bloom. Sampling was conducted using identical methods in April-May in each of 2 years (2010 and 2011). Each data collection event included 20 minutes of observation and 20 minutes of netting, for a total of 1 hour each of observation and netting per site-day. Honey bees were recorded during timed observation samples, but not netted, so data for honey bees includes only observations. Data were only collected during weather suitable for bee activity, the exact conditions for which shifted over the course of the season, as blueberry is an early spring crop in our region. Bees were identified by professional taxomists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**53<sup>18</sup> Watermelon (*Citrullus lanatus*); USA, New Jersey/Pennsylvania; 2004; 29.18; 187; 11; 112; 0.51**

**54<sup>18</sup> Watermelon (*Citrullus lanatus*); USA, New Jersey/Pennsylvania; 2005; 31.17; 256; 23; 1217; 0.62**

**55<sup>18</sup> Watermelon (*Citrullus lanatus*); USA, New Jersey/Pennsylvania; 2007; 32.45; 249; 16; 232; 0.54**

**56<sup>18</sup> Watermelon (*Citrullus lanatus*); USA, New Jersey/Pennsylvania; 2008; 35.71; 276; 18; 792; 0.63**  
**57<sup>18</sup> Watermelon (*Citrullus lanatus*); USA, New Jersey/Pennsylvania; 2010; 34.83; 265; 18; 2048; 0.70**

**Methods:** Bees were surveyed in watermelon fields in the years 2004-2005 and 2007-2009. One 50 meter transect per farm was used within which all data were collected. All non-*Apis* bees visiting crop flowers were collected by net along the entire length of the transect. Total minutes of sampling effort varied across years (2004, 2005, 2007, 2008, 2010) but was always standardized across all farms within a given year. Each day the transect was sampled at three temporally stratified samples between 8:00 and 13:00. One sample day per farm per year was conducted in 2007 and 2008, 2 sample days per farm per year were conducted in 2005 and 3 sample days per farm were conducted in 2010. In years with multiple sampling days per year, sampling was organized into rounds, with the rounds temporally stratified throughout the period of bloom. Data were collected between June and August in each year. Data collection was only conducted on days suitable for bee activity (sunny, partly cloudy or bright overcast; wind speeds <2.5 m/s; >18 C), with a few exceptions. Honey bees were observed visiting flowers in timed samples, but not netted, so data used for honey bees include only observed visitors. Bees were identified by professional taxonomists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**58<sup>19</sup> Cranberry (*Vaccinium macrocarpon*); USA, Massachusetts; 1990; 13.68; n.a.; 8; 350; 0.62**  
**59<sup>19</sup> Cranberry (*Vaccinium macrocarpon*); USA, Massachusetts; 1991; 16.72; 1080; 9; 390; 0.57**

**Methods:** Data were extracted from reference (70). Bees were surveyed from mid-June to mid-July on cranberry bogs. Eight bogs were surveyed in 1990 and nine in 1991, three of which were the same as in 1990. In each bog, as many bees as possible were captured with either an insect net or jar as the individual collecting moved through the bog over 15 min in 1990 and 10 min in 1991. Collections were carried out three times during cranberry bloom. All bees, including honey bees, foraging on cranberry bloom were collected. The bees were collected and pinned and identified to species in the laboratory.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**60<sup>20</sup> Squash (*Cucurbita pepo*); USA, Virginia; 2008; 22.67; 284; 15; 330; 0.99**  
**61<sup>20</sup> Apple (*Malus domestica*); USA, Virginia; 2009; 31.28; 509; 6; 129; 0.94**  
**62<sup>20</sup> Highbush Blueberry (*Vaccinium corymbosum*); USA, Virginia; 2009; 64.65; 2932; 6; 185; 1.00**  
**63<sup>20</sup> Squash (*Cucurbita pepo*); USA, Virginia; 2009; 21.05; 243; 12; 179; 0.91**  
**64<sup>20</sup> Apple (*Malus domestica*); USA, Virginia; 2010; 30.46; 556; 5; 177; 0.73**

**Methods:** Between 2008 and 2010, bees were surveyed on apple, blueberry, and squash flowers on farms in southwest Virginia. Bees were netted at flowers for 15 minutes when temperatures exceeded 21°C, cloud cover was less than 35%, and wind was less than 3 Beaufort. Exceptions included overcast days when temperatures were relatively warm and honey bees were clearly active, due to the small sampling window for apples and blueberries. Data were used from 15 and 12 squash fields surveyed in 2008 and 2009, respectively, 6 blueberry fields surveyed in 2009 and 6 and 5 apple orchards surveyed in 2009 and 2010, respectively.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**65<sup>H.S.Sardiñas</sup> Sunflower (*Helianthus annuus*); USA, California; 2011; 1.57; 648; 11; 203; 0.08**

**Methods:** Eleven hybrid sunflower fields were surveyed in Yolo County, California between June and August, 2011. Bees were collected on male-fertile and male-sterile flowers between 8:00 and 14:00 on sunny days with temperatures exceeding 18°C and wind speeds below 3 m.s<sup>-1</sup>. In each field, bees were netted 10, 50, 100 and 200 m from the field edge for 16 minutes at each distance, stopping the clock during specimen handling. Honey bees were counted in visual surveys. Species were identified to the lowest taxonomic level possible.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**66<sup>A.M.Klein</sup> Almond (*Prunus dulcis*); USA, California; 2009; 39.89; 3638; 15; 130; 0.22**

**Methods:** In February and March, 2009, bees were surveyed in 15 almond orchards in California. Six experienced entomologists conducted the flower observations under sunny to lightly overcast conditions, when temperatures exceeded 13°C and when wind speeds were below 2.5 m·s<sup>-1</sup>. In each orchard we observed flower visitors on five trees at the orchard edge closest to semi-natural habitat. At each tree, eight groups of flowers were observed for three times 20 seconds each, two each in the inner top, inner bottom, outer top and outer bottom quadrants of the tree (total of around 13 min per orchard). Species were identified mainly by close observations of the flower bundles or caught for identification in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**67<sup>21</sup>, L.Button H. blueberry (*V. corymbosum*); Canada, British Columbia; 2011; 2.73; 1825.6; 26; 657; 0.25**  
**68<sup>21</sup>, L.Button H. blueberry (*V. corymbosum*); Canada, British Columbia; 2012; 3.28; n.a.; 37; 492; 0.17**

**Methods:** In 2011 and 2012, bees were observed on four highbush blueberry varieties. Fields were sampled 2-5 times in each year at varying times of day (morning, mid day, and afternoon) during peak blueberry bloom. Observations for Duke and Bluecrop varieties were conducted along three transects per field, with ten 1 minute observation periods per transect. Draper and Liberty sites only contained two transects. Observations were conducted on either sunny days with temperatures >14°C, or cloudy days with temperatures > 17°C.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**69<sup>22</sup> Tomato (*Solanum lycopersicum*); USA, California; 2001; 66.75; 661; 11; 708; 0.99**

**Methods:** In July and August, 2001, bees were surveyed in 11 tomato fields in northern California. In each tomato field, bees were surveyed by walking transects at the rate of 10 m/min, covering each row twice, once in each direction, and recording all bee visits to tomato flowers. In small fields, transects were walked along all rows. In larger fields, surveys were carried out at up to four transects, each 80m long. Each field was sampled between 8:30 and 12:30 on three different days, in the early, mid, and late morning, respectively.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**70<sup>A.R.Scilligo</sup> Strawberry (*Fragaria x ananassa*); USA, California; 2011; 56.45; n.a.; 7; 179; 0.61**  
**71<sup>A.R.Scilligo</sup> Strawberry (*Fragaria x ananassa*); USA, California; 2012; 58.96; n.a.; 17; 458; 0.44**

**Methods:** In 2011 and 2012, bees were surveyed in organic strawberry crops in northern California. In 2011, surveys were conducted once each at 7 sites. In 2012, surveys were conducted twice, once in spring and once in summer at each of 17 sites (though one site was dropped from summer sampling because strawberries were pulled up). Bees were collected via netting in good weather conditions (at least partially sunny with low wind between 0.4 and 3.5 m·s<sup>-1</sup>, and temperatures above 14°C). At each site, six 10-minute sample periods took place in the same good weather conditions. Clocks were stopped when handling specimens. All bees collected were identified by a professional taxonomist to the lowest taxonomic level possible. For a number of *Lasioglossum* species, only females could be identified to species level. We therefore allocated all unidentified *Lasioglossum* males in proportion to the numbers that were identified as female *Lasioglossum* specimens. Honeybees were not collected and observed counts were recorded.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*  
**72<sup>N.Williams</sup> Watermelon (*Citrullus lanatus*); USA, California; 2010; 34.83; 265; 21; 551; n.a.**  
**73<sup>N.Williams</sup> Watermelon (*Citrullus lanatus*); USA, California; 2011; 34.36; 306; 25; 477; n.a.**

**Methods:** In 2010 and 2011 bees were netted during standardized time periods on production watermelon fields in central California. Some farms were sampled in both years but never the same field. Within a year each site was visited three times during peak bloom at 4-5 day intervals. Sites were visited between 8 June and 3 August, 2010 and between 22 June and 16 August, 2011 during sunny conditions with temperatures between 22 °C and 33 °C and with wind speeds below 3 m·s<sup>-1</sup>. On each sampling date, bees were netted during four 10-minute periods during the day along the same 50 m transect (40 min total). All specimens were collected and identified to species in the lab. For a

number of *Lasioglossum* species, only females could be identified to species level. We therefore allocated all unidentified *Lasioglossum* males in proportion to the numbers that were identified as female *Lasioglossum* specimens.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**74<sup>23</sup> Coffee (*Coffea arabica*); Indonesia, Sulawesi; 2001; 0.43; 762.8; 24; 1769; 0.87**

**75<sup>24</sup> Coffee (*Coffea canephora*); Indonesia, Sulawesi; 2001; 0.43; 762.8; 15; 2113; 0.93**

**Methods:** In 2000 to January, 2001 bees visitating highland coffee flowers were surveyed in 24 agroforestry systems and bees visiting lowland coffee flowers were surveyed in 15 agroforestry systems. Agroforestry systems were dominated by coffee and cacao and located in the buffer zone of the Lore-Lindu National Park in Central Sulawesi. Bee flower visitation was observed for 25 minutes on a full-blooming coffee plant per agroforestry system and this was repeated three times for a total of 75 minutes of observation time for each of the 24 agroforestry systems. Each day, a different full-blooming coffee plant than that used the day before was observed. Sampling was carried out between 9:00 and 14:00 on sunny to slightly overcast days. Easily recognizable species were identified in the field while others were collected and identified with the help of trained locals in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**76<sup>25</sup> Onion (*Allium cepa*); New Zealand, South Island; 2004; n.a.; n.a.; 11; 1085; 0.14**

**77<sup>25</sup> Onion (*Allium cepa*); New Zealand, South Island; 2005; n.a.; n.a.; 11; 897; 0.10**

**78<sup>B.Howlett</sup> Onion (*Allium cepa*); New Zealand, South Island; 2006; n.a.; n.a.; 9; 216; 0.07**

**79<sup>B.Howlett</sup> Onion (*Allium cepa*); New Zealand, South Island; 2007; n.a.; n.a.; 8; 161; 0.07**

**80<sup>B.Howlett</sup> Onion (*Allium cepa*); New Zealand, South Island; 2008; n.a.; n.a.; 4; 163; 0.12**

**Methods:** From 2004 to 2008 bees were surveyed on 4-11 onion fields. Each field contained 5 sample points (4 at each corner and one in the centre). At each observation point, bee counts were conducted on 75 male sterile and 75 male fertile flowering umbels, each containing more than 30 open flowers. Bee counts were carried out by slowly walking along each row of flowering umbels and recording individuals on a spreadsheet at the lowest taxonomic level possible. Each observation point was surveyed three times during the day (10-11 am, 12-1 pm and 2-3 pm). Hand collection of bees using vials, containers and nets were also utilised to help identify bees to species level.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**81<sup>B.Howlett</sup> Carrot (*Daucus carota*); New Zealand, South Island; 2010; n.a.; n.a.; 4; 149; 0.23**

**Methods:** In 2010 bees were surveyed on 4 carrot fields. In each carrot field three observation points (two corner and one centre point) were marked. At each observation point, observations were conducted on 150 carrot inflorescences within a 5 metre radius. Three observations were carried out during the day at each point. These were at 10-11 am, 12-1 pm and 2-3 pm. Only umbels with more than 30% of flowers open were observed. Umbels were examined along rows within the confines of the marked observation points. Approximately 15 minutes were required to complete the observations at each point and 60 minutes to complete observations across an entire field. When the identity of the bee species was unknown, specimens were collected using vials, containers and nets for identification in the laboratory.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**82<sup>26</sup> Sunflower (*Helianthus annuus*); South Africa, Limpopo; 2009; 1.26; 341.8; 33; 802†; n.a.**

**Methods:** In March and April, 2009 bees were surveyed in commercial sunflower farms by capturing all visitors of flowerheads. Surveys were conducted in 33 plots (4 x 4 m, sunflower density of 10 plants m<sup>2</sup>) within sunflower fields and plots were at least 350 m away from each other. Each plot was surveyed on two different days (once in the morning and once in the afternoon) during the week of peak flowering. In each survey, three locations (one for each of three observers) were randomly selected within the plot and all the sunflower heads that could be reached were observed for 4 minutes, during which all insects that touched the reproductive parts of the flowers were recorded. In

total, each plot was observed for 24 minutes. All bees collected were identified to the lowest possible taxonomic level by an expert entomologist.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**83<sup>J.F.Colville</sup> Sunflower (*Helianthus annuus*); South Africa, Limpopo; 2010; 1.23; 404.0; 10; 3652†; n.a.**

**Methods:** During 16-23 March, 2011 insect pollinators were surveyed on ten commercial sunflower farms. Five field study sites were selected adjacent to natural vegetation (<200 m) and five were selected at a distance >2000 m from natural vegetation. On each field study site, 100 flower heads in each of four parallel transects spaced 20 m apart (total 400 flower heads) were surveyed in the morning (09:00 – 12:00) and afternoon (14:00 – 16:00). Surveys were conducted by walking along a transect between rows of plants and recording the number of insect pollinators seen on individual flower heads, one by one. Voucher specimens for all insect flower visitors that touched the reproductive structures of surveyed sunflower heads were collected. From this, all bee specimens were identified to the lowest possible taxonomic level.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**84<sup>R.Veldtman</sup> Apple (*Malus domestica*); South Africa, Western Cape; 2011; 34.32; 515.2; 10; 3133†; n.a.**

**Methods:** From 7-13 October, 2011 bees were surveyed on Royal Gala Apples in the Grabouw and Viliersdorp areas of the Western Cape. Five fields were within 200 m of natural vegetation while five others were at least 2 km away from natural vegetation. All sites stocked managed honeybees at an average of two hives per hectare. Each crop was surveyed in the morning and afternoon for one good weather day. On each survey, one side of eight trees along a transect (trees spaced 5 m apart) were scanned for five minutes each and bee species were recorded and voucher specimens collected (800 minutes of total observation time; average of 758.5 +/- 265.1 [1SD] open flowers per apple tree). All pollinators visiting flowers were identified to the lowest possible taxonomic level by an expert entomologist.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**85<sup>M.Brand</sup> Onion (*Allium cepa*); South Africa; 2009; n.a.; n.a.; 4; 1815†; n.a.**

**86<sup>M.Brand</sup> Onion (*Allium cepa*); South Africa; 2010; n.a.; n.a.; 8; 659†; n.a.**

**Methods:** In 2009 and 2010 bees were surveyed on hybrid onion seed crops in South Africa. Different crop fields were used each year. Each crop was surveyed for one good weather day during the blooming season from 23 October to 11 November, 2009 and from 18 October to 30 November, 2010). Field workers made observations during four data collection periods spread over 2 hour intervals between 9:00 and 16:00 on each observation day. Observations were replicated five times on both male-fertile and male-sterile rows during each collection period. Four neighbouring umbels in at least 50% bloom were selected and observed for 4 minutes. Bees visiting the umbels were collected and identified in the lab.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**87<sup>27</sup> Coffee (*Coffea arabica*); Costa Rica, Perez Zeledon; 2001; 1.33; 521.5; 12; 279; 0.49**

**88<sup>27</sup> Coffee (*Coffea arabica*); Costa Rica, Perez Zeledon; 2002; 1.24; 605.1; 16; 339; 0.72**

**Methods:** In 2001 and 2002, bees were surveyed on highland coffee bushes (*Coffea arabica*, var. Caturra). In 2001, 12 sites were surveyed, and in 2002 16 sites were surveyed (8 of which had been surveyed in 2001). At each site, on each day in which coffee was in flower, 2 simultaneous samples of flower visitors were taken. Each sample involved recording each visitor and the number of flowers visited for 10 minutes on an area of one bush comprising approximately 250 flowers.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**89<sup>B.F.Viana</sup> Passion fruit (*Passiflora edulis*); Brazil, Bahia; 2005; n.a.; n.a.; 16; 1049; 0.75**

**Methods:** In 2005, bees were surveyed in 16 sites with passion fruit crops in São Francisco Valley region. In each field, bees were surveyed in a 50 m long transect, laid within the crop field, with a mean of 90 flowers observed for 15 minutes during three times on three different days. Each

crop was surveyed by experienced biologists. All flower visiting wild bees were collected for identification by specialists.

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*Study no<sup>reference</sup> Crop; Location; year; yield (tonnes.ha<sup>-1</sup>); price (\$.tonne<sup>-1</sup>); no. sites; no. wild bees; ratio wild/honey bee*

**90<sup>28</sup> Coffee (*Coffea arabica/robusta*); Mexico, Chiapas; 2006; 0.37; 244.9; 13; 140; 0.32**

**Methods:** In April 2006, bees were surveyed on coffee flowers at 13 different sites in coffee plantations in Nueva Alemania in the southern highlands of Chiapas. In the study region, *Coffea arabica* and *Coffea robusta* are planted (approximately 4000 coffee bushes per hectare) under a canopy of overstorey trees. Surveys were conducted in 15 minute periods between 8:00 and 14:00. At each site, four fully flowering branches (minimum of 20 blossoms) were randomly chosen from a randomly selected coffee bush. During observation periods, the identity of the visitor was noted and, when possible, bees were captured after the observation period for identification.

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† Includes managed bees hired for pollination as well.



**Supplementary Table 2 | The top 100 bee species with the highest mean contribution to crop production value and their occurrence in different studies and crops.** Mean contribution to crop production is based on the 53 studies for which contribution to production value could be calculated (i.e. data on crop production value and the relative contribution between wild and managed bees were available). Occurrences also include crops and studies for which no contribution to crop production value could be calculated.

Rank	Species	Biogeographic region of study	Mean contributed value in region (\$·ha <sup>-1</sup> )	95% CI interval	Maximum contributed value in region (\$·ha <sup>-1</sup> )
1	<i>Bombus impatiens</i>	Eastern North-America	963.0	645-1279	2800
2	<i>Bombus terrestris/lucorum</i> †	Europe	425.0	122-892	4532
3	<i>Bombus lapidarius</i>	Europe	366.0	59-896	5707
4	<i>Anthophora urbana</i>	Western North-America	314.0	0-930	1240
5	<i>Andrena chrysoseles</i>	Europe	299.0	14-736	4256
6	<i>Andrena vicina</i>	Eastern North-America	296.0	116-511	1865
7	<i>Andrena flavipes</i>	Europe	289.0	60-548	2185
8	<i>Augochlora pura</i>	Eastern North-America	268.8	164-402	974
9	<i>Andrena haemorrhhoa</i>	Europe	268.0	43-583	2969
10	<i>Andrena crataegi</i>	Eastern North-America	254.0	47-542	1823
11	<i>Bombus vosnesenskii</i>	Western North-America	244.0	20-674	886
12	<i>Andrena carantonica</i>	Europe	218.0	17-541	3326
13	<i>Andrena carlini</i>	Eastern North-America	210.0	35-471	2264
14	<i>Lasioglossum versatum</i>	Eastern North-America	206.8	107-320	722
15	<i>Bombus bimaculatus</i>	Eastern North-America	180.0	68-313	1065
16	<i>Andrena cerasifolii</i>	Western North-America	177.0	0-556	741
17	<i>Peponapis pruinosa</i>	Eastern North-America	160.8	31-359	1547
18	<i>Ceratina calcarata/dupla/mikmaqi</i> †	Eastern North-America	155.9	71-250	666
19	<i>Lasioglossum imitatum</i>	Eastern North-America	138.2	40-270	1010
20	<i>Andrena barbara</i>	Eastern North-America	136.6	0-344	1435
21	<i>Osmia cornifrons</i>	Eastern North-America	133.5	18-264	906
22	<i>Andrena regularis</i>	Eastern North-America	132.0	0-286	1023
23	<i>Bombus griseocollis</i>	Eastern North-America	118.9	55-205	679
24	<i>Xylocopa virginica</i>	Eastern North-America	113.3	49-195	599
25	<i>Lasioglossum hitchensi</i> <sup>1</sup>	Eastern North-America	107.8	62-160	314
26	<i>Lasioglossum leucocomum/pilosum</i> †	Eastern North-America	95.7	40-161	469
27	<i>Bombus melanopygus</i>	Western North-America	89.1	0-216	252
28	<i>Lasioglossum (Evyli.) sp. E (Calif.)</i>	Western North-America	88.0	0-260	347
29	<i>Bombus flavifrons</i>	Western North-America	83.1	0-246	329
30	<i>Bombus pascuorum</i>	Europe	81.5	19-155	665
31	<i>Augochlorella aurata</i>	Eastern North-America	80.4	38-133	389
32	<i>Osmia lignaria</i>	Eastern North-America	75.8	2-188	1005
33	<i>Andrena nasonii</i>	Eastern North-America	75.4	8-187	949
34	<i>Panurginus gracilis</i>	Western North-America	73.5	0-225	300
35	<i>Halictus confusus</i>	Eastern North-America	72.7	27-140	606
36	<i>Andrena miserabilis</i>	Eastern North-America	71.2	17-140	500
37	<i>Colletes inaequalis</i>	Eastern North-America	67.8	20-137	537
38	<i>Bombus mixtus</i>	Western North-America	64.2	0-189	252
39	<i>Bombus perplexus</i>	Eastern North-America	57.3	23-104	395
40	<i>Bombus sandersoni</i>	Eastern North-America	49.9	4-109	466
41	<i>Bombus vagans</i>	Eastern North-America	46.3	2-130	756
42	<i>Osmia taurus</i>	Eastern North-America	45.3	0-113	599
43	<i>Andrena hippotes</i>	Eastern North-America	44.9	13-98	341
44	<i>Melissodes bimaculata</i>	Eastern North-America	41.1	16-69	172
45	<i>Andrena fulva</i>	Europe	40.8	8-85	396
46	<i>Andrena dorsata</i>	Europe	40.8	5-89	475
47	<i>Lasioglossum nymphaearum</i>	Eastern North-America	38.3	8-78	306
48	<i>Andrena rugosa</i>	Eastern North-America	34.6	9-67	223
49	<i>Andrena pruni</i>	Eastern North-America	34.6	3-74	302
50	<i>Andrena perplexa</i>	Eastern North-America	34.0	11-65	227

†Consisting of two or more indistinguishable species; <sup>1</sup>species originally identified as *L. mitchelli*

Supplementary Table 2 | Continued.

Rank	Species	Biogeographic region of study	Mean contributed value in region	95% CI interval	Maximum contributed value in region
51	<i>Andrena w-scripta</i>	Eastern North-America	33.5	0-90	550
52	<i>Lasioglossum weemsi</i>	Eastern North-America	33.2	12-62	194
53	<i>Lasioglossum tegulare</i>	Eastern North-America	31.5	11-59	239
54	<i>Halictus rubicundus</i>	Eastern North-America	30.8	9-66	320
55	<i>Andrena forbesii</i>	Eastern North-America	30.0	7-57	209
56	<i>Lasioglossum calceatum</i>	Europe	29.2	4-74	475
57	<i>Agapostemon virescens</i>	Eastern North-America	28.7	0-72	332
58	<i>Andrena bradleyi</i>	Eastern North-America	28.6	0-73	305
59	<i>Bombus terricola</i>	Eastern North-America	26.9	0-81	533
60	<i>Bombus affinis</i>	Eastern North-America	24.3	0-72	481
61	<i>Lasioglossum malachurum</i>	Europe	23.8	6-45	169
62	<i>Bombus hypnorum</i>	Europe	21.0	4-42	197
63	<i>Colletes validus</i>	Eastern North-America	20.4	0-57	323
64	<i>Melitta americana</i>	Eastern North-America	20.0	0-56	291
65	<i>Osmia bicornis</i>	Europe	19.8	1-45	259
66	<i>Bombus pratorum</i>	Europe	19.1	6-35	111
67	<i>Andrena imitatrix</i>	Eastern North-America	18.7	3-40	177
68	<i>Andrena dunningi</i>	Eastern North-America	18.2	3-36	151
69	<i>Lasioglossum paradmirandum</i>	Eastern North-America	18.0	7-30	94
70	<i>Osmia pumila</i>	Eastern North-America	17.8	2-39	151
71	<i>Augochloropsis metallica</i>	Eastern North-America	17.8	3-41	193
72	<i>Andrena illini</i>	Eastern North-America	17.6	0-39	151
73	<i>Triepeolus remigatus</i>	Eastern North-America	17.5	2-38	145
74	<i>Lasioglossum illinoense</i>	Eastern North-America	17.1	1-45	271
75	<i>Andrena nitida</i>	Europe	17.1	4-35	190
76	<i>Nomada luteoloides</i>	Eastern North-America	16.8	1-39	200
77	<i>Andrena fenningeri</i>	Eastern North-America	16.5	0-44	227
78	<i>Andrena minutula</i>	Europe	16.1	2-35	190
79	<i>Eucera lunata</i>	Western North-America	15.9	0-47	63
80	<i>Lasioglossum zephyrum</i>	Eastern North-America	15.6	3-31	123
81	<i>Andrena mariae</i>	Eastern North-America	15.2	0-45	302
82	<i>Halictus ligatus</i>	Eastern North-America	14.5	5-26	67
83	<i>Bombus hortorum</i>	Europe	13.7	3-28	137
84	<i>Lasioglossum callidum</i>	Eastern North-America	13.5	4-25	74
85	<i>Ceratina strenua</i>	Eastern North-America	13.4	3-27	84
86	<i>Nomada maculata</i>	Eastern North-America	13.4	0-34	200
87	<i>Andrena mandibularis</i>	Eastern North-America	13.3	0-31	141
88	<i>Lasioglossum politum</i>	Europe	13.0	3-27	98
89	<i>Andrena tridens</i>	Eastern North-America	12.9	0-31	183
90	<i>Lasioglossum (Evyli.) sp. F (Calif.)</i>	Western North-America	12.3	0-36	47
91	<i>Lasioglossum morio</i>	Europe	12.3	0-32	190
92	<i>Lasioglossum foxii</i>	Eastern North-America	11.9	2-25	76
93	<i>Colletes thoracicus</i>	Eastern North-America	11.7	1-26	133
94	<i>Andrena milwaukeensis</i>	Eastern North-America	11.6	0-25	94
95	<i>Osmia virga</i>	Eastern North-America	11.5	0-32	200
96	<i>Lasioglossum leucozonium</i>	Eastern North-America	11.2	1-25	111
97	<i>Andrena cressonii</i>	Eastern North-America	11.0	1-24	95
98	<i>Bombus fervidus</i>	Eastern North-America	11.0	3-21	67
99	<i>Andrena cineraria</i>	Europe	9.5	4-16	48
100	<i>Andrena commoda</i>	Eastern North-America	9.1	0-22	110

Supplementary Table 2 | Continued.

Rank	Species	Alfalfa	Almond	Apple	Carrot	Coffee	Cranberry	Field Bean	H. Blueberry	Leek	Musk melon	Oil Seed Rape	Onion	Passion fruit	Pear	Red Clover	Squash	Strawberry	Sunflower	Tomato	Watermelon	Total no. crops	Total no. studies
1	<i>Bombus impatiens</i>		6			4	3	1								2				2	5	7	23
2	<i>Bombus terrestris/lucorum</i> †	9	2	1			2	1	10	5				2	5		2	5				11	44
3	<i>Bombus lapidarius</i>	9	2				2	1	10					2	5			2	4			9	37
4	<i>Anthophora urbana</i>																		1	1	1	3	3
5	<i>Andrena chrysoseles</i>		2								5			2			2					4	11
6	<i>Andrena vicina</i>		6			4	3															3	13
7	<i>Andrena flavipes</i>	9	2					1	10					2					5			6	29
8	<i>Augochlora pura</i>		6			2	3	1									2			2	5	7	21
9	<i>Andrena haemorrhoa</i>		2				2				9			2				1				5	16
10	<i>Andrena crataegi</i>		4			1	1															3	6
11	<i>Bombus vosnesenskii</i>		1					2										2	1	1	2	6	9
12	<i>Andrena carantonica</i>		2				2				3			2			1					5	10
13	<i>Andrena carlini</i>		6			1	2															3	9
14	<i>Lasioglossum versatum</i>		4			2	2	1									2			2	5	7	18
15	<i>Bombus bimaculatus</i>		6			4	3	1									2				4	6	20
16	<i>Andrena cerasifolii</i>		1																			1	1
17	<i>Peponapis pruinosa</i>								1								2				6	3	9
18	<i>Ceratina calcarata/dupla/mikmaqi</i> †		7			3	2	1													5	5	18
19	<i>Lasioglossum imitatum</i>		2														2			2	5	4	11
20	<i>Andrena barbara</i>		3				1															2	4
21	<i>Osmia cornifrons</i>		6				1															2	7
22	<i>Andrena regularis</i>		3																			1	3
23	<i>Bombus griseocollis</i>		5			4	3										2			1	3	6	18
24	<i>Xylocopa virginica</i>		5			3	3	1													3	5	15
25	<i>Lasioglossum hitchensi</i> <sup>1</sup>		4				1										2			2	5	5	14
26	<i>Lasioglossum leucocomum/pilosum</i> †		1			2	3										2			1	4	6	13
27	<i>Bombus melanopygus</i>		1				2											1				3	4
28	<i>Lasioglossum (Evyli.) sp. E (Calif.)</i>		1															1				2	2
29	<i>Bombus flavifrons</i>						2															1	2
30	<i>Bombus pascuorum</i>	7	2				2	1	6					2	5			2	4			9	31
31	<i>Augochlorella aurata</i>		3			2	3	1									2			2	4	7	17
32	<i>Osmia lignaria</i>		5				1															2	6
33	<i>Andrena nasonii</i>		5																			1	5
34	<i>Panurginus gracilis</i>		1																			1	1
35	<i>Halictus confusus</i>		3			2		1									1			1	5	6	13
36	<i>Andrena miserabilis</i>		6																			1	6
37	<i>Colletes inaequalis</i>		5				3															2	8
38	<i>Bombus mixtus</i>						2															1	2
39	<i>Bombus perplexus</i>		5			4	3	1									1				1	6	15
40	<i>Bombus sandersoni</i>		4			1	1															3	6
41	<i>Bombus vagans</i>		1			4	1										1				1	5	8
42	<i>Osmia taurus</i>		3				1															2	4
43	<i>Andrena hippotes</i>		4																			1	4
44	<i>Melissodes bimaculata</i>								1								2				5	3	8
45	<i>Andrena fulva</i>		2								4			2				1				4	9
46	<i>Andrena dorsata</i>		2								5			2								3	9
47	<i>Lasioglossum nymphaeorum</i>		2														1			2	4	4	9
48	<i>Andrena rugosa</i>		5																			1	5
49	<i>Andrena pruni</i>		4				1															2	5
50	<i>Andrena perplexa</i>		6				1															2	7

†Consisting of two or more indistinguishable species; <sup>1</sup>species originally identified as *L. mitchelli*

Supplementary Table 2 | Continued.

Rank	Species	Alfalfa	Almond	Apple	Carrot	Coffee	Cranberry	Field Bean	H. Blueberry	Leek	Musk melon	Oil Seed Rape	Onion	Passion fruit	Pear	Red Clover	Squash	Strawberry	Sunflower	Tomato	Watermelon	Total no. crops	Total no. studies
51	<i>Andrena w-scripta</i>		3																			1	3
52	<i>Lasioglossum weemsi</i>		3					1												2	4	4	10
53	<i>Lasioglossum tegulare</i>																1			2	5	3	8
54	<i>Halictus rubicundus</i>	3	4			3	1			1	1							1			4	8	18
55	<i>Andrena forbesii</i>		6																			1	6
56	<i>Lasioglossum calceatum</i>	6	2								2			2			2	1				6	15
57	<i>Agapostemon virescens</i>																2				2	2	4
58	<i>Andrena bradleyi</i>							2														1	2
59	<i>Bombus terricola</i>		1			2																2	3
60	<i>Bombus affinis</i>					2																1	2
61	<i>Lasioglossum malachurum</i>	9	1						1		2			1					6	2		7	22
62	<i>Bombus hypnorum</i>		2				1				2			1	2		1	1				7	10
63	<i>Colletes validus</i>							2														1	2
64	<i>Melitta americana</i>					4																1	4
65	<i>Osmia bicornis</i>		2								5			1			1					4	9
66	<i>Bombus pratorum</i>		2				2				5			1	3		2					6	15
67	<i>Andrena imitatrix</i>		5			2	1															3	8
68	<i>Andrena dunningi</i>		6																			1	6
69	<i>Lasioglossum paradmirandum</i>		3																	1	5	3	9
70	<i>Osmia pumila</i>		5			2	2															3	9
71	<i>Augochloropsis metallica</i>					3	1										1			1	2	5	8
72	<i>Andrena illini</i>		2				1															2	3
73	<i>Triepeolus remigatus</i>									1							1				3	3	5
74	<i>Lasioglossum illinoense</i>																1				3	2	4
75	<i>Andrena nitida</i>		2				1				7			2			1					5	13
76	<i>Nomada luteoloides</i>		4				1															2	5
77	<i>Andrena fenningeri</i>		2				2															2	4
78	<i>Andrena minutula</i>		2				1	1		3				2			1					6	10
79	<i>Eucera lunata</i>		1																			1	1
80	<i>Lasioglossum zephyrum</i>		1				1										2			1	2	5	7
81	<i>Andrena mariae</i>		1																			1	1
82	<i>Halictus ligatus</i>		1				1		1										1	1	5	6	10
83	<i>Bombus hortorum</i>	7	2				2			3				1	5				2			7	22
84	<i>Lasioglossum callidum</i>							1									2			1	2	4	6
85	<i>Ceratina strenua</i>																				5	1	5
86	<i>Nomada maculata</i>		1				1															2	2
87	<i>Andrena mandibularis</i>		4				1															2	5
88	<i>Lasioglossum politum</i>																		4	2		2	6
89	<i>Andrena tridens</i>		2																			1	2
90	<i>Lasioglossum (Evy.) sp. F (Calif.)</i>		1																			1	1
91	<i>Lasioglossum morio</i>	3									2			2								3	7
92	<i>Lasioglossum foxii</i>		5				1															2	6
93	<i>Colletes thoracicus</i>		1				3															2	4
94	<i>Andrena milwaukeensis</i>		4																			1	4
95	<i>Osmia virga</i>					2	1															2	3
96	<i>Lasioglossum leucozonium</i>	6	3														2		1	1		5	13
97	<i>Andrena cressonii</i>		3			2	1															3	6
98	<i>Bombus fervidus</i>		1				1		1											2	1	5	6
99	<i>Andrena cineraria</i>		2				1			8								1				4	12
100	<i>Andrena commoda</i>		3																			1	3

**Supplementary Table 3 | The species that were identified as dominant bee crop pollinators in the 90 studies.** Listed are all species that make up at least five per cent of all individuals of wild bees on crop flowers in at least one study.

Species	Species	Species
<b>Brazil</b>	<i>Nomada lathburiana</i>	<i>Colletes inaequalis</i>
<i>Trigona spinipes</i>	<i>Osmia bicolor</i>	<i>Colletes validus</i>
<i>Xylocopa frontalis</i>	<i>Rhophitoides canus</i>	<i>Dialictus admirandus</i>
<i>Xylocopa griseescens</i>	<b>Indonesia</b>	<i>Habropoda laboriosa</i>
<b>Costa Rica</b>	<i>Apis dorsata binghami</i>	<i>Halictus confusus</i>
<i>Nannotrigona mellaria</i>	<i>Apis nigrocinta</i>	<i>Lasioglossum hitchensi</i> <sup>1</sup>
<i>Plebeia frontalis</i>	<i>Heriades</i> sp. 1	<i>Lasioglossum illinoense</i>
<i>Plebeia jatiformis</i>	<i>Megachile (Creightonella) atrata</i> <sup>5</sup>	<i>Lasioglossum imitatum</i>
<i>Tetragonisca angustula</i> <sup>3</sup>	<i>Nomia thoracica</i> <sup>6</sup>	<i>Lasioglossum leucocomum/pilosum</i> †
<i>Trigona</i> sp. 1	<i>Trigona (Heterotrigona)</i> sp. 2	<i>Lasioglossum nymphaearum</i>
<i>Trigona fulviventris</i>	<i>Trigona (Lepidotrigona) terminata</i>	<i>Lasioglossum versatum</i>
<b>Europe</b>	<b>Mexico</b>	<i>Lasioglossum weemsi</i>
<i>Andrena carantonica</i>	<i>Dialictus</i> sp. 2	<i>Melitta americana</i>
<i>Andrena chrysoceles</i>	<i>Halictus hesperus</i>	<i>Osmia cornifrons</i>
<i>Andrena cineraria</i>	<i>Nannotrigona perillampoides</i> <sup>4</sup>	<i>Osmia lignaria</i>
<i>Andrena decipiens</i>	<i>Plebeia</i> sp. 2	<i>Peponapis pruinosa</i>
<i>Andrena distinguenda</i>	<i>Scaptotrigona mexicana</i>	<i>Xylocopa virginica</i>
<i>Andrena dorsata</i>	<b>New Zealand</b>	<b>Western North America</b>
<i>Andrena flavipes</i>	<i>Bombus terrestris</i>	<i>Andrena cerasifolii</i>
<i>Andrena haemorrhoea</i>	<i>Lasioglossum sordidum</i>	<i>Anthophora urbana</i>
<i>Andrena helvola</i>	<i>Leioproctus fulvescens</i>	<i>Bombus flavifrons</i>
<i>Andrena labialis</i>	<i>Leioproctus huakiwi</i>	<i>Bombus melanopygus</i>
<i>Andrena lagopus</i>	<i>Leioproctus waipounamu</i>	<i>Bombus mixtus</i>
<i>Andrena nigroaenea</i>	<b>South Africa</b>	<i>Bombus vosnesenskii</i>
<i>Andrena nitida</i>	<i>Apis mellifera</i>	<i>Diadasia enavata</i>
<i>Andrena ovatula</i>	<b>Eastern North America</b>	<i>Halictus tripartitus</i>
<i>Andrena subopaca</i>	<i>Agapostemon virescens</i>	<i>Lasioglossum (Dialictus)</i> sp. AS-2
<i>Anthidium septemspiniosum</i>	<i>Andrena barbara</i>	<i>Lasioglossum (Dialictus)</i> sp. D
<i>Bombus hortorum</i>	<i>Andrena bradleyi</i>	<i>Lasioglossum (Evylaeus)</i> sp. E
<i>Bombus lapidarius</i>	<i>Andrena carlini</i>	<i>Lasioglossum imbrex</i> <sup>2</sup>
<i>Bombus pascuorum</i>	<i>Andrena crataegi</i>	<i>Lasioglossum incompletum</i>
<i>Bombus pratorum</i>	<i>Andrena miserabilis</i>	<i>Lasioglossum kincaidii</i>
<i>Bombus subterraneus</i>	<i>Andrena morrisonella</i>	<i>Melissodes agilis</i>
<i>Bombus terrestris/lucorum</i> †	<i>Andrena nasonii</i>	<i>Melissodes lupina</i>
<i>Ceratina cucurbitina</i>	<i>Andrena nuda</i>	<i>Panurginus gracilis</i>
<i>Ceratina mandibularis</i>	<i>Andrena perplexa</i>	<i>Svastra obliqua</i>
<i>Eucera clypeata</i>	<i>Andrena regularis</i>	
<i>Halictus resurgens</i>	<i>Andrena vicina</i>	
<i>Halictus rubicundus</i>	<i>Andrena w-scripta</i>	
<i>Halictus scabiosae</i>	<i>Augochlora pura</i>	
<i>Halictus simplex</i>	<i>Augochlorella aurata</i>	
<i>Halictus tetrazonianellus</i>	<i>Augochloropsis metallica</i>	
<i>Hylaeus punctulatus</i>	<i>Bombus affinis</i>	
<i>Hylaeus taeniolatus</i>	<i>Bombus bimaculatus</i>	
<i>Lasioglossum malachurum</i>	<i>Bombus griseocollis</i>	
<i>Lasioglossum pauxillum</i>	<i>Bombus impatiens</i>	
<i>Lasioglossum politum</i>	<i>Bombus perplexus</i>	
<i>Lasioglossum subhirtum</i>	<i>Bombus terricola</i>	
<i>Lasioglossum xanthopus</i>	<i>Bombus vagans vagans</i>	
<i>Melitta leporina</i>	<i>Ceratina calcarata/dupla/mikmaq</i> †	

† Consisting of two or more indistinguishable species; ‡ Including West Coast observations; <sup>1</sup>Species originally identified as *L. mitchelli*; <sup>2</sup>Species originally identified as *L. tegulariforme*; <sup>3</sup>Originally identified as *Trigona (tetragonisca) angustula*; <sup>4</sup>Originally identified as *Nannotrigona testaceicornis*; <sup>5</sup>Originally identified as *Creightonella frontalis atrata*; <sup>6</sup>Originally identified as *Nomia (Thoraconomia) thoracica*.

**Supplementary Table 4 | The relationship between flower visitation frequency and crop pollination.** For each crop and year we show the number of pollinator species groups analysed (n; number of species are in parentheses), the Pearson correlation (r) between visitation frequency and total pollination, the correlation between mean per visit pollen deposition and total pollination, the correlation between visitation frequency and mean per visit pollen deposition, and the ratio of the standard deviations of the logarithm of the visitation frequency and logarithm of the per visit pollen deposition (the parameter R of reference 28).

Crop, year	n	r visitation- total pollination	r mean per visit deposition - total pollination	r visitation-mean per visit deposition	SD (log visitation) / SD (log per visit deposition)
H. Blueberry, 2010	8 (23)	0.89	0.07	-0.21	1.34
H. Blueberry, 2011	8 (30)	0.86	-0.06	-0.33	1.59
Cranberry, 2009	11 (48)	0.79	0.51	0.02	1.91
Cranberry, 2010	10 (40)	0.93	0.41	0.11	1.73
Tomato, 2004	9 (19)	0.97	-0.56	-0.72	6.31
Tomato, 2005	4 (17)	0.90	0.47	0.03	5.70
Watermelon, 2004	9 (24)	0.91	-0.26	-0.46	1.38
Watermelon, 2005	11 (55)	0.81	-0.03	-0.26	2.34
Watermelon, 2007	6 (17)	0.94	0.28	0.02	1.63
Watermelon, 2008	10 (39)	0.72	0.38	-0.10	2.55
Watermelon, 2010	11 (45)	0.85	-0.02	-0.25	2.06

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