A global-scale expert assessment of drivers and risks associated with pollinator decline

Article

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Pollinator declines have attracted public and policy attention globally in recent years[1,2], and substantial efforts are underway to respond through national pollinator strategies and action plans[3]. Using a formal process for expert elicitation, we evaluated the relative importance of eight pressures driving pollinator declines, and the relative risks to human well-being from ten direct impacts of pollinator decline, at global scale. Our assessment indicates that policy responses should focus on mitigating impacts of changes in land cover and configuration, land management and pesticide use, to reverse or prevent ongoing pollinator decline, as these are considered very important drivers of pollinator decline in almost all regions, and globally. Climate change is consistently considered an important driver of pollinator decline across the world, but evidence for this is incomplete. The greatest risks to human well-being are the indirect risk from loss of wild pollinator diversity, and the direct risk to food production from crop pollination deficits. We found perceived risk to be higher in the Global South, with South America the region where pollinators face the greatest range of threats and where people are at greatest risk from pollinator decline.

Main text

Background

Animal pollination is key to the reproductive success of >75% of flowering plants globally, including many culturally and economically significant plants[4]. Pollination services are estimated to add billions of dollars to global crop productivity[5] and contribute significantly to dietary health[6]. Despite these values, there is growing evidence of wild pollinator population declines[7,8] and deficits in crop production due to insufficient pollination[9], while global demand for pollination services is at an all-time high[10] and likely to continue to grow[11]. Populations of managed honeybees, while declining in North America and Europe, are increasing in many countries[12]. Observed trends in wild pollinators have been mostly linked with changes in land management[13], climate change[14,15] and agrochemical use[16], although these analyses are largely restricted to Europe and North America. Conversely, restoring or diversifying habitats and reducing management pressures such as pesticides and grazing have been shown to positively affect wild pollinator populations and managed honeybee health[17-20].

In response to growing evidence of pollinator declines, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reviewed and assessed evidence on pollinator declines in 2016[4]. This global assessment prompted the adoption of commitments to support pollinator conservation by member states of the Convention on Biological Diversity[21] and subsequent steps towards developing national pollinator strategies and action plans in many nations (e.g. the Netherlands, Sri Lanka, Colombia[3]). However, the global assessment did not make an integrated, evaluative assessment of either the drivers of pollinator decline or the risks it generates for society.

Evidence on the status and trends in pollinator populations, and impacts of their decline, is concentrated in high income countries, and often absent in regions thought to be most significant for, or vulnerable to decreases in pollinator diversity[22] and pollination services[5]. Consequently, although researchers have made broad, global recommendations about how to respond to pollinator decline[2], it has proven more difficult to identify objectives to address risk even at a regional scale, resulting in often potentially ineffective policies[23].

Here, we use a structured expert elicitation technique and a globally representative group of pollinator and pollination experts to evaluate the relative importance of eight major drivers of pollinator decline, and the risks to human well-being associated with ten direct impacts of pollinator decline defined by the IPBES report[4] (Table 1). We make a separate assessment for each of six global regions, defined as geographic continents, with the exception that Pacific Islands are grouped with Asia as 'Asia-Pacific', rather than with Australia and New Zealand as 'Oceania' (see Methods; Figure S1). Indirect impacts, such as increased land conversion in response to lower yields, were not assessed. We also do not consider interactions between different drivers. While such interactions are clearly important in fully understanding pollinator decline[24,25], we consider current knowledge about interactions between drivers is not sufficient to enable an assessment of the scale and scope presented here.

We take a scientific-technical approach to risk, in which a risk is understood as the probability of a specific hazard or impact taking place. We use a semi-quantitative risk matrix, with risk scores calculated as the product of probability, scale and severity of impacts, and a 'four-box model' established by the IPBES to communicate levels of confidence[1,26], thus highlighting the key known unknowns in current scientific understanding. Our assessment used a modified Delphi technique[27], an approach designed to reduce bias, but particularly suitable for elicitation of expert judgements about complex issues, where the judgement requires a range of different perspectives and areas of expertise not necessarily held by each participant[27,28].

What's driving pollinator declines?

Figure 1 shows final scores for the importance of the six drivers defined in Table 1, following three rounds of scoring. Globally, land cover and configuration, and land management are the most important drivers of pollinator declines, according to our assessment (Figure 1; Ext Data Tables 2 & 4). Land cover and configuration was scored 'very important' in all six regions, while land management was the only variable considered to be 'the most important' in any region (Europe) and was 'very important' in all other regions except Africa. These conclusions are supported by considerable evidence from multiple regions[29,30] and continuing global trends towards agricultural expansion and intensification in regions of the Global South, driven by international trade[31]. Land management was less important in Africa, where access to the necessary financial and technical capital to intensify production is still limited[32] and there was considerable uncertainty over the influence of land cover and configuration change on that continent.

We agreed that pesticides are 'important' or 'very important' drivers of pollinator decline in all regions, with greatest confidence in Europe and Asia/Pacific. Pesticides were considered less important than land use and land management in Europe and Australia/New Zealand, but much more important in Africa. The impact of pesticides on pollinators has received considerable attention in recent years, following studies demonstrating widespread exposure[33] and detrimental impacts on populations[16,34,35], but there is far less evidence available to quantify the exposure in regions beyond Europe and North America[36]. Also, pesticide regulations are weaker in the Global South, adding considerably to the risk[4].

While climate change was considered an ‘important’ or ‘very important’ driver in every region, there was unanimous lack of confidence over its importance relative to other drivers: median confidence scores were ‘medium’ in every region except Africa, for which seven of the 10 scorers responded that climate change effects are ‘unknown’ (Figure S1 and Extended Data Table 2). Limited long-term data are available to demonstrate impacts of climate change on pollinators, and studies available are restricted to a small number of taxa such as bumblebees[14,15] and butterflies[36,37].

Genetically modified organisms (GMOs) were the least important driver overall, not categorized as important in any region except South America, which is the second largest producer of GM crops among our regions, after North America[38]. Levels of confidence and agreement were lower overall for GMOs and Invasive Alien Species as drivers of pollinator decline.

What are the risks to human well-being?

Figure 2 shows the final risk scores following three rounds of scoring, partitioned into probability and magnitude (scale x severity), for each of the direct impacts listed in Table 1, in each major global region. Overall, loss of wild pollinator diversity and crop pollination deficit were the highest and most widespread risks, scoring as serious or high risks in every region (see Ext Data Tables 3 & 7). Although much of the published evidence for pollinator declines is from Europe and North America (where the evidence was considered ‘well established’)[24], there is growing evidence of pollinator declines in other regions[22], as well as broader global evidence of general biodiversity decline[26], including for vertebrate pollinators[39]. Evidence for pollination deficits is also growing across several regions[9,40-43], although for Australia/NZ and Africa, the degree of confidence was ‘inconclusive’, indicating low amounts of evidence and low agreement among our experts (see Table 2 for definitions). This is a particular concern in Africa, where pollinated crops are both nutritionally[44] and economically[45] important to livelihoods and well-being. Yield instability in pollinator-dependent crops, which is higher than that for non-dependent crops at global scale[46], was classed as a serious or high risk in four of the six regions but moderate in Europe and North America, where the economic dependence and relative area of highly pollinator dependent crops is lower. Direct impacts of wild fruit production losses had very low risk scores in economically developed regions of North America, Europe and Australia/New Zealand (median scores <6), but were highly polarized, classed as a serious risk in Africa, Asia-Pacific and South America. These are regions are dominated by low- to middle-income countries, where at least for Africa and Asia-Pacific, large portions of the population live in rural communities[47].

Risks were greatest in South America than in other regions (Extended Data Table 3: mean risk score across all ten impacts = 48.2), with four ‘high’ risks (pollination deficits, yield instability, food system resilience and wild pollinator diversity) and five ‘serious’ risks. The high risks reflect the high diversity of insect pollinated crops grown and exported throughout the region[48], often by small holder farmers, in and around areas of natural habitats that contain a high diversity of pollinating insects[49]. Continuing losses of pollinators are therefore likely to destabilise both regional food production and international trade, affecting livelihoods across the region. Like other regions of the Global South, South America is also home to a high diversity of extant indigenous cultures and people, many of whom rely upon subsistence agriculture and natural resources such as non-timber forest products[50], increasing the risks impacts from a decline in honey, wild fruits and cultural values.

In contrast to South America, Africa had very low risk scores for honey production and managed pollinators (both 'low' risk; see Figure 2 and Extended Data Table 3). Beekeeping is unique in Africa, since it is the only global region that has large, genetically diverse populations of native honey bees still thriving in the wild[51]. There are few reports of colony losses, numbers of managed hives are increasing in many African countries and managed honey bee populations seem relatively resilient to *Varroa* mite[52].

The risk of loss of aesthetic values, happiness or well-being associated with wild pollinators or wild plants dependent on pollinators was perhaps the most difficult to score, in all regions. In some contexts, one can make an argument that aesthetic values associated with pollinators are increasing, as people become more aware of their roles, beauty and diversity. Discussions focused on what constitutes aesthetic values, and how they might be changing in response to pollinator decline. Here also, South America and Africa had sharply contrasting scores, with the highest and lowest risk among regions, respectively (42 vs 4, Extended Data Table 3). While clear links can be identified between people and pollinators or pollinator-dependent plants, in both regions, for South America these links are often relate to specific taxa at immediate risk of decline, such as hummingbirds and orchids. In Africa, connections with pollinator-dependent plants are frequently associated with entire landscapes, such as the flower-rich grasslands of Namaqualand, southern Africa. There, potential impacts of pollinator decline on these values are far less clear.

Europe was the region where human well-being was considered at lowest risk from pollinator declines overall (mean risk score across all ten impacts = 19.6), with no 'high' risks, and only two 'serious' risks (pollination deficit and wild pollinator diversity). Unlike South America, many European countries grow few crops that are highly pollinator dependent and food systems, particularly within the European Union, are highly industrialised and globalised[48], greatly reducing the importance of wild fruits and buffering against the impacts of changes on food systems (both 'low' risk). Although there is evidence that habitats containing pollinator-dependent plants are aesthetically valued in Europe[53], their cultural importance may be lower than in other parts of the world, although this highly uncertain, classed as 'inconclusive' due to low confidence and low agreement among scorers.

The availability of managed pollinators was only considered a serious risk to people in North America, where honey bees *Apis mellifera* represent a key input to large scale, industrialised cropping systems such as almond[54], and have suffered serious declines in the past due to outbreaks of disease, pests and 'colony collapse disorder'[55]. Experts were divided (low agreement) on the impacts of losing managed pollinators in Europe, where markets for pollination services are less well developed[56], and South America, where the number of managed colonies has expanded substantially but pressures on populations remain high[10].

Across both risks and drivers, the majority of factors had high agreement but low confidence, placing them in the 'established but incomplete' confidence category. Our confidence in several direct impacts was low because of numerous gaps in knowledge about the ecology and status of all but the most common pollinator species, and the relationships between pollinators, human economies and culture[5]. Furthermore, while statistical information on crop production, managed pollinators and honey production is often collected at a national scale, the quality of these data vary considerably within a region, and often miss subsistence agriculture.

Despite high profile, extensive research on the drivers and impacts of pollinator decline, our analysis reveals considerable scientific uncertainty about what this means for human society, at a global scale. There are clear risks of wild pollinator diversity loss and pollination deficits globally, yet less is understood about the broader implications of these risks for human well-being. The case for action to address pollinator decline is most clearly made for South America, while there is an urgent need for further research in Africa, to address the substantial uncertainties around the risks to people from pollination deficits, and the importance of changes in land cover and configuration, as a driver of pollinator decline.

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Author contributions

L.V.D conceived and designed the study. L.V.D and T.D.B. contributed equally to data collection, analysis and writing the paper. S.G.P. and H.T,N. convened the expert panel. S.G.P., D.S., T.D.B., H.T.N. and L.V.D. designed, organised and ran the workshop. All authors contributed to all rounds of scoring and discussion, commented on and edited the final text.

Methods

We assessed drivers and risks using a modified version of a formal consensus method known as the Delphi technique[27], in which the second and third rounds of anonymous, independent scoring took place following detailed discussions at a face-to-face workshop in November 2017. This modification of the Delphi technique is frequently used in environmental research, where issues are multi-disciplinary and interpretations of the same phrase can differ strongly among individuals[28]. All but one of the authors of this paper (hereafter 'experts') took part in all rounds of the Delphi process (D.S. facilitated only and did not score). This set of 20 pollination experts was carefully selected to cover the range of necessary expertise, including biodiversity science, economics, social science and indigenous and local knowledge, and to ensure that the main global regions were each represented by at least two scorers either originating from or mainly working in that region. Thirteen of the 21 authors (59%) were also authors of the IPBES global pollinators assessment[4] and the team has a balanced gender ratio of 11 men : 10 women.

Definitions of regions, parameters and scores

We divided the world into six global regions, largely representing geographic continents of North America, South America, Asia, Europe, Africa and Oceania, with one important difference: we included the Pacific islands in a region known as 'Asia-Pacific', rather than combining them with Australia and New Zealand in the geographic continent 'Oceania'. Our 'Asia-Pacific' region is equivalent to most of the Asia-Pacific as defined by IPBES[57], but excludes Australia and New Zealand. We named 'Australia/New Zealand' as a separate region, because they are very different from mainland Asia and the Pacific islands, both biogeographically and geopolitically (see Figure S1).

For each region, experts individually assigned probability, scale and severity scores for each of eight impacts of pollinator decline, and importance scores to each of 10 drivers of pollinator declines defined by the IPBES[4] (Table 1), using the five-point Likert scales described in Table S1. All scores were accompanied by a *confidence* score of low, medium or high, enabling experts to qualify their judgements with a level of confidence, based on the amount of evidence they were aware of, and its quality.

The following definitions of probability, scale and severity were available for authors to consult throughout the process:

Probability: A high probability of impact suggests that the impact is already taking place or is very likely, at least in some circumstances. Low probability implies that the impact is NOT taking place or is unlikely. Unknown means there is not enough evidence to make a judgement on whether or not the impact is happening, or likely to happen.

Scale of impact either refers to the numbers of people or area affected. Large means there is evidence for impacts on people and livelihoods, either over a large area or affecting many people. Moderate means there is evidence for impacts on people and livelihoods, either over a moderate area or affecting a moderate proportion of people, and small means there is evidence for impacts on people and livelihoods, either in a small localised area, or only affecting a small number of people. Unknown means there is not enough evidence on the scale of this impact to make a judgement.

Severity of impact refers to the nature of the impact on individual people or families. Large means there is evidence for a substantial or severe impact on people and livelihoods. Moderate means there is evidence for a moderate impact on people and livelihoods, and small means a small impact. Unknown means there is not enough evidence on the severity of this impact to make a judgement.

Experts rated the *importance* of each driver in affecting pollinators in each specific region, on a 1-5 scale from not important to the most important (Tables 1 and S1).

We set an *a priori* expectation of consensus as an interquartile distance of < 2 between scores for a particular element (not including confidence). This still allows us to distinguish between high and low agreement following criteria in Table 3, in which high agreement is denoted by mean IQR ≤1 (where half of all scores are the same or an adjacent score).

Three iterative rounds of scoring

In an initial scoping phase, all experts were invited to comment on the proposed scoring structure described above. Following this, the first round of scoring was conducted online in October 2017. Each expert was asked to score for all regions, considering the evidence in the IPBES report[4] alongside their own expertise. Experts could add comments to support their scores, and were encouraged to cite parts of the IPBES report[4] and other specific literature. Scores and comments were compiled and summaries sent to the experts, detailing the median and interquartile range of scores for each element, and the proportions of 'unknown' responses.

Each expert was then assigned a region (always one they were familiar with) and a driver, and asked to play a cynic role, doing focused background research to challenge, refute or support the scores from the first round, with evidence. Cynic roles were not made known during later discussions, but cynics were invited to comment appropriately and to actively introduce new evidence to the discussions.

In November 2017, all experts attended a workshop in Reading, UK. Experts were divided into two groups, which each discussed the results from the first round, and the evidence that supports them, for three regions. Group 1 discussed and scored in rounds 2 and 3 for Europe, North America and Africa; Group 2 discussed and scored South America, Asia Pacific and Australia/New Zealand. Discussions were facilitated and notes taken throughout. Facilitators kept in contact and discussed any specific issues arising about how to score, to ensure that both groups responded in the same way. At the end of each part of the discussion, participants scored again for each element of risk, and each driver, for each region in turn. Scoring was conducted independently and anonymously, using Excel spreadsheets on personal laptops. All members of a group were encouraged to score for each region discussed in their group, with the following guidance: "Score if you can (but you don't have to). If you feel confident to score for a region outside your own personal knowledge, please do so. These issues are complex and open to interpretation. This is why we employ a subjective scoring process, with anonymous scoring. Listen to the discussion, and then score as you understand it."

These round 2 results were compiled as before, and any scores with interquartile range (IQR) ≥2 (our *a priori* criterion for consensus), progressed to round 3 for rescoring.

Round 3 scoring took placed on the second day of the workshop in a plenary discussion. This allowed a further opportunity for any consistent differences in scoring or approach across groups to be revealed, although this was not the case. Second round scores were presented and made the subject of debate and discussion. Experts scored again anonymously and independently, using laptops, for the regions they scored for in round 2, although the discussion was open to both groups. In total, 19 variables (3 drivers, 16 impacts) were rescored, along with associated confidence levels. Due to an error, four impact variables (South America: Pollination Deficit [severity], Yield Instability [scale], Wild Fruit Availablility [scale], Wild Plant Diversity [scale]) with IQR ≥2 were not flagged for rescoring during the workshop and were later rescored during a teleconference. Only five of the ten scorers from group 2 were able to attend the teleconference, due to time differences, so these four variables have only n=5 scorers in the final dataset (Figure S3). All other variables have at least 8 scorers. Following the third round, three variables still failed to reach consensus (IQDs ≥2) - Australia/New Zealand: Pollination Deficit [probability], Wild Fruit Availability [probability] and South America: Managed Pollinators [probability] (Figure S3).

Analysis

Median scores following the third round of scoring were used to derive risk scores (the product of probability, scale and severity scores) and associated risk categories (boundaries described in Figure 2), importance scores for drivers, and confidence categories for all final scores, following criteria given in Table 3. In assigning confidence categories, the quantity and quality of evidence was based on assigned confidence scores for each risk or driver. The confidence score is the percentage of the maximum possible confidence score (9 for risks, 3 for drivers), represented by the median confidence scores from the final round, with the three medians summed in the case of impacts (confidence score for risk = (∑ Confidence scores for probability, scale and severity/9) * 100)).

Overall global scores for the importance of drivers were calculated as a median of the six region-level scores and confidence scores, to ensure equal weight was given to each region (although the numbers were unchanged if individual scores across all six regions were used). We did not calculate overall global risk scores for different impacts of pollinator decline, because these scores were based on assessments of probability, scale and severity for different global regions and it does not make sense to average these across regions. All figures were drawn using the ggplot2 package[58], in R version 4.0.0[60].

We hypothesized that the scores participants gave for each component of the risk, or driver importance, were dependent on the impact, or driver, being scored, and on the region being scored, rather than reflecting individual scorer differences or differences emerging from the style of discussion between the two groups. We tested this hypothesis using Cumulative Link Models and Cumulative Link Mixed Models with logit link functions (also called proportional odds or ordinal logistic regression models), with the ordinal package[59], in R version 4.0.0[60]. The top and bottom two score categories (scores 1 and 2, and 4 and 5 respectively) were collapsed to create three-point scales for probability, scale and severity of impacts, and importance of drivers.

We consider the effect of Region and Impact, or Region and Driver, on score, for each of four dependent variables: probability, scale, severity and importance. ‘Unknown’ responses were treated as ‘na’ for this analysis. The dataset is not large enough to examine the interaction between Region and Impact or Driver with this type of model (n≤10 scorers for each combination of factors).

For each model, we tested the proportional odds assumption, that the effects of region or impact group were the same, regardless of where the cut-off points were placed across the five score categories, using the nominal test and scale test functions, which use likelihood ratio tests. When this assumption was violated, we used partial proportion odds models where possible, given our data structure. Independent variables that failed the tests were examined, with scale (dispersion of latent variable) allowed to vary among levels of the dependent variable (failure of scale_test) or effects of the relevant factor assumed to be nominal rather than ordinal (failure of the nominal_test).

These models do not account for the random effects of scorer or group, because the scorers were divided among two separate groups, each of which only scored half of the regions. We ran Cumulative Link Mixed Models separately for each group, including scorer as a random effect to account for differences between individual scorers. The effects of group cannot be analysed as a random factor with this study design, because there are only two levels. The effect of Group cannot be separated from the effect of Region in a single model.

We used McFadden's pseudo R^2 value (ρ^2) to provide an indication of goodness of fit for all models, as recommended by Menard (2002)[61]. This is calculated relative to a null model using the following equation:

$$\rho^2 = 1 - \frac{LL_{mod}}{LL_0}$$

where LL_{mod} is the log likelihood value for the fitted model and LL_0 is the log likelihood for the null model which includes only an intercept as predictor (so that every score is predicted the same probability).

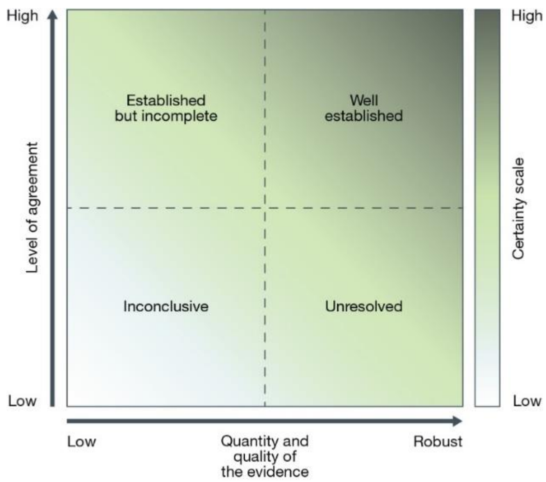
Results of this analysis are provided and discussed in Extended Data Tables 4-9 and accompanying text.

Table 1 The potential drivers and direct impacts of pollinator decline on human well-being, defined by IPBES[4] , including original wording shown in inverted commas, with section numbers indicated.

Short Form	Definitions from IPBES pollinators and pollination assessment report [4]
Direct drivers of pollinator decline	
Pollinator management	Management of bees (honey bees, bumblebees, stingless bees and solitary bees) for honey production, and of bees or other insects for pollination. “Two major *Apis* species are managed around the world: the western honey bee *Apis mellifera* and the eastern honey bees *Apis cerana* and *Apis indica*.” (Section 2.4.2.1) “Five species of bumble bees are currently used for crop pollination, the major ones being *Bombus terrestris* from Europe and *Bombus impatiens* from North America.” (Section 2.4.2.2). “Bee management is a global and complex driver of pollinator loss.” (Section 2.4.3).
Pests and Pathogens	Parasites, pathogens and disease of all pollinating animals are included, both naturally circulating in populations and those associated with human management. “Bee diseases by definition have some negative impacts at the individual bee, colony or population level. Parasites and pathogens can be widespread in nature but may only become problematic when bees are domesticated and crowded.” (Section 2.4.1)
Pesticide use	“Pesticides (fungicides, herbicides, insecticides, acaricides, etc.) are primarily used in crop and plant protection against a range of pests and diseases and include synthetic chemicals, biologicals, e.g., *Bacillus thuringiensis* (Bt) or other chemicals of biological origin such as spider venom peptides.” (Section 2.3.1.) Veterinary medicines are also included.
Land management	Land management refers to “arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it” (Section 2.2.1). “Land management such as agricultural and conservation practices has a great influence at both landscape and local scales on the nesting and foraging environment of pollinators.” (Section 2.2.2)
Land cover and configuration	“Land cover has been defined by the UN FAO as the observed (bio)physical cover on the earth’s surface”. (Section 2.2.1.) This includes the extent of different habitat and land use types, and their spatial configuration at landscape scale.
Invasive alien species	“Alien species’ are defined as a (non-native, non-indigenous, foreign, exotic) species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce. ‘Alien invasive species’ are alien species that become established in natural or semi-natural ecosystems, and are an agent of change, threatening native biological diversity” (Section 2.5.1)
GMOs	“Genetically modified (GM) organisms (GMOs) are organisms that have been modified in a way that does not occur naturally by mating and/or natural recombination. One of the most common methods to do this is by bioengineering transgene(s) into the new organism. The most common plant transgenes confer herbicide tolerance (HT), or toxicity towards herbivores (insect resistance, IR), although other characteristics have been

	also engineered (e.g., drought resistance in wheat, nutritional values in sorghum).” (Section 2.3.2.)	
Climate change	“a change in the state of the climate that can be identified … by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.” (Section 2.6)	
Direct impacts of pollinator decline		
Pollination Deficits	Crop pollination deficit leading to lower quantity or quality of food (and other products).	Reduction in the quantity or quality of food, fibre, fuel or seed that can be produced, as a result of pollinator loss.
Yield Instability	Crop yield instability	Crop yields becoming less stable or predictable between years, or locations.
Honey Production	Fall in honey production (and other hive products)	Reduction in the amount of honey or hive products that can be produced, as a result of pollinator loss
Food system Resilience	Decline in long term resilience of food production systems	Resilience is the ability of the food production system to withstand or recover from shocks or adverse effects, such as changes in climate.
Wild Fruit Availability	Decline in yields of wild fruit, harvested from natural habitats by local communities	Fruits or seeds harvested for food by people (not by animals). Could include, for example, blueberries harvesting from wetlands, or *Rubus fruticosus* fruits harvested from hedgerows.
Wild Plant Diversity	Loss of wild plant diversity due to pollination deficit	Loss of species richness, or abundance of particular species of wild plants due to pollination deficit. This impact is intermediate; the ultimate impact on human well-being is through loss of aesthetic value, cultural practices and traditions.
Wild Pollinator Diversity	Loss of wild pollinator diversity	Loss of species richness, or abundance of particular species of wild pollinators, including invertebrates and vertebrates. This impact is intermediate; the ultimate impact on human well-being is through loss of aesthetic value, cultural practices and traditions.
Managed Pollinators	Reduced availability of managed pollinators	Managed pollinators are animals used to provide crop pollination, rather than for the production of honey.
Aesthetic Values	Loss of aesthetic value, happiness or well-being associated with wild pollinators or wild plants dependent on pollinators	This could include amenity values of specific plant communities, cultural values of emblems or symbols.
Cultural Values	Loss of distinctive ways of life, cultural practices and traditions in which pollinators or their products play an integral part	Cultures, traditions and behaviours involving pollinators or pollinator products. This includes beekeeping, honey-hunting, specific dances or rituals associated with pollinators.

Table 2: Communication of the degree of confidence. We follow the four-box model for the qualitative communication of confidence, used by the IPBES, shown on the left[4,26]. The degree of confidence in each finding is based on the quantity and quality of evidence, represented by confidence scores (see methods), and level of agreement among scorers, represented by inter-quartile ranges (IQRs) of expert scores for each variable.



Confidence category	Definition	Thresholds, based on third round modified-Delphi scores
Well established	Robust evidence	Confidence score ≥66.7% **AND** proportion unknowns<40%
	High agreement	For risks, ∑IQRs ≤3; for drivers, IQR ≤1
Established but incomplete	Low quality evidence	Confidence score <66.7% **OR** ≥40% of responses “unknown”
	High agreement	For risks, ∑IQRs ≤3; for drivers, IQR ≤1
Unresolved	Robust evidence	Confidence score ≥66.7% **AND** proportion unknowns<40%
	Low agreement	For risks, ∑IQRs >3; for drivers, IQR >1
Inconclusive	Low quality evidence	Confidence score <66.7% **OR** ≥40% of responses “unknown”
	Low agreement	For risks, ∑IQRs >3; for drivers, IQR >1

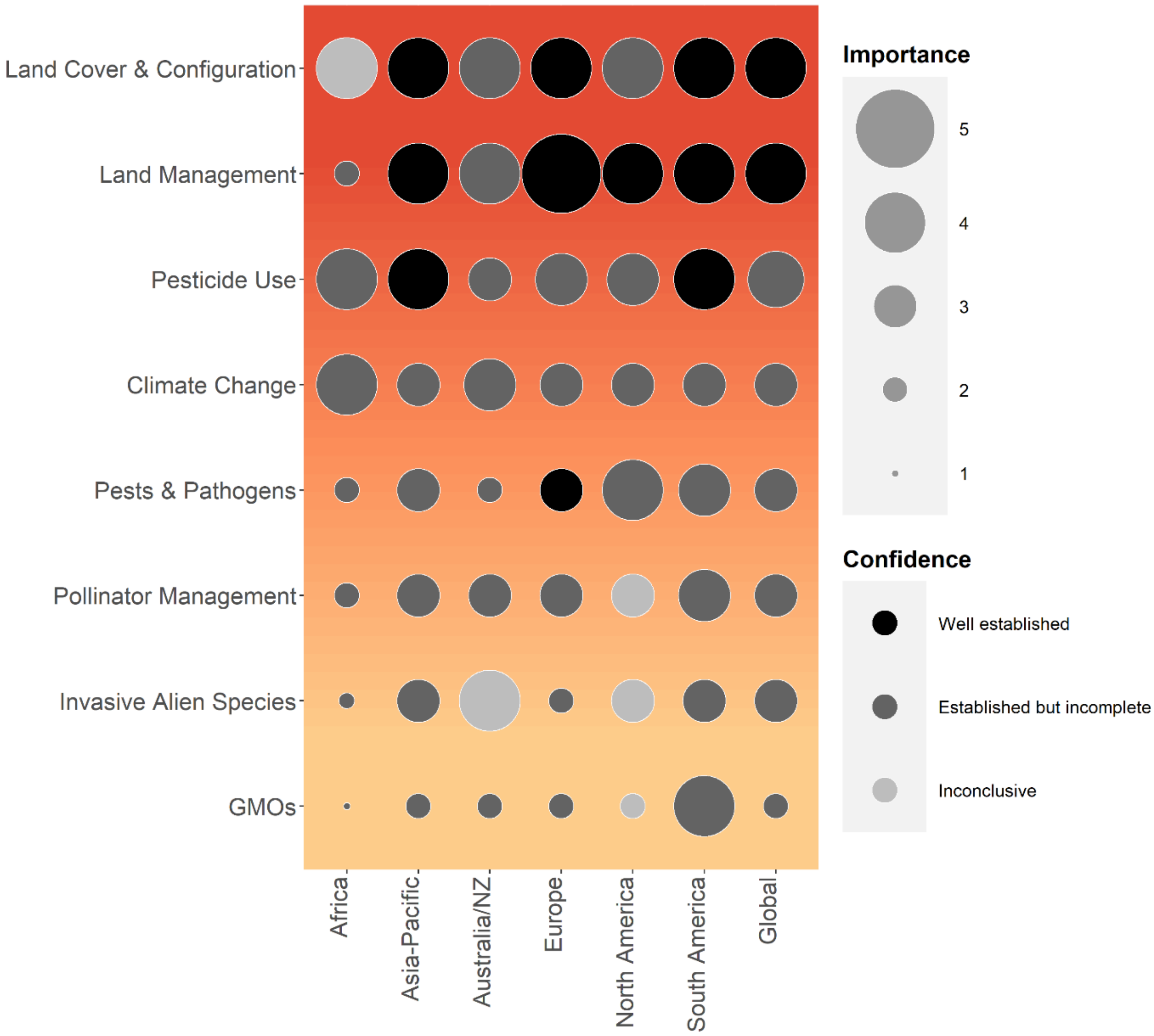


Figure 1 Assessment of the importance of eight major drivers of pollinator decline defined by the IPBES[4], for six regions, and a global median (right). Importance is represented by circle size, reflecting median scores across 9-10 experts, following three rounds of anonymous scoring. Drivers are ordered according to effects on score values estimated by proportional odds models (see Extended Data Table 4), with higher scoring drivers at the top. All drivers except 'Pests and Pathogens' were scored significantly differently from 'Climate Change', either higher or lower. Degree of confidence is shown by the grey-scale, following the IPBES four-box model based on the confidence score and level of agreement, according to the criteria in Table 2.

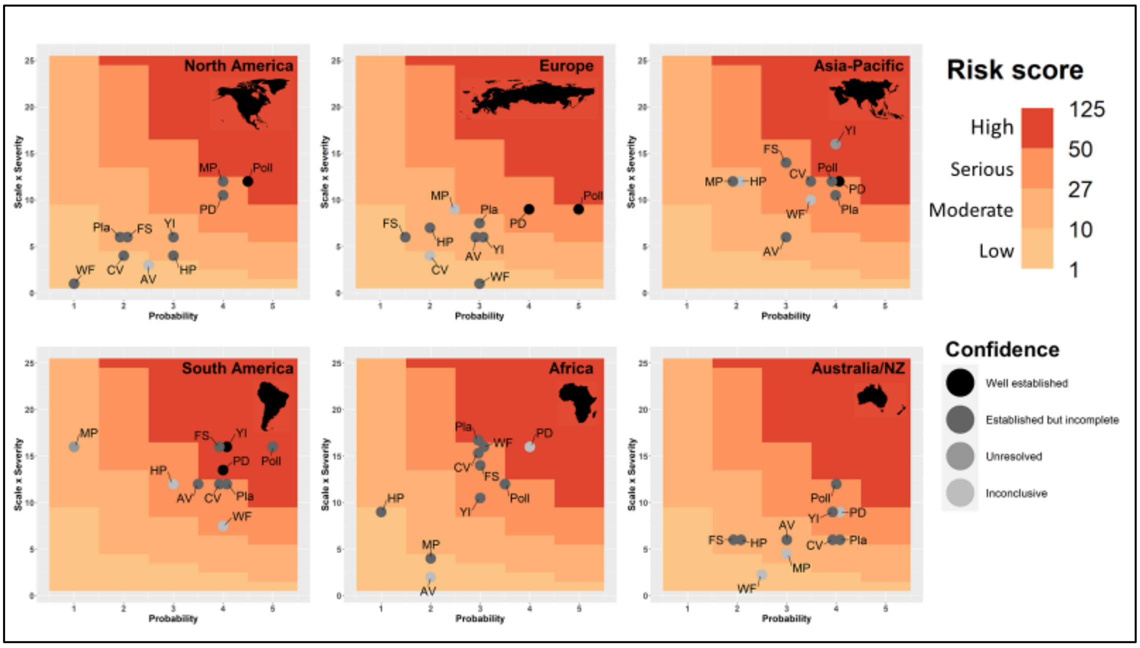
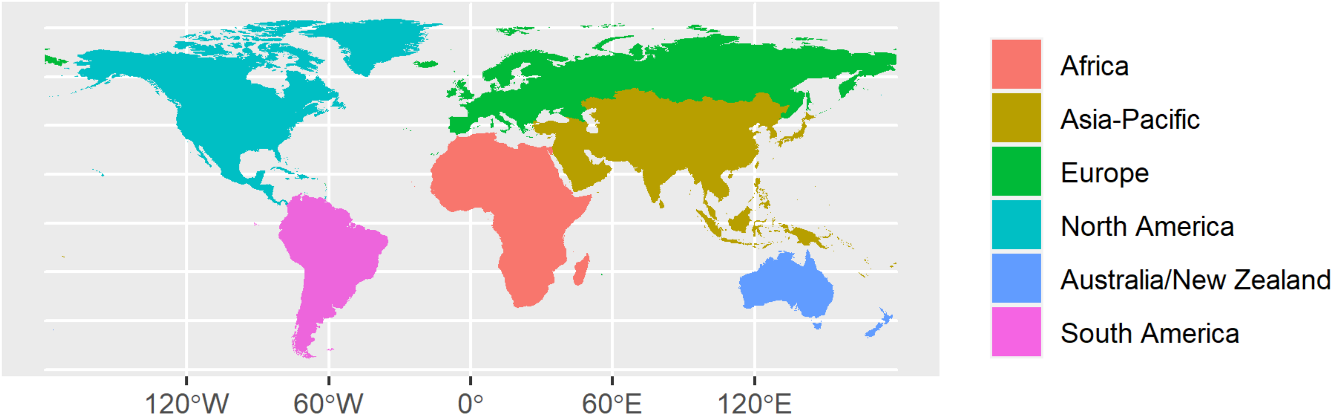


Figure 2 Assessment of the risks to human well-being associated with pollinator decline. Ten direct impacts are assessed separately, with risks evaluated based on probability, scale and severity of specific impacts occurring in six global regions. PD = Pollination Deficits, YI = Yield Instability, HP = Honey Production, FS = Food System Resilience, WF = Wild Fruit Availability, Pla = Wild Plant Diversity, Poll = Wild Pollinator Diversity, MP = Managed Pollinators, AV = Aesthetic Values, CV = Cultural Values. Scores are median scores across 5-10 experts, following three rounds of anonymous scoring. The underlying risk matrix, shown by the background colours, provides categories of risk according to an overall risk score (the product of probability, scale and severity scores): <10 = **low** risk; 10-27 = **moderate** risk; 28-50 **serious** risk; 50 = **high** risk. Degree of confidence is shown by the grey-scale, following the IPBES four-box model based on the confidence score and level of agreement, according to the criteria in Table 2. Impacts with the same scores on both axes are shown overlapping, jittered evenly, to enable confidence category to be visible.

Extended Data Table 1 Scoring system used during three scoring rounds. Scorers were provided with verbal descriptions for how to score on each scale (see 'Methods'). For impacts, participants gave separate confidence scores for each element.

Score	**Five point scale**					**unknown**
IMPACT	1	2	3	4	5	
Probability	very low	low	moderate	high	very high	unknown
Scale	very small	small	medium	large	very large	unknown
Severity	very small	small	medium	large	very large	unknown
Confidence (repeated x3 for each scale)	low	medium	high			unknown
DRIVERS	1	2	3	4	5	
Driver x in region y	not important	a little important	important	very important	the most important	unknown
Confidence (repeated for every driver)	low	medium	high			unknown

Figure S1 How we defined the global regions



Extended data table 2 Final driver scores summarised
Median scores for importance (1-5) and confidence (1-3) are shown from the final third round scores, according to the scales defined in Extended Data Table 1. Interquartile ranges are shown in brackets. Number of scorers and percentage scoring 'unknown' are shown, along with the confidence category, assigned according to the rules in Table 2.

Region	Driver	Importance (IQR)	Confidence score (IQR)	Number of scores	% unknown	Confidence category
Africa	Climate Change	4 (0.5)	3 (1.5)	10	70	Established but incomplete
	GMOs	1 (0)	1.5 (2)	10	30	Established but incomplete
	Invasive Alien Species	1.5 (1)	2 (0.75)	10	40	Established but incomplete
	Land Cover & Configuration	4 (1.5)	2 (0.75)	10	0	Inconclusive
	Land Management	2 (1)	1.5 (1)	10	50	Established but incomplete
	Pesticide Use	4 (1)	1 (1)	10	0	Established but incomplete
	Pests & Pathogens	2 (0)	2 (1.5)	10	0	Established but incomplete
	Pollinator Management	2 (0)	2 (0.75)	10	0	Established but incomplete
Asia-Pacific	Climate Change	3 (1)	2 (1)	10	10	Established but incomplete
	GMOs	2 (1)	2 (1)	10	20	Established but incomplete
	Invasive Alien Species	3 (1)	2 (0)	10	10	Established but incomplete
	Land Cover & Configuration	4 (0)	3 (1)	10	0	Well established
	Land Management	4 (0)	3 (1)	10	0	Well established
	Pesticide Use	4 (0.75)	2.5 (1)	10	0	Well established
	Pests & Pathogens	3 (0)	2 (0)	10	10	Established but incomplete
	Pollinator Management	3 (1)	2 (0.25)	9	0	Established but incomplete
Australia/ NZ	Climate Change	3.5 (1)	2 (0.75)	10	0	Established but incomplete
	GMOs	2 (0.5)	1 (1)	9	22	Established but incomplete
	Invasive Alien Species	4 (1.25)	2 (0)	9	11	Inconclusive
	Land Cover & Configuration	4 (1)	2 (1)	9	0	Established but incomplete
	Land Management	4 (1)	2 (0)	10	0	Established but incomplete
	Pesticide Use	3 (1)	2 (1)	9	0	Established but incomplete
	Pests & Pathogens	2 (1)	2 (0)	9	0	Established but incomplete

Region	Driver	Importance (IQR)	Confidence score (IQR)	Number of scores	% unknown	Confidence category
	Pollinator Management	3 (1)	1.5 (1)	9	22	Established but incomplete
Europe	Climate Change	3 (0)	2 (1.75)	10	0	Established but incomplete
	GMOs	2 (0)	2 (0)	10	10	Established but incomplete
	Invasive Alien Species	2 (1)	2 (0.75)	10	0	Established but incomplete
	Land Cover & Configuration	4 (1)	3 (0)	10	0	Well established
	Land Management	5 (1)	3 (0)	10	0	Well established
	Pesticide Use	3.5 (1)	2 (0.75)	10	0	Established but incomplete
	Pests & Pathogens	3 (0.75)	3 (1)	10	0	Well established
	Pollinator Management	3 (1)	2 (1)	10	0	Established but incomplete
North America	Climate Change	3 (0.75)	2 (0.75)	10	0	Established but incomplete
	GMOs	2 (1.5)	1 (1)	10	30	Inconclusive
	Invasive Alien Species	3 (1.5)	2 (0)	10	30	Inconclusive
	Land Cover & Configuration	4 (0.75)	2 (0)	10	0	Established but incomplete
	Land Management	4 (0.75)	2.5 (1)	10	0	Well established
	Pesticide Use	3.5 (1)	2 (0)	10	0	Established but incomplete
	Pests & Pathogens	4 (0)	2 (1)	10	0	Established but incomplete
	Pollinator Management	3 (1.75)	2 (1)	10	0	Inconclusive
South America	Climate Change	3 (0.75)	2 (0.75)	10	0	Established but incomplete
	GMOs	4 (1)	2 (0)	10	20	Established but incomplete
	Invasive Alien Species	3 (1)	2 (0)	10	0	Established but incomplete
	Land Cover & Configuration	4 (0.75)	3 (0)	10	0	Well established
	Land Management	4 (0)	3 (0.75)	10	10	Well established
	Pesticide Use	4 (0)	3 (0)	10	0	Well established
	Pests & Pathogens	3.5 (1)	2 (1)	10	0	Established but incomplete
	Pollinator Management	3.5 (1)	2 (0)	10	0	Established but incomplete
Global	Climate Change	3 (0.75)	2 (0.875)	60	13	Established but incomplete
	GMOs	2 (0.75)	1.75 (1)	59	22	Established but incomplete
	Invasive Alien Species	3 (1)	2 (0)	59	15	Established but incomplete

Region	Driver	Importance (IQR)	Confidence score (IQR)	Number of scores	% unknown	Confidence category
	Land Cover & Configuration	4 (0.875)	2.5 (0.375)	59	0	Well established
	Land Management	4 (0.875)	2.75 (0.875)	60	10	Well established
	Pesticide Use	3.75 (1)	2 (0.875)	59	0	Established but incomplete
	Pests & Pathogens	3 (0.375)	2 (1)	59	2	Established but incomplete
	Pollinator Management	3 (1)	2 (0.875)	58	3	Established but incomplete

Extended data table 3 Final risk scores summarised Median risk scores for probability, scale and severity (1-5) and confidence (1-3) are shown from the final third round scores, according to the scales defined in Extended Data Table 1. Interquartile ranges are shown in brackets. Risk score = probability x scale x severity. Total number of scores given across the three elements of risk and percentage of these scores that were ‘unknown’ are shown, along with the confidence category, assigned according to the rules in Table 2.

Region	Impact	Probability (IQR)	Probability confidence (IQR)	Scale (IQR)	Scale confidence (IQR)	Severity (IQR)	Severity confidence (IQR)	Risk score	Total number of scores	% unknowns	Confidence category
Africa	Pollination Deficits	4 (1.5)	2 (0)	4 (1)	2 (0)	4 (0.75)	1.5 (1)	64	30	0.00	Inconclusive
	Yield Instability	3 (0)	1 (1)	3 (0)	1 (0)	3.5 (1)	1 (1)	31.5	30	13.33	Established but incomplete
	Honey Production	1 (0)	2 (0)	3 (0)	2 (1)	3 (1)	2 (1)	9	30	16.67	Established but incomplete
	Food System Resilience	3 (0.5)	2 (2)	3.5 (1)	2 (1)	4 (0)	2 (1)	42	30	33.33	Established but incomplete
	Wild Fruit Availability	3 (0.75)	1 (1)	4 (0)	1.5 (1)	4 (1)	2 (0.75)	48	30	13.33	Established but incomplete
	Wild Plant Diversity	3 (0)	2 (0)	4 (0)	2 (1)	4 (0)	1 (0)	48	30	0.00	Established but incomplete
	Wild Pollinator Diversity	3.5 (1)	3 (1)	3 (1)	1 (1.75)	4 (0.75)	1 (1)	42	30	50.00	Established but incomplete
	Managed Pollinators	2 (0.75)	2 (0)	2 (1)	2 (0.75)	2 (1)	2 (1)	8	30	3.33	Established but incomplete
	Aesthetic Values	2 (1)	1 (0.75)	1 (1)	2 (1)	2 (1.5)	2 (0.25)	4	30	23.33	Inconclusive
	Cultural Values	3 (0.25)	2 (1)	4 (1)	1.5 (1.75)	4 (0.75)	1.5 (1)	48	30	23.33	Established but incomplete
							Mean risk score, Africa	34.45			
Asia-Pacific	Pollination Deficits	4 (0.75)	3 (0)	4 (1)	3 (1)	3 (1)	2 (1)	48	30	3.33	Well established
	Yield Instability	4 (1.5)	3 (1)	4 (0.75)	2 (0)	4 (1)	2 (0)	64	30	3.33	Unresolved
	Honey Production	2 (1.75)	2 (1)	4 (1.75)	2 (0)	3 (1)	2 (1)	24	30	0.00	Inconclusive

Region	Impact	Probability (IQR)	Probability confidence (IQR)	Scale (IQR)	Scale confidence (IQR)	Severity (IQR)	Severity confidence (IQR)	Risk score	Total number of scores	% unknowns	Confidence category
	Food System Resilience	3 (0.75)	2 (1)	4 (1)	2 (0)	3.5 (1)	2 (0)	42	30	3.33	Established but incomplete
	Wild Fruit Availability	3.5 (1.75)	1 (1)	2.5 (1)	1.5 (1)	4 (1)	2 (0.75)	35	30	3.33	Inconclusive
	Wild Plant Diversity	4 (1)	1 (1)	3.5 (1)	1 (1)	3 (1)	1 (1)	42	30	3.33	Established but incomplete
	Wild Pollinator Diversity	4 (0)	2 (0)	4 (0.75)	2 (0)	3 (1)	1 (1)	48	29	3.45	Established but incomplete
	Managed Pollinators	2 (1.5)	2 (1)	4 (0.75)	2 (0)	3 (0.25)	2 (1)	24	30	6.67	Established but incomplete
	Aesthetic Values	3 (0.75)	2 (1)	2 (1)	2 (1)	3 (1)	2 (0.5)	18	30	6.67	Established but incomplete
	Cultural Values	3.5 (1.75)	2 (0)	3 (0)	2 (0.75)	4 (1)	2 (0)	42	30	3.33	Established but incomplete
						Mean risk score, Asia-Pacific		38.7			
Australia/ New Zealand	Pollination Deficits	4 (2)	2 (1)	3 (1)	2 (1)	3 (0.25)	2 (0.25)	36	27	3.70	Inconclusive
	Yield Instability	4 (0)	2 (1)	3 (1)	2 (0)	3 (1.25)	2 (1)	36	27	3.70	Established but incomplete
	Honey Production	2 (1)	2 (0)	2 (1)	2 (1)	3 (1)	1 (1)	12	27	0.00	Established but incomplete
	Food System Resilience	2 (1)	2 (0)	3 (0.75)	2 (0.25)	2 (1)	2 (0)	12	29	0.00	Established but incomplete
	Wild Fruit Availability	2.5 (2.5)	1 (1)	1.5 (1)	1 (0)	1.5 (1.25)	1 (0)	5.625	28	42.86	Inconclusive
	Wild Plant Diversity	4 (1)	2 (0)	3 (0.75)	2 (0)	2 (0.75)	1 (1)	24	28	10.71	Established but incomplete
	Wild Pollinator Diversity	4 (0)	2 (1)	4 (0)	2 (1)	3 (1.5)	2 (0.75)	48	26	7.69	Established but incomplete
	Managed Pollinators	3 (1)	2 (1)	3 (1)	2 (1)	1.5 (1.25)	1 (1)	13.5	28	3.57	Inconclusive
	Aesthetic Values	3 (0.5)	2 (0.25)	2 (0.5)	1 (1)	3 (1.5)	1 (0)	18	24	8.33	Established but incomplete

Region	Impact	Probability (IQR)	Probability confidence (IQR)	Scale (IQR)	Scale confidence (IQR)	Severity (IQR)	Severity confidence (IQR)	Risk score	Total number of scores	% unknowns	Confidence category
	Cultural Values	4 (0)	2 (0)	2 (0.25)	1 (1)	3 (1)	2 (0)	24	28	0.00	Established but incomplete
					Mean risk score, Australia/New Zealand			22.9			
Europe	Pollination Deficits	4 (0)	3 (1)	3 (0)	2 (0)	3 (0.75)	2 (0)	36	30	0.00	Well established
	Yield Instability	3 (0)	2 (1.5)	3 (0.75)	2 (1)	2 (0)	2 (1.5)	18	30	3.33	Established but incomplete
	Honey Production	2 (1)	2 (0.75)	3.5 (1.75)	2 (1)	2 (0)	2 (0)	14	30	0.00	Established but incomplete
	Food System Resilience	1.5 (1)	3 (1.25)	3 (1)	2 (1)	2 (0)	2 (1)	9	30	43.33	Established but incomplete
	Wild Fruit Availability	3 (1.5)	1.5 (1)	1 (1)	2 (1)	1 (0)	2 (1.25)	3	30	26.67	Established but incomplete
	Wild Plant Diversity	3 (1)	2 (1)	3 (0.5)	2 (1)	2.5 (1)	1 (1.25)	22.5	30	26.67	Established but incomplete
	Wild Pollinator Diversity	5 (1)	3 (0)	3 (0.75)	2 (0.75)	3 (1)	2 (0.75)	45	30	6.67	Well established
	Managed Pollinators	2.5 (1.75)	2 (0)	3 (0.75)	2 (0)	3 (1)	2 (0.75)	22.5	30	0.00	Inconclusive
	Aesthetic Values	3 (1)	2 (1)	3 (0)	2 (0.75)	2 (0)	2 (0.75)	18	29	10.34	Established but incomplete
	Cultural Values	2 (1.75)	1 (1)	2 (0.75)	1 (1)	2 (1)	1 (0)	8	30	3.33	Inconclusive
						Mean risk score, Europe		19.6			
North America	Pollination Deficits	4 (1)	2 (0)	3.5 (1)	2 (0)	3 (1)	2 (0)	42	30	0.00	Established but incomplete
	Yield Instability	3 (0.75)	1 (0)	3 (0.75)	1 (0)	2 (0)	1 (1)	18	30	3.33	Established but incomplete
	Honey Production	3 (1)	2 (1)	2 (1)	1 (1)	2 (1)	1 (0.25)	12	30	10.00	Established but incomplete
	Food System Resilience	2 (1)	1 (2)	3 (0.5)	1 (2)	2 (0.5)	1.5 (2)	12	30	56.67	Established but incomplete
	Wild Fruit Availability	1 (0)	2 (1)	1 (0)	1 (1)	1 (0.25)	1 (1)	1	30	46.67	Established but incomplete

Region	Impact	Probability (IQR)	Probability confidence (IQR)	Scale (IQR)	Scale confidence (IQR)	Severity (IQR)	Severity confidence (IQR)	Risk score	Total number of scores	% unknowns	Confidence category
	Wild Plant Diversity	2 (1)	1 (1)	3 (1)	1 (1)	2 (0.75)	2 (2)	12	30	33.33	Established but incomplete
	Wild Pollinator Diversity	4.5 (1)	3 (1)	4 (1)	2 (0.75)	3 (1)	2 (1.5)	54	30	20.00	Well established
	Managed Pollinators	4 (1)	2 (1)	3 (0.75)	2 (1)	4 (0.75)	1.5 (1)	48	30	0.00	Established but incomplete
	Aesthetic Values	2.5 (1.75)	1 (1)	2 (0.75)	1 (1)	1.5 (1.25)	1 (1.5)	7.5	30	46.67	Inconclusive
	Cultural Values	2 (0)	1 (1)	2 (1.75)	1 (0)	2 (1)	1 (1)	8	30	16.67	Established but incomplete
						Mean risk score, North America		21.45			
South America	Pollination Deficits	4 (0.75)	3 (0)	4.5 (1)	3 (0)	3 (0)	2 (0)	54	25	0.00	Well established
	Yield Instability	4 (0)	3 (1)	4 (1)	2 (1)	4 (1)	2 (1)	64	25	0.00	Well established
	Honey Production	3 (1)	2 (0)	4 (1.75)	2 (1.75)	3 (1.5)	2 (0.25)	36	30	3.33	Inconclusive
	Food System Resilience	4 (1)	2 (0)	4 (0.75)	2 (0)	4 (1)	2 (1)	64	30	0.00	Established but incomplete
	Wild Fruit Availability	4 (1.5)	2 (0.75)	3 (0)	1 (1)	2.5 (1.75)	1 (0.25)	30	23	17.39	Inconclusive
	Wild Plant Diversity	4 (1)	2 (1)	4 (1)	1 (0)	3 (1)	1.5 (1)	48	24	12.50	Established but incomplete
	Wild Pollinator Diversity	5 (1)	2 (1)	4 (0)	2 (1)	4 (1)	2 (0)	80	27	3.70	Established but incomplete
	Managed Pollinators	1 (2)	3 (1)	4 (1.5)	2 (0)	4 (1)	2 (1)	16	29	3.45	Unresolved
	Aesthetic Values	3.5 (1)	2 (1.75)	3 (0)	2 (1)	4 (1)	2 (0.25)	42	30	6.67	Established but incomplete
	Cultural Values	4 (0.75)	2 (0.75)	3 (1)	2 (0)	4 (0.5)	2 (0.75)	48	29	6.90	Established but incomplete
						Mean risk score, South America		48.2			

Figure S2 Full breakdown of final driver important scores by region and driver

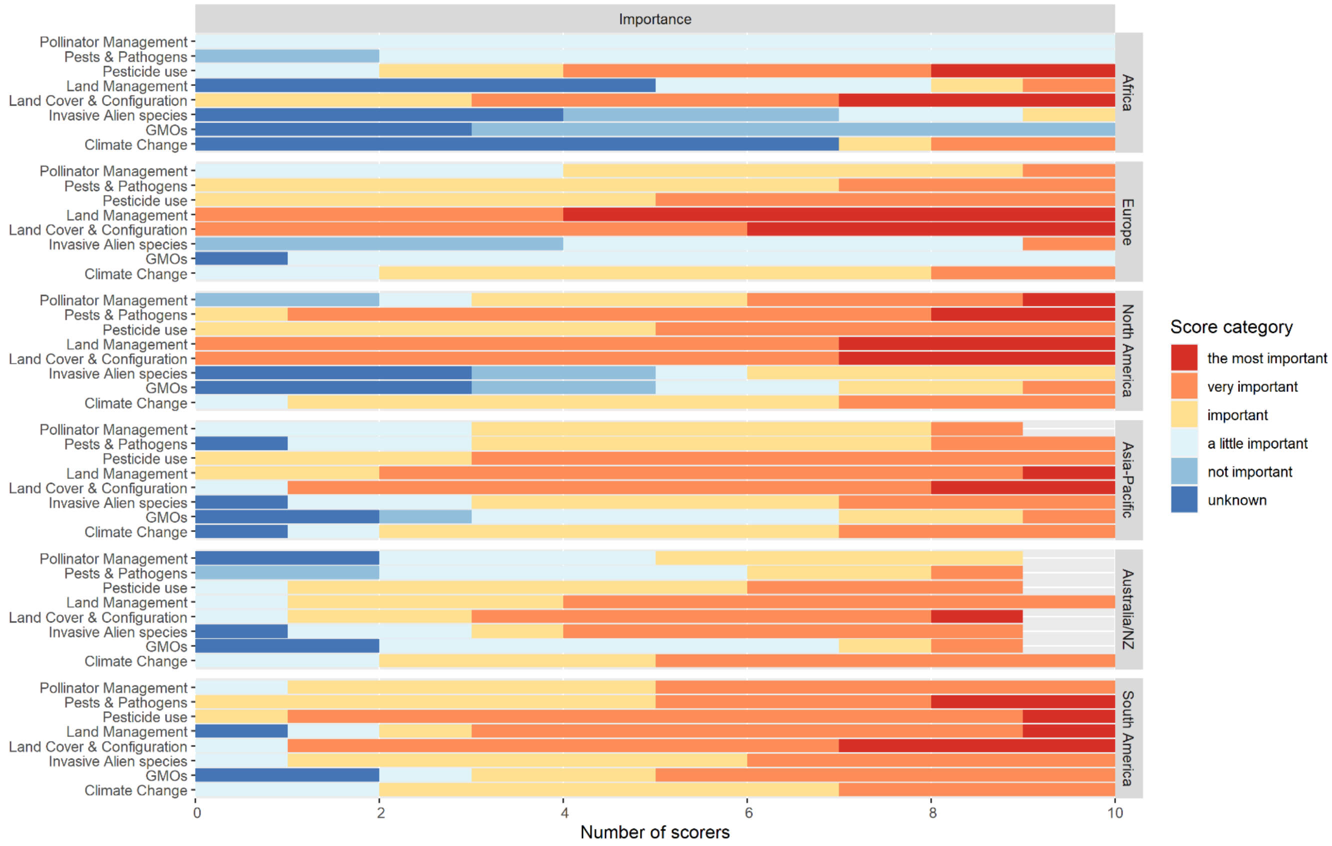
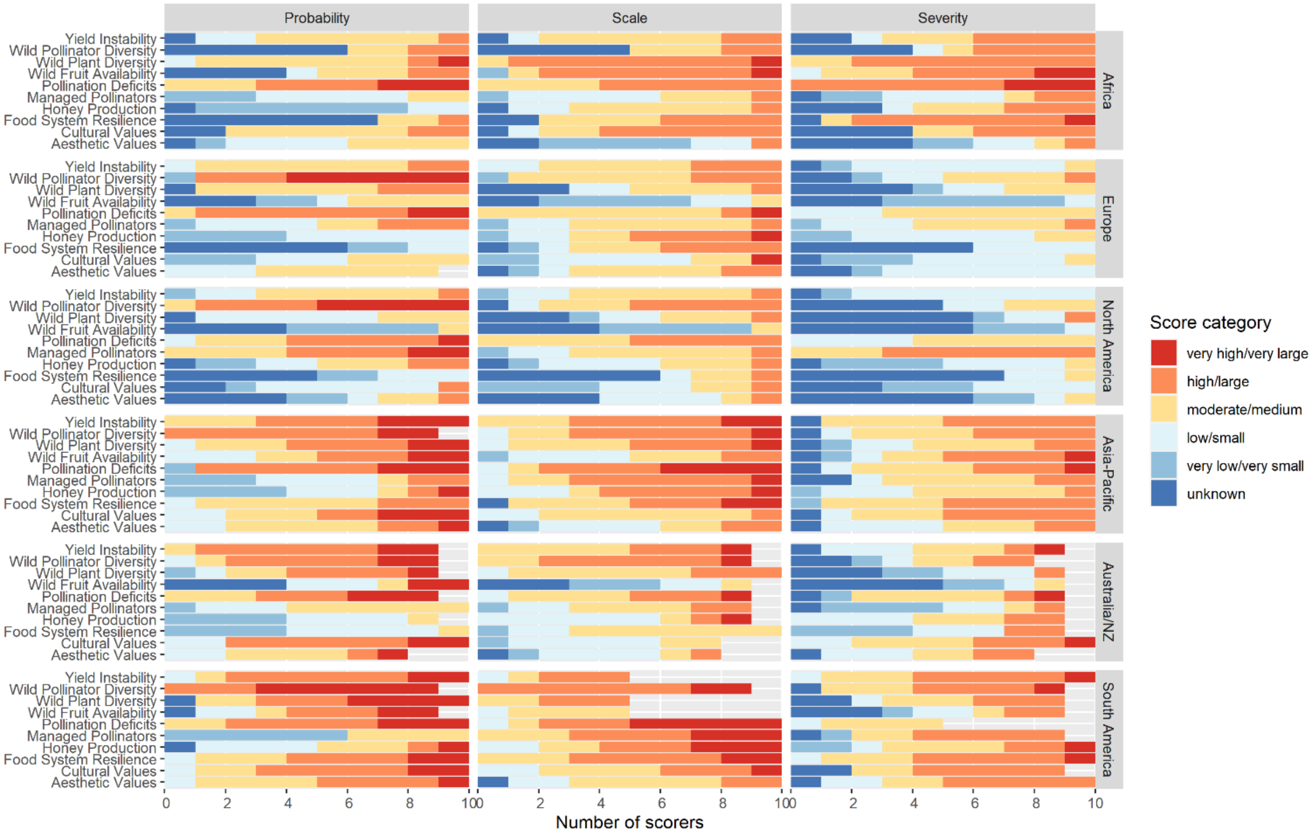


Figure S3 Full breakdown of final risk scores by region, impact and element of risk



Extended data tables 4-9: Ordinal logistic regression analysis

Results and discussion

In Extended Data Tables 4 and 7, we present results of Cumulative Link Models for drivers and risks respectively, along with scale and nominal tests of the proportional odds assumption for each independent variable. In Extended Data Tables 5 and 8, we present partial proportion odds models, where the original models failed the nominal test and these models were significantly different from the scale models, according to a likelihood ratio test.

In Extended Data Tables 6 and 9, we report the results of Cumulative Link Mixed Models separately for each discussion group, for drivers and risks respectively, including scorer as a random effect. These results show that scorer identity had a significant effect on risk scores, but not on driver scores. Most of the differences among impacts and regions persist, when variation among individual scorers is accounted for. For risk scores, all the independent variables that are significantly different in the overall model (Extended Data Table 7) are also significant in either one or both groups in separate models taking account of scorer effects (Extended Data Table 9). There is, however, one risk variable – the severity of cultural values - that is not scored significantly differently from others in the overall model (Extended Data Table 7), but is significantly different in both groups in the separate models (Extended Data Table 9). In group 2, it is the *only* impact for which severity was scored significantly higher that the baseline comparison, aesthetic values. This implies that variation among scorers influenced the way this variable was scored overall, and could be explained for example, if individual scorers who tended to score more highly than others across the board scored particularly highly on this aspect.

There is a significant effect of discussion group, if Region is replaced by Group in the basic Cumulative Link Models (i.e. Score ~ Group + Driver; Score ~ Group + Impact; results not shown) but it cannot be separated from the effect of Region, because of the design of our workshop. However, it is clear from the results in Extended Data Tables 4 and 7 that there was not a consistent bias, whereby one group always scored higher than the other. The regions in group 2 are significantly different from each other, and from those in group one, in both directions. If there is any inter-regional pattern in the drivers of pollinator decline, they seem to be stronger in the Americas than in the western biogeographic regions. For risks, regions of the Global South (Asia-Pacific, South America, Africa) tend to score more highly than regions of the Global North (Europe, North America, Australia/NZ), a pattern that can be seen clearly in Figure 2.

The coefficient values in Extended Data Tables 4-9 cannot be taken as indicators of an absolute change in impact/driver scores, but instead must be interpreted relative to one another. Effects of region are relative to Africa. Effects of impact are reported relative to Aesthetic Values. Effects of drivers are relative to the effect of Climate change. A negative location coefficient for a particular level of an image element indicates that it will tend to reduce ratings, while positive coefficients lead to increased ratings.

Extended Data Table 4 Cumulative Link Model results for drivers. Outputs include location coefficients (effects on score values) and scale parameters (effects on score ranges), where scale was not homogenous across score categories (i.e. failure of scale_test). Standard errors in brackets. Regions organised by discussion group (Group). Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results for nominal test and scale test (Pr>Chisq) are given for the basic model in each case: Score ~ Region + Driver.

Group	Region/Driver	Importance: Coefficient	Importance: Scale coefficient
1	Africa	0	0
	Europe	**1.389**** (0.372)	**-0.944**** (0.311)
	North America	**2.029**** (0.497)	ns
2	Asia-Pacific	**1.769**** (0.454)	ns
	Australia/NZ	**1.278**** (0.441)	ns
	South America	**2.624**** (0.646)	ns
	Climate Change	0	-
	GMOs	**-1.405**** (0.484)	-
	Invasive Alien Species	**-0.876*** (0.349)	-
	Land Cover & Configuration	**2.478**** (0.710)	-
	Land Management	**1.634**** (0.470)	-
	Pesticide Use	**0.848*** (0.342)	-
	Pests & Pathogens	ns	-
	Pollinator Management	**-0.530*** (0.300)	-
	McFadden's Pseudo R^2	0.259	
		Nominal test result	Scale test result
	Region	0.178	**0.000****
	Driver	**0.045***	0.066

**p<0.01; * p<0.05

Extended Data Table 5 Results of Cumulative Link Models with partial proportional odds, for importance of drivers. Outputs are location coefficients (effects on score values), with odds allowed to vary among levels of the dependent variable. Standard errors in brackets. Regions organised by discussion group (Group). Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results for comparison with full proportional odds models (Score ~ Region + Impact) are given (Pr>Chisq). The probability dependent variable is not included, because the partial proportional odds model was not significantly different from the proportional odds models with scale effects (Pr>Chisq = 0.1389)

<table>
<tr><th>Group</th><th>Region/Driver</th><th colspan="3">Importance</th></tr>
<tr><th></th><th></th><th>Coefficient</th><th>not important|
important</th><th>important|
very important</th></tr>
<tr><td>1</td><td>Africa</td><td>0</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Europe</td><td>1.604**
(0.391)</td><td>-</td><td>-</td></tr>
<tr><td></td><td>North America</td><td>2.514**
(0.413)</td><td>-</td><td>-</td></tr>
<tr><td>2</td><td>Asia-Pacific</td><td>2.083**
(0.400)</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Australia/NZ</td><td>1.376**
(0.403)</td><td>-</td><td>-</td></tr>
<tr><td></td><td>South America</td><td>2.957**
(0.418)</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Climate Change</td><td>-</td><td>0</td><td></td></tr>
<tr><td></td><td>GMOs</td><td>-</td><td>-2.378
(0.519)</td><td>-0.950
(0.507)</td></tr>
<tr><td></td><td>Invasive Alien Species</td><td>-</td><td>-1.423
(0.502)</td><td>-0.458
(0.456)</td></tr>
<tr><td></td><td>Land Cover & Configuration</td><td>-</td><td>1.908*
(0.742)</td><td>3.175**
(0.530)</td></tr>
<tr><td></td><td>Land Management</td><td>-</td><td>0.949
(0.634)</td><td>2.163**
(0.465)</td></tr>
<tr><td></td><td>Pesticide Use</td><td>-</td><td>1.655*
(0.729)</td><td>1.293**
(0.423)</td></tr>
<tr><td></td><td>Pests & Pathogens</td><td>-</td><td>-0.541
(0.507)</td><td>0.032
(0.422)</td></tr>
<tr><td></td><td>Pollinator Management</td><td>-</td><td>-1.151*
(0.495)</td><td>-0.774
(0.464)</td></tr>
<tr><td colspan="2">McFadden’s Pseudo R^2</td><td>0.249</td><td></td><td></td></tr>
<tr><td colspan="2">Likelihood ratio test vs proportional odds model (Pr>Chisq)</td><td>0.045*</td><td></td><td></td></tr>
</table>

**p<0.01; * p<0.05

Extended Data Table 6 Cumulative Link Mixed Models by Discussion Group for importance of drivers Outputs are location coefficients (effects on score values), standard errors in brackets. Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results are given for comparison with a proportional odds model *not* accounting for the random effect of scorer within each group (Score ~ Region + Impact) (Pr>Chisq), and indicate that individual scorers did not differ significantly from one another when scoring importance of drivers. These results should be compared with those in Extended Data Table 3, where the random effect of scorer could not be taken into account.

Region/Driver	Importance	
	Discussion group 1	Discussion group 2
Africa	0	-
Europe	**2.142****	-
	(0.471)	
North America	**3.250****	-
	(0.517)	
Asia-Pacific	-	0
Australia/NZ	-	ns
South America	-	**0.869***
		(0.345)
Climate Change	0	0
GMOs	**-3.256****	ns
	(0.791)	
Invasive Alien Species	**-2.465****	ns
	(0.678)	
Land Cover & Configuration	**4.261****	**2.059****
	(0.859)	(0.630)
Land Management	**2.642****	**1.556****
	(0.734)	(0.563)
Pesticide Use	**1.482***	**1.257***
	(0.588)	(0.535)
Pests & Pathogens	ns	ns
Pollinator Management	**-1.128***	ns
	(0.572)	
McFadden's Pseudo R^2	0.385	0.143
Likelihood ratio test vs proportional odds model	0.324	0.065

**$p<0.01$; * $p<0.05$

Extended Data Table 7 Cumulative Link Model results for elements of risk. Outputs include location coefficients (coeff = effects on score values) and scale parameters (scale coeff = effects on score ranges), where scale was not homogenous across score categories (failure of scale_test). Standard errors in brackets. Regions organised by discussion group. Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results for nominal test and scale test (Pr>Chisq) are given for the basic model in each case: Score ~ Region + Impact.

Group	Region/Impact	Probability		Scale		Severity	
		Coeff	Scale coeff	Coeff	Scale coeff	Coeff	Scale coeff
1	Africa	0	0	0	-	0	0
	Europe	ns	ns	-0.627** (0.228)	-	-1.580** (0.506)	-1.157** (0.328)
	North America	ns	0.672* (0.262)	-0.738** (0.258)	-	-1.632** (0.530)	-0.915* (0.401)
2	Asia-Pacific	2.603** (0.880)	ns	ns	-	-0.556* (0.228)	ns
	Australia/NZ	ns	ns	-0.566* (0.234)	-	-1.149** (0.400)	ns
	South America	3.853** (1.165)	0.489* (0.232)	ns	-	ns	ns
	Aesthetic Values	0	0	0	0	0	0
	Cultural Values	ns	ns	ns	ns	ns	-0.952* (0.378)
	Food System Resilience	ns	ns	1.187** (0.355)	-0.781* (0.304)	ns	ns
	Honey Production	-4.944* (1.977)	ns	0.806* (0.390)	ns	ns	ns
	Managed Pollinators	ns	0.924** (0.288)	0.930** (0.337)	ns	1.242* (0.495)	ns
	Pollination Deficits	4.978** (1.483)	ns	1.638** (0.422)	-0.715* (0.303)	0.909* (0.396)	-0.914* (0.386)
	Wild Fruit Availability	ns	0.668* (0.328)	ns	ns	ns	ns
	Wild Plant Diversity	2.032** (0.768)	ns	1.312** (0.380)	-0.651* (0.321)	ns	ns
	Wild Pollinator Diversity	7.836* (3.216)	ns	1.846** (0.473)	ns	0.965* (0.416)	ns
	Yield Instability	ns	ns	1.259** (0.366)	-0.674* (0.295)	ns	-0.827* (0.357)
	McFadden's Pseudo R^2	0.242		0.149		0.214	
		Nominal test result	Scale test result	Nominal test result	Scale test result	Nominal test result	Scale test result
	Region	0.011*	0.000**	0.607	0.101	0.023*	0.001**
	Impact	0.083	0.001**	0.020*	0.024*	0.010*	0.001**

*p<0.05; **p<0.01

Extended Data Table 8 Results of Cumulative Link Models with partial proportional odds, for scale and severity elements of risk. Outputs are location coefficients (effects on score values), with proportional odds allowed to vary among levels of the dependent variable, for independent variables where the proportional odds assumption is not met (shown by failure of nominal_test, results in Ext Data Table 6). Standard errors in brackets. Regions organised by discussion group (Group). Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results for comparison with full proportional odds models (Score ~ Region + Impact) are given (Pr>Chisq). The probability dependent variable is not included, because the partial proportional odds model was not significantly different from the proportional odds models with scale effects, shown in Ext Data Table 6 (Pr>Chisq = 0.1389).

Group	Region/Impact	Scale			Severity		
		Coefficient	Small|med	Med|high	Coefficient	Small|med	Med|high
1	Africa	0				0	0
	Europe	**-0.935**** (0.295)	-	-	-	**-2.796**** (0.406)	**-4.210**** (0.763)
	North America	**-1.236**** (0.309)	-	-	-	**-2.685**** (0.421)	**-2.625**** (0.468)
2	Asia-Pacific	ns	-	-	-	ns	**-1.006**** (0.323)
	Australia/NZ	**-0.985**** (0.301)	-	-	-	**-1.769**** (0.387)	**-1.643**** (0.369)
	South America	**0.754*** (0.310)	-	-	-	ns	ns
	Aesthetic Values		0	0		0	0
	Cultural Values	-	ns	ns	-	**1.229*** (0.489)	ns
	Food System Resilience	-	**2.306**** (0.542)	**1.180*** (0.490)	-	ns	ns
	Honey Production	-	ns	**1.050*** (0.482)	-	ns	ns
	Managed Pollinators	-	**1.364**** (0.434)	ns	-	**1.256**** (0.480)	**1.120*** (0.511)
	Pollination Deficits	-	**3.365**** (0.674)	**1.979**** (0.478)	-	**2.484**** (0.529)	ns
	Wild Fruit Availability	-	ns	ns	-	ns	ns
	Wild Plant Diversity	-	**2.211**** (0.520)	**1.455**** (0.492)	-	ns	ns
	Wild Pollinator Diversity	-	**3.232**** (0.676)	**2.342**** (0.494)	-	**2.055**** (0.548)	ns
	Yield Instability	-	**2.354**** (0.518)	**1.236*** (0.489)	-	**0.913*** (0.477)	ns
McFadden's Pseudo R^2			0.149			0.191	
Likelihood ratio test vs proportional odds model Pr>Chisq			**0.020***			**0.003****	

*p<0.05; **p<0.01

Extended Data Table 9 Cumulative Link Mixed Models by Discussion Group Outputs are location coefficients (effects on score values), standard errors in brackets. Effects are shown relative to an arbitrary base category, indicated by 0. *p*-values for model estimates are based on the Wald statistic. Likelihood ratio test results are given for a comparison with a proportional odds model *not* accounting for the random effect of scorer within each group (Score ~ Region + Impact) (Pr>Chisq), and indicate significant differences between individual scorers in every case. These results should be compared with those in Extended Data Table 7, where the random effect of scorer could not be taken into account.

Region/Impact	Probability		Scale		Severity	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Africa	0	-	0	-	0	-
Europe	ns	-	-0.948**	-	-3.741**	-
			(0.298)		(0.455)	
North America	ns	-	-1.229**	-	-3.376**	-
			(0.310)		(0.455)	
Asia-Pacific	-	0	-	0	-	0
Australia/NZ	-	ns	-	-1.516**	-	-1.256**
				(0.321)		(0.316)
South America	-	ns	-	ns	-	0.381
						(0.301)
Aesthetic Values	0	0	0	0	0	0
Cultural Values	ns	1.185*	ns	ns	1.816*	1.358*
		(0.556)			(0.919)	(0.571)
Food System Resilience	ns	ns	1.797**	1.805**	3.248**	ns
			(0.615)	(0.563)	(0.946)	
Honey Production	-1.680**	-2.327**	ns	1.154*	1.757	ns
	(0.652)	(0.586)		(0.579)	(0.896)	
Managed Pollinators	ns	-1.902**	ns	2.133**	4.058**	ns
		(0.550)		(0.582)	(0.925)	
Pollination Deficits	3.492**	2.262**	2.218**	2.878**	4.085**	ns
	(0.618)	(0.629)	(0.571)	(0.623)	(0.882)	
Wild Fruit Availability	ns	ns	ns	ns	1.832*	ns
					(0.893)	
Wild Plant Diversity	ns	1.121*	1.745**	2.201**	3.395**	ns
		(0.552)	(0.600)	(0.598)	(0.911)	
Wild Pollinator Diversity	4.197**	3.341**	2.113**	3.880**	3.670**	ns
	0.748	(0.854)	(0.599)	(0.710)	(0.934)	
Yield Instability	ns	2.162**	1.111**	2.779**	ns	ns
		(0.621)	(0.562)	(0.630)		
McFadden's Pseudo R^2	0.239	0.278	0.106	0.213	0.309	0.107
Likelihood ratio test for effect of scorer Pr>Chisq	0.000**	0.000**	0.004**	0.000**	0.002**	0.000**

*p<0.05; **p<0.01

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