Developing a rapid assessment tool for identifying and safeguarding pollinators: a case study from a global avocado company

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Developing a rapid assessment tool for identifying and safeguarding pollinators: A case study from a global avocado company

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Abstract

Agricultural intensification poses a global threat to many wild species, including insect pollinators. Despite the dependence of many companies on insect-pollinated crops within their supply chains, only a limited number of them actively implement measures to protect pollinators. This study aims to address this issue by developing a tool that businesses can employ to create effective pollinator conservation strategies. To create this tool, we utilized an existing roadmap as a foundational structure and adapted it into a practical tool through a comprehensive review of the literature and the development of specific methodologies. Subsequently, we applied this tool to a case-study company to further refine the methods and gather industry feedback. The developed tool identifies seven specific activities that companies can implement to achieve the following objectives: (1) understand the threats to pollinators, (2) recognize the significance of pollinators to their business (3) assess current pollinator actions, and (4) explore additional pollinator protection measures. The results from our case study indicate that increasing knowledge transfer to growers and supporting them to participate in environmental certification schemes could serve as effective strategies. The tool developed in this study aims to assist companies in identifying effective strategies to safeguard pollinators. Its potential implementation across a wide range of companies could greatly benefit growers and contribute to the conservation of various pollinator species.

KEYWORDS

avocado supply chain, pollinator conservation, private sector, sustainability assessment tool

1 | INTRODUCTION

Recent evidence suggests that insects are declining in both abundance and diversity across Europe and North America, which is likely indicative of a global trend (Wagner, 2020). Multiple factors contribute to this decline, however, the most influential threat is agricultural intensification and expansion due to the associated natural habitat loss and fragmentation, and the application of pesticides (Campbell et al., 2017; Vanbergen et al., 2020). These declines include many important wild insect pollinators such as bees, flies, beetles, and butterflies (Potts et al., 2016), which is concerning given the crucial role such pollinators play in enhancing human well-being. Animal pollination is responsible for approximately 35% of the global food supply (Klein et al., 2007) and this includes some of the most nutritious crops for human health (Chaplin-Kramer et al., 2014; Eilers et al., 2011; Hristov et al., 2020). Additionally, nearly 90% of wild flowering species rely, at least partially, on pollinators (Ollerton et al., 2011) thereby contributing to broader ecosystem functions and biodiversity enhancement (IPBES, 2016).

It is therefore imperative to develop land management solutions that conserve pollinators in agricultural landscapes. Various practices, such as creating or conserving pollinator resources on farms (Kovács-Hostyánszki et al., 2017) diversifying farming systems (Batáry et al., 2011; Kennedy et al., 2013), reducing agrochemical inputs (Dicks et al., 2014; Kuldna et al., 2009), and protecting and restoring remnant natural areas (Dicks et al., 2021; Duque-Trujillo et al., 2023), have proven efficient in promoting pollinator populations. Encouraging landowners to implement these practical measures often requires support such as legal regulations, financial incentives or disincentives, technical advice, and persuasion techniques. While such initiatives are typically implemented through governmental policies, the private sector can also play a pivotal role (Garibaldi et al., 2019), particularly in cases where government financial capacity or will is lacking.

For many private sector companies, safeguarding pollination services holds significant importance, as declines in wild pollinators can adversely impact the sustainability and profitability of their business. The extent of this threat depends on the company's reliance on insect-pollinated crops and its position within the supply chain (e.g., grower, supplier, processor, or retailer) (Breeze et al., 2022). Growers may experience reduced yield, quality, and production stability, whereas suppliers, processors, and retailers could face supply chain disruption and/or an increase in the purchasing price resulting from global production declines (Murphy et al., 2022; Tremlett et al., 2020). Inaction on pollinator protection also poses reputational risks, as consumers are increasingly aware of the threats to pollinators (Hoshide et al., 2018) and may adapt their purchasing habits based on agricultural production methods.

Similarly, actors within the supply chain have the power to influence pollination services through their actions. Growers directly impact pollinators through their choice of land management practices, while suppliers, processors, and retailers can shape these practices by implementing pollinator-friendly strategies. For instance, supermarkets such as Marks and Spencer, Waitrose, and the Co-operative, encourage or require their growers to plant wildflower seeds and/or reduce their pesticide application (Co-operative, 2009; Marks and Spencer, 2023) and Jordans, a cereal supplier company, requires that all their growers provide pollinator habitats on their land (Jordans, 2023). However, overall, the implementation of pollinator strategies from businesses remains limited. In a recent report, the University of Cambridge Institute for Sustainability Leadership (2018) highlighted that many companies are reluctant to invest in protecting pollinators due to a perceived lack of accessible evidence demonstrating crop dependencies on pollinators, the absence of an immediate threat to their business, and the lack of evidence of a clear return on investment for pollinator protection strategies. Furthermore, comprehensive information on creating pollinator strategies is not widely available. While there are some resources that identify strategies companies could employ to improve biodiversity and nature more broadly (see UK Business and Biodiversity Forum and Get Nature Positive), there is currently limited guidance specifically focused on actions for pollinators. Consequently, there is a clear need to develop a practical tool that businesses can utilize to develop pollinator protection strategies.

In their 2018 report, the Cambridge Institute for Sustainable Initiatives et al., proposed a high-level roadmap that companies can follow to understand the importance of pollination services to their business and identify ways to support these services. However, the existing roadmap does not provide a specific and tangible methodology that can be readily implemented. Therefore, the objective of this study is to build upon this roadmap and create a tool that suppliers, processors, and retailers can use to assess their dependencies on pollinators and identify effective pollinator management strategies in a quick, practical, and cost-effective manner. Firstly, we describe the development of the tool and provide a high-level overview of the assessment process. Secondly, we apply this tool to a real-life case study for an avocado supplier business, providing a detailed demonstration of the approach. Finally, we explore the potential applications and limitations of our approach and identify potential avenues for further development and adaptation of the tool for wider use.

2 | METHODS

2.1 | Developing the tool

To develop this tool, we used the roadmap outlined in the pollination deficit report as a foundational structure (University of Cambridge Institute for Sustainability Leadership, 2018) (Data S1). This roadmap was developed based on research conducted with 27 companies that rely, at least in part, on pollinators. It aims to enable companies to understand pollination services and implement sustainable pollinator management by defining high-level steps, aims, and activities required for the evaluation process. For this purpose, we modified the structure of the roadmap to ensure the objectives of our tool were met, for example, an effective, rapid, and cost-effective process that could easily be conducted by non-technical experts.

Firstly, we eliminated some activities outlined in the original roadmap if they were considered too time-consuming and complex for our purposes. For example, in Step 2 (Does it matter?), we removed Activity 2 (Consideration of context) as gaining an understanding of local, national, and regional policies that could exacerbate or mitigate the risk was considered a time intensive task.

Additionally, the final step in the roadmap, 'implement and monitor', was excluded from our process as there was not sufficient time to implement the identified pollinator strategies and monitor their effects. However, we acknowledge this is an essential phase in refining and improving the tool.

Importantly, we expanded the framework to provide a practical implementation method for each activity. To develop these methods, we conducted a thorough review of relevant literature associated with each activity identified in the roadmap. The IPBES (2016) report on pollinators served as a comprehensive resource to identify appropriate methods. However, if this report did not provide the necessary information, then we conducted a detailed Google Scholar search using key terms associated with each activity. For example, a methodology on how to conduct an assessment on honeybee deficits was not provided in the IPBES report and so we searched in google scholar using terms such as "Honeybee" AND "Deficit" AND "Country". We then reviewed the abstracts of the first 50 returned papers and read the full text of any papers that identified a suitable methodology. If multiple methods were available, we selected the one that was most aligned with the aims of this study. For instance, chapter 4: section 2 of the IPBES (2016) report outlines several methods to calculate the economic value from pollinators. We deemed dependency ratio calculations to be the most appropriate as this method represents pollination benefits on a large scale and therefore is applicable to global businesses and moreover, it does not require time intensive field work to collect pollination data.

In some instances, existing methods were unavailable or deemed unsuitable for our criteria. For example, in the literature, the methods available to assess the threats to wild pollinators are highly time consuming, expensive, and knowledge intensive (e.g., the use of remote sensing technology) and additionally, there is limited existing data on the status of wild pollinator trends, especially outside of Europe and North America. In such cases, we developed new approaches based on a comprehensive review of the broader literature combined with the aims of our study.

2.2 | Case study application

To test the applicability of our process, we applied the tool to a global business that specializes in trading avocados (*Persea americana*). Avocado was perceived to be a suitable case study as this crop has a high dependence on insect pollination (40%–90% dependence range; Dymond et al., 2021; Klein et al., 2007).

The case study application identified several small changes to further improve the process. For example, when developing the methodology to assess the threats to pollinators, we initially wanted to include an assessment of climate change and pests and pathogens as these factors are important threats (Dicks et al., 2021). However, obtaining accurate data on these indicators proved to be a complicated and time-consuming task, and so we dropped this part of the assessment from the final process. Finally, we shared and discussed the tool with the case study business and incorporated their feedback to develop the final tool (Figure 1).

3 | APPLYING THE METHODS

3.1 | Step 1. Is there an issue?

3.1.1 | Activity 1. Identify how dependent the crop is on animal pollination

Pollination dependency is the extent to which a crop relies on animal pollination for the succesfull production of fruits and seeds. As outlined in Klein et al. (2007), we categorized crop dependency based on the reduction in production without pollinators. As such, dependency is grouped into one of the following categories; essential

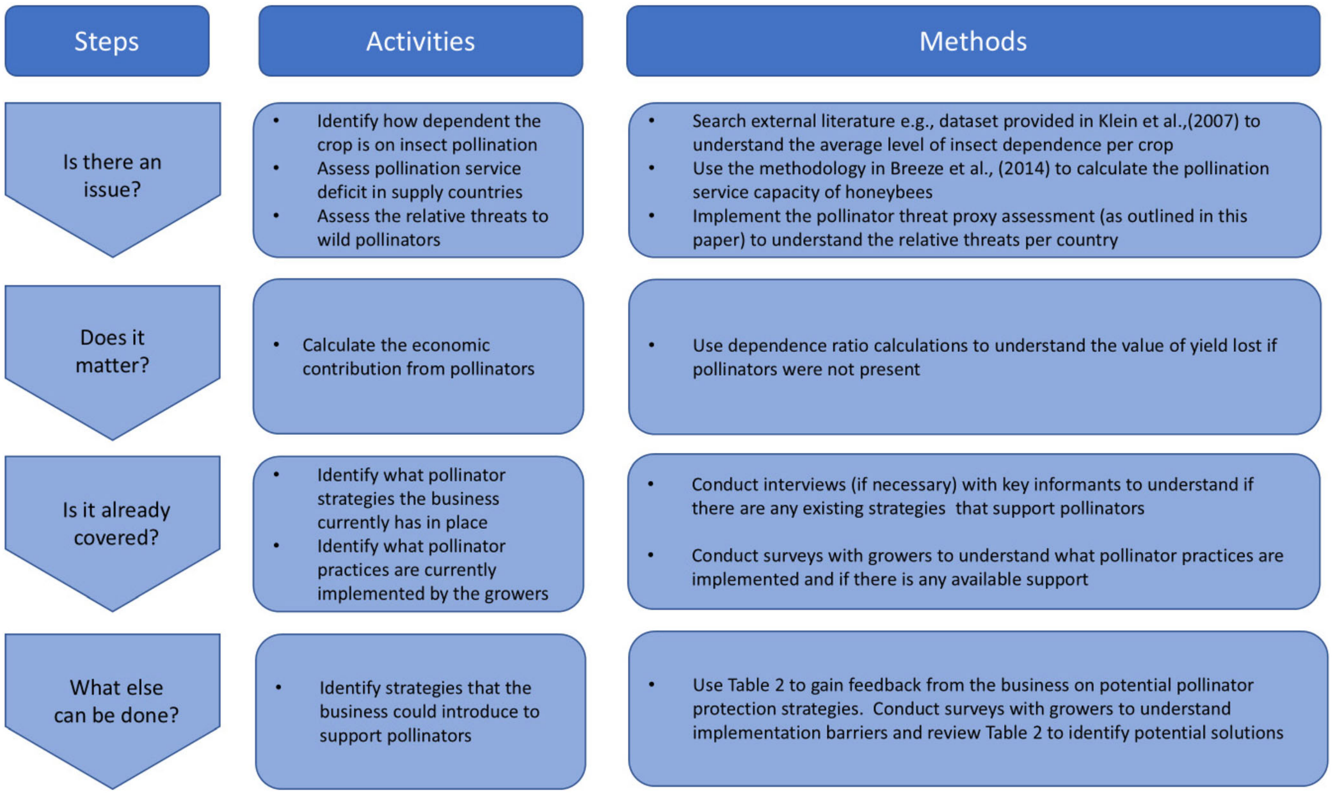

FIGURE 1 Overview of the tool that companies can use to understand the importance of pollinators to their business and to identify pollination management strategies. Adapted from 'The Pollination deficit report: Towards supply chain resilience in the face of pollinator decline' (University of Cambridge Institute for Sustainability Leadership et al. 2018).

(>90% reduction), great (40%–90% reduction), modest (10%–40% reduction), little (>0 to <10% reduction), no increase, and unknown.

To clasify the depencecy level of the focal crop, a literature search using the terms "pollination dependency" and the crop(s) of interest should be undertaken to identify relevant studies or reviews. Alternatively, for a more rapid assessment, the review by Klein et al. (2007) offers a comprehensive dataset of pollination reliance of the top 100 globally traded crops, however, more up-to-date information may be available.

Our literature search identified a meta-analysis by Dymond et al. (2021) that focused on the contribution of insect pollinators to avocados. However, as this study did not exclusively state the level of dependency, we combined the information from this study with the data from Klein et al. (2007) to inform our results.

3.1.2 | Activity 2. Assess honeybee pollination deficits in supply countries

This assessment aims to identify whether there is a deficit in the current honeybee supply relative to the levels necessary for maximum crop yield in each country. To evaluate this, we adopted the methodology outlined in Breeze et al. (2014), which measures pollination service capacity per country, for example, the percentage supply of honeybees relative to demand per country.

To implement this method, data on the number of honeybee hives per country, the area (hectares) of insect-pollinated crops grown per county, and the recommended stocking rate (RSR) for each of these crops should be collected. The number of honeybee hives can be obtained from the FAOSTAT website or the respective governmental website (department of agriculture). Data on the area of insect-pollinated crops can also be found on the FAO statistics website. Data S2 outlines the crops for which data should be extracted, as this table shows all crops which have a modest, great, or essential contribution to production as outlined in the Klein et al. (2007) review. The RSR for each insect-pollinated crop is also provided in Data S2, which was developed by reviewing various external sources. In cases where RSR data was unavailable, a rate was based on recommendations for a similar crop or an average for all crops can be used.

Using the data collected above, the following calculations can be applied:

1. Supply Density of Honeybees per Country

$$= \frac{\text{Number of honeybee hives per country}}{\text{Total area of all insect pollinated crops per country (hectares)}}$$

2. Total Demand of Honeybees per Country

$$= \frac{\sum(\text{Area of insect pollinated crop (hectares)} * \text{RSR})}{2}$$

3. Demand Density of Honeybees per Country

$$= \frac{\text{Total demand of honeybees per country}}{\text{Total area of all insect pollinated crops per country (hectares)}}$$

4. Pollination Service Capacity

$$= \frac{\text{Supply Density of Honeybees per Country}}{\text{Demand Density of Honeybees per Country}}$$

The RSR is divided by two to allow for one movement in honeybee hives per year. Although the number of hive movements may vary depending on the country and crop, we opted to use two movements to simplify the process.

For this study, we focused on five countries—Peru, South Africa, Israel, Chile, and Spain—as these are currently the biggest suppliers of avocadoes to our business case study. For most countries, data on the number of honeybee hives were obtained from the FAO statistic database (FAO, 2022). However, for Peru, FAO data on hive numbers were not available and therefore this information was sourced from the governmental website for the Department of Agriculture. Data on the area of insect-pollinated crops (hectares) and the RSR were collected using the methods and sources described above.

3.1.3 | Activity 3. Assess the threats to wild pollinators

To assess the threats to wild pollinators, we developed a method that utilizes easily obtainable proxy data. This allows businesses to understand which supplier companies are most vulnerable to pollinator losses. However, as this method does not provide a quantitative understanding of how crop pollination might be affected, it is best suited for comparisons between countries and cannot provide an absolute level of threat and so is less applicable for single country assessments.

To design this process, we initially identified key indicators which are known to negatively affect the abundance and diversity of wild pollinators. The selected indicators were land cover and configuration, land management, and pesticide use, as these three factors were identified as highly important in the IPBES pollinator report and further highlighted as the most influential factors, with the highest amount of evidence, in a recent global assessment (Dicks et al., 2021). Next, for each indicator, we selected suitable and easily obtainable proxies and sources (Table 1). The proxy selected for the indicator 'land cover and configuration' was 'predicted loss of suitable habitat' and the data was sourced from a recent global assessment of predicted global habitat loss by Powers and Jetz (2019). Although this article does not specifically include insects in its evaluation, many studies have demonstrated the importance of natural and semi-natural habitats as predictors of pollinator abundance, diversity, and pollination (Dainese et al., 2019; Martin et al., 2019). Fertilizer use was identified as a proxy for overall land management, as high levels of chemical fertilizer are often used as indication of intensive agricultural production (Tilman et al., 2011).

To apply this process, data for each proxy should be obtained from the source identified in Table 1 for each supplier country. The following ranking system can then be applied to compare the threats to pollinators across the countries in the supply chain. For each proxy, the data is split into five equal brackets and every country is then assigned a number (1–5) based on which bracket that country's data is in, for example, one for the lowest bracket and five for the highest bracket. An overall score can then be calculated by summing up the ranking figures for all the proxies. The same bracketing principle can be applied to the final score to provide a high, medium, or low relative threat level.

In this example, we focused on the five biggest supplier countries for our business case study (as described above). Data were available for all countries and proxies

TABLE 1 Proxies and information sources for key indicators that threaten wild pollinators.

Key Indicators	Proxy	Source
Land cover and configuration	Predicted average decadal loss of habitat suitable range (HSR) % per country	Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios, Powers and Jetz (2019)
Land management	Fertilizer application on agricultural land (kg/hectare) per country. Average taken for the last 4 years	FAO statistics, Data, Land inputs and Sustainability, Input, Fertilizer by Nutrient https://www.fao.org/faostat/en/#data
Pesticide use	Pesticide application on agricultural land (Kg/hectare) per country. Average taken for the last 4 years	FAO statistics, Data, Land inputs and Sustainability, Input, Pesticide Use https://www.fao.org/faostat/en/#data

apart from predicted loss of HSR for Israel, as this article only assessed countries bigger than 50,000M^2. Therefore, to obtain data for Israel, an average was calculated using the data from surrounding countries (Jordan, Syria, and Egypt).

3.2 | Step 2: Does it matter?

3.2.1 | Activity 1. Calculate the economic contribution of pollinators

To calculate the economic contribution of pollinators, we selected the method 'dependence ratios'. This method allows us to estimate the economic value of yield lost if pollinators were not present. The formula used is as follows:

$$\begin{aligned}&\text{Economic Value of Insect Pollination (EVIP)}\\&=\text{Quantity of crop}*\text{Export price of crop}\\&\quad*\text{Dependency value of crop}\end{aligned}$$

The dependency values identified in Step 1, Activity 1 can be utilized in this equation and data on the quantity of crops sold can be obtained from the company. To calculate the export price, the trade section of the FAOSTAT website can be used as this provides data on the total export volume and total export value of avocados per country per year. These values can then be used to calculate an average export price per MT (e.g., Average export price = Total export value/Total export quantity).

For this study, we again focused on the five largest supplier companies. To obtain the dependency value of the crop we used the dataset in Klein et al. (2007), and the midpoint of 65% was used. The quantity of avocados was the average amount of avocados (in metric tons) that the company had exported per country over the last 3 years (2018–2020). To calculate the export price, we summed the total quantity of exported avocados for the last 3 years (2018–2020) per country as well as the export value of avocados for the same years, per country (FAO, 2023). We then divided the total export value by the total quantity to obtain an average export price per MT per country and finally, we averaged the price across all countries.

3.3 | Step 3. Is it already covered?

3.3.1 | Activity 1. Identify what company strategies currently exist

The method to identify current pollinator strategies depends on who is conducting the research. If the investigator has limited knowledge on this topic, then key informant interviews should be conducted with staff working in this area e.g., the departmental manager for environmental social and governance (ESG) (or similar). The questions designed for this study (Data S3) can be used as an overarching structure, but the interviews should follow a semi-structured format to allow for clarification or exploration. These questions ask whether the company uses advice/training, regulation, financial incentives, or certification to encourage pro-environmental behavior, as these areas were identified in the literature as common strategies to promote change. If one of these strategies is used, follow-up questions can be asked to gather more details, particularly regarding the relevance to pollinators (Data S3).

As our study was implemented by an external researcher, we conducted key informant interviews with the global head of sustainability at the company and their research and development manager in Chile. The interviews were conducted via an online video call at a prearranged time between May and September 2021.

Ethical clearance for these interviews and the surveys described in the following section was given by the University of Reading, School of Agriculture, Policy and Development Ethical Committee 2021 (application reference number 001866).

3.3.2 | Activity 2. Identify what pollinator practices are currently being implemented by the growers

Similar to Step 3, Activity 1, the methods to understand current pollinator practices will depend on who is conducting the research. If the person has a limited understanding of farm level practices, then it may be necessary to conduct a simple survey with growers. The surveys used in this study (Data S4) can be utilized or adapted. This multiple-choice survey begins with a general question asking farmers about the practices they implement on their land to protect pollinators e.g., providing native habitat, controlling pesticide application, etc. The options presented for pollinator practices were sourced from the IPBES pollinator report (section 6.1.1.1 technical response to restore and protect pollination) and were selected only if the evidence supporting their efficacy was 'well established'. If respondents indicate the implementation of certain practices, follow-up questions are available to gather further details on these actions. Additionally, the survey asks if the participants receive any support and, if so, the type of support and its source.

For our study, surveys were only conducted in Chile where additional avocado research was being carried out and therefore grower surveys could be deployed, however, data should ideally be collected from all countries of interest. A list of suitable growers was provided by the case study business and partner organizations (INIA La Cruz: Instituto

TABLE 2 Pollinator protection strategies and ways in which they can be adapted for the private sector.

Theme	Examples of pollinator management strategies	Adaptation for the private sector
Regulations: legal or mandatory rules.	Bans, regulations, or compulsory labeling on certain pesticides or GMO products. Mandatory inspections and/or registrations for beekeepers. Regulations on the importation and trade of honeybee hives. Prohibited release of nonnative insects. Protected natural areas to maintain or improve biodiversity.	*Environmental contract or mandate certification schemes* Create regulations on environmental/pollinator management that growers must abide by to sell their produce to the company or require that growers are part of environmental certification schemes.
Economic: financial *incentives* for positive behavior or *disincentives* for negative behavior.	Direct payments to farmers who implement practices that support pollinators. Certification schemes that pay higher prices for products if they are produced in a pollinator-friendly manner e.g., fair to nature. Crop insurance schemes for farmers who participate in certain land management practices e.g., IPM. Inputs provided to farmers for pollination management e.g., wildflower seeds. Taxes or fees for pesticide use.	*Certification schemes* Increase grower participation in relevant certification schemes. *Insurance scheme* Provide insurance to growers who make specified environmental changes on their land. *Environmental inputs* Provide environmental inputs for pollination management.
Persuasion: Encouraging behavior change and enhancing knowledge.	Training farmers and agronomists on pollinators and pollination management. Community voluntary codes of practice for pollination management. Research on pollinator management/ agroecological farming and increased farmer collaboration in research. Monitoring and evaluation schemes for pollinators on farms	*Knowledge transfer* Increase knowledge transfer to growers on environmental/pollination management. *Environmental reporting platform* Create an online platform where growers can report on environmental achievements/targets. *Agri-environmental research* Implement more research in agroecological farming (including pollination management) either on research stations or by encouraging farmer experimentation.

de Investigaciones Agropecuarias in Spanish). Farmers were contacted to see if they would be willing to participate in a short survey and if they responded positively, a date was scheduled. Surveys took place between June 2022 and May 2023 and were conducted via an online call. Before the participants gave their consent for the survey to proceed, the purpose of the study, as well as details regarding data storage and usage were explained to the farmers.

3.4 | Step 4. What else can be done

3.4.1 | Activity 1. Identify strategies that the company could introduce to support pollinators

To identify suitable strategies, we developed a method to collect structured feedback from stakeholders on existing pollinator strategies.

Initially, we created a table to summarize existing strategies applicable for the private sector (Table 2). To achieve this, we conducted a structured literature review. First, we carried out a detailed search in google scholar to identify general strategies to promote environmental change or pro-environmental behavior. This search identified three key themes: regulations, economics, and persuasion. Under each of these themes, we searched for examples of when this strategy has been used in pollinator management. As several examples were only applicable at the national level, we extended the table to include examples of how this strategy has been or could be adapted to the private sector. Finally, we reviewed papers that had assessed the effectiveness of these strategies and summarized this information (Data S5).

The developed table (Table 2) can be used as a tool to gain feedback from stakeholders. The implementing company should review the column 'adaptation for the private sector' and identify strategies that they perceive would work well for their business. Additionally, information from growers should be collected to identify implementation barriers, for example, lack of knowledge on pollinator practices, cost of implementation etc. (Data S5; Question 10). These data can be collected via the same online surveys used to identify pollination practices and the data should be analyzed to identify the most prevalent barriers. Table 2 can then be reviewed to see which options would best resolve these barriers. Finally, the information from the company, the growers, and the literature on effectiveness (Data S5) should be synthesized to identify potential strategies e.g., an effective policy, that is suitable for the company and helps the growers overcome prevalent barriers.

For our study, we gained grower feedback by conducting online growers' surveys (as described in Step 3, activity 2) (Data S4; Question 10). To obtain feedback from the company, we conducted key informant interviews (as explained in Step 3, activity 1) (Data S3; Question 6). We then synthesized this data using the process described above to identify potential strategies.

4 | RESULTS

4.1 | Step 1. Is there an issue?

4.1.1 | Activity 1. Identify how dependent the crop is on insect pollination

As indicated in the Klein et al. (2007) review, avocados have a great (40%–90% reduction without pollinators) reliance on insect pollination. This finding was further confirmed by Dymond et al. (2021), whose meta-analysis shows significantly higher fruit set in all open-pollinated treatments compared to treatments where pollinators were excluded.

4.1.2 | Activity 2. Assess managed honeybee pollination service deficits in supply countries

The results indicate that managed honeybees can provide sufficient pollination services in Israel with a pollination service capacity >100%. Chile and Spain exhibited low honeybee pollination deficits (approximately 15%), whereas Peru and South Africa had very high deficit levels, with the capacity to provide pollination to <20% of all insect-pollinated crops (Table 3).

4.1.3 | Activity 3. Assess the threats to wild pollinators

When considering the overall threat to wild pollinators, all regions in the study exhibited either a medium or high threat (Table 4). Israel and Chile showed the highest level of threat, as these countries had a high ranking for all proxies. On the other hand, Peru, Spain, and South Africa showed a medium threat level primarily attributed to less intensive agriculture in these countries.

4.2 | Step 2: Does it matter?

4.2.1 | Activity 1. Calculate how much pollinators contribute economically to the business

Across the five study countries, pollinators potentially contributed around 225 M USD in revenue to the company (Table 5).

4.3 | Step 3. Is it already covered?

4.3.1 | Activity 1. Identify what company strategies currently exist

The interviews revealed that there are no hard strategies (e.g., mandatory and audited) in place to protect pollinators or regulate environmental land management. However, the company emphasized that their core principles are centered around environmental protection, and as such, they exemplify soft strategies (e.g., voluntary and encouraged).

TABLE 3 The pollination service capacity of managed honeybees in supplier countries.

Country	Supply Density (available colonies/ha of insect-pollinated crops)	Demand Density (mean colonies required/ha of pollinated crops)	Pollination Service Capacity (% supply of honeybees relative to demand)
South Africa	0.05	1.0	4.66
Chile	1.68	2.04	82.48
Israel	2.83	2.14	132.12
Spain	1.69	1.98	85.52
Peru	0.39	2.15	17.46

TABLE 4 The relative threat to pollinators in supplier countries through a proxy assessment.

Proxy used	South Africa		Spain		Israel		Chile		Peru	
	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank
Average decadal habitat suitable range loss %	0.79	5	0.29	2	0.36	3	0.58	4	0.45	3
Fertilizer application (kg/hectare)	63	2	112	3	184	4	273	5	88	2
Pesticide application (kg/hectare)	2.16	1	3.02	2	14.62	5	5.8	3	1.74	1
Total ranking score		*8*		*7*		*12*		*12*		*6*

TABLE 5 The contribution from pollinators to the company revenue.

Country	Total Revenue (USD)	Pollinator Contribution to Revenue (USD)
South Africa	87,780,000	57,057,000
Spain	26,910,000	17,491,500
Chile	72,375,000	47,043,750
Israel	36,270,000	23,575,500
Peru	122,730,000	79,774,500
Total for all pollinators	346,065,00	224,942,250

Additionally, the company requires all their growers to be part of the Global GAP certification scheme, and they encourage their suppliers to participate in environmental certification schemes such as the Rainforest Alliance. Although these certification schemes don't specifically focus on pollinators or pollination management, both schemes, particularly the Rainforest Alliance, include requirements that may benefit pollinators such as allocating a percentage of land for natural habitats.

4.3.2 | Activity 2. Identify what pollinator practices are currently being implemented

The surveys showed that the three most common pollinator practices implemented by avocado growers were 'controlling pesticide management to benefit pollinators', 'hiring managed honeybees throughout the pollination season', and 'protecting natural habitat around the edge of the farm' with over 90% of farmers carrying out these practices (Figure 2). In-between 40% and 70% of farmers actively managed their land for pollinators by either planting floral bands (50%) or restoring non-productive areas of their land with native (70%) or non-native (40%) floral resources. Only a small number of farmers kept their own bees and only two out of 10 respondents managed other pollinators such as flies and bumblebees.

All farmers stated that they did not receive any form of support such as training, or financial assistance to implement these pollinator management practices.

4.4 | Step 4. What else can be done?

4.4.1 | Activity 1. Identify strategies that the company could introduce to support pollinators

Based on the literature and feedback from the growers and the company, the following summary discusses potential strategies to support pollinators (see Data S5 for literature on effectiveness and S6 for data from the grower surveys).

4.4.2 | Regulations

In this case study, strict regulations are unlikely to be suitable. The literature suggests that environmental regulations are most effective when there is evidence of high public risk (Pannell, 2008), and the company perspective aligns with this view. For example, one interviewee stated, "*If it is a critical issue, then we can talk about regulations if not, then we talk about principles*." Additionally, for regulations to be effective, there needs to be strong enforcement (Steg & Vlek, 2009). The company perceived this difficult to achieve, as they source around 70% of their produce from external growers and noted that "*ensuring that 3rd party suppliers are meeting certain standards is really tricky*". It is possible to enforce environmental standards by requiring suppliers to join a certification scheme. However, the company was not keen to mandate this (apart from the Global GAP certification scheme) as they perceive their suppliers will sell elsewhere if other certification schemes were required.

4.4.3 | Economic

Economic strategies to encourage pollinator management are likely to be effective, as data from the grower surveys identified that a 'lack of financial resources' was one of the biggest barriers to implementing pollinator practices (48% of respondents). However, only economic incentives are recommended, as the literature highlights that this strategy is generally more effective than economic

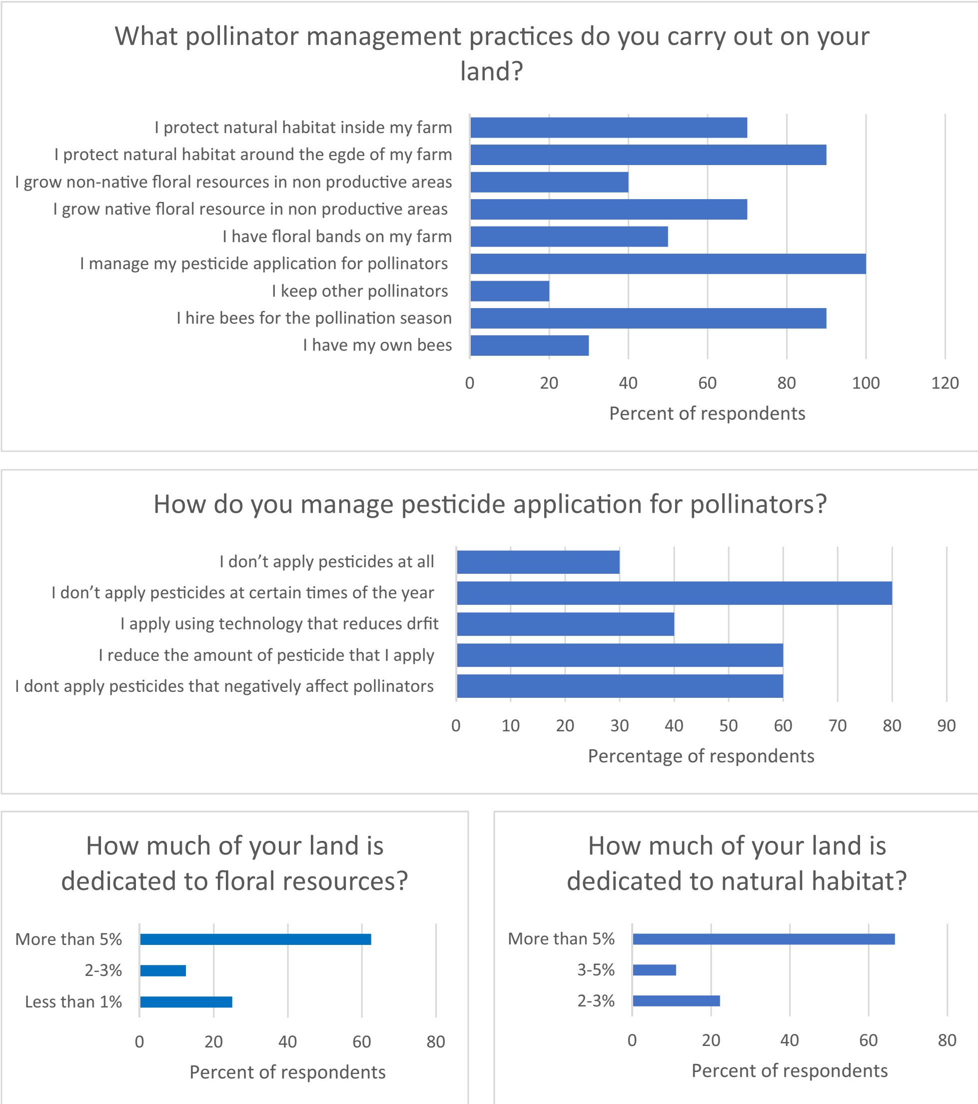

FIGURE 2 Questions and responses to grower survey on pollinator management. Surveys were conducted with 10 Chilean avocado farmers who primarily export their avocados to international markets.

sanctions (Steg & Vlek, 2009). Furthermore, there is substantial evidence that financial incentives paid to farmers for pollination practices can increase pollinator abundance and diversity (IPBES, 2016). However, direct payments were not seen as a feasible or effective option by the company. They prefer to encourage change by paying premiums through certification schemes and by "*demonstrating to farmers that doing things* (an environmental action) *in a certain way will give them more profit*."

4.4.4 | Persuasion

For this case study, persuasion techniques are likely to be a suitable strategy. The literature shows that persuasion techniques can enhance intrinsic motivation, thus improving a farmer's willingness to take action (Mills et al., 2018). The company perspective agrees with this view, considering persuasion techniques as generally the most effective and appropriate. They believe that education and environmental reporting are the most effective methods to create change. Survey feedback also indicated that persuasion, especially education, would be an effective tool, as a lack of access to advice on pollinator conservation measures was identified as another key barrier for implementation (48% of respondents).

5 | SUMMARY OF RESULTS

Overall, the results demonstrate that pollinators are highly important for this company, as avocados are greatly dependent on insect pollination and contribute approximately 225 M USD in revenue. Protecting pollinators is especially critical in Peru, South Africa, Israel, and Chile, as these countries showed either a honeybee deficit or a high level of threat to wild pollinators. Currently, the company has no policies in place for pollinator protection, and while some pollination practices are being implemented by growers in Chile, they do so without company or governmental support. Providing such support could increase the quantity and effectiveness of these actions. The most applicable strategies identified for the company include supporting and persuading growers to participate in certification schemes and enhancing knowledge transfer, with a specific emphasis on the economic benefits of pollinator management.

6 | DISCUSSION

6.1 | Tool application and potential benefits

Agricultural production often contributes to declines in pollinators through natural habitat destruction and agrochemical use (Campbell et al., 2017; Vanbergen et al., 2020). However, many agricultural companies rely on pollination services to provide products for their supply chains. As such, many companies have a strong interest in, and responsibility to, protect pollinators but currently, there is no clear strategy for how they can achieve this. Thus, this article aims to fill this gap. Utilizing literature reviews, this study combines new and established methods to design a rapid assessment tool that allows agricultural businesses to take actions that safeguard pollinators and pollination in their supply chains in the face of pollinator declines. The tool provides information to businesses on the importance of pollinators to their supply chains, understand what the primary risks to pollination are, and allows them to identify effective strategies to protect pollinator species.

The tool can be applied to other agricultural industries within the supply chain, such as retailors and processors, and can be adapted for different crops and countries with relative ease. Minor adjustments, such as identifying different data sources (e.g., a crop's dependence on pollinators or predicted loss of suitable habitat per country) may be required if the examples used in this article do not provide information for the crop or country of interest.

The tool's implementation is expected to benefit growers by supporting them to implement pollinator practices, thereby increasing their short-term (Blaauw & Isaacs, 2014; Raderschall et al., 2021) and potentially long-term production (Dainese et al., 2019). Companies further up the supply chain should also benefit from implementing effective pollinator strategies, as they will ensure sustainable and stable supplies of their trading crop and enhance their sustainability image among the public (Murphy et al., 2022; Tremlett et al., 2020). Wide-scale implementation of such strategies could have a positive impact on pollinator conservation, considering the significant threat posed by intensive agriculture and the need for targeted actions in these landscapes.

6.2 | Study limitations and potential solutions

Limitations associated with this tool stem from the trade-off between conducting an accurate and detailed assessment in a quick and efficient manner. Throughout the process, it was often necessary to use generalized global data to provide specific and localized outputs. For instance, crop dependency values from external research papers were utilized at various steps in this process but it is well established that a crop's dependency can vary depending on the cultivar and the country (Breeze et al., 2016). Similarly, data used to calculate managed honeybee deficits relied on global estimates for the RSR which may not represent actual stocking rates. Additionally, complex assessments were frequently simplified to make the tool more useable by a non-expert. For instance, the method used to assess threats to wild pollinators considered only three out of several known pollinator threats, employed high-level proxies that may not necessarily indicate a key pollinator threat (e.g., fertilizer application rate), and relied on national overview indicators that may not represent the local scale, where the risk matters most.

While the limitations listed above were deemed justifiable to ensure efficiency, a more detailed approach could overcome some of the challenges. For example, to develop a more tailored pollinator strategy, a co-design approach that incorporates recommendations from the growers and the company could be employed (Berthet et al., 2019; Quinio et al., 2022). To better understand pollinator abundance and diversity in different regions, systematic, high-resolution, and long-term data collection on wild pollinator populations globally is required. However, such data is currently unavailable and therefore improvements to the proxy process developed in this study could be applied. For example, in the future, other threats such as climate change and pests and pathogens could be included in the process especially when we have a better understanding of climate refugia for pollinators or technology that can accurately monitor pathogens in the field.

6.3 | Future directions

This tool has the potential to be expanded to provide a more comprehensive assessment of pollinator strategies. Conducting a return-on-investment analysis of the recommended pollinator strategies would be of great value for businesses, as economic considerations often influence decision-making regarding pollinator declines (University of Cambridge Institute for Sustainability Leadership, 2018). Although excluded from this tool due to the perceived challenges and time constraints, such an analysis could be incorporated as part of step 4 (identifying suitable strategies). Future reiterations of the tool should also include a description of the monitoring and evaluation methodology, which is a necessary component of the implementation process but was not covered in this study due to the impracticality of testing it with the case study.

Furthermore, the tool could be adapted to broaden the scope of species conserved by incorporating an assessment of other ecosystem services, such as natural pest regulation and soil health. Implementing a single environmental assessment for multiple ecosystem services would be cost-effective and should not complicate the execution, as environmental practices and strategies are often complementary. For instance, pollinator practices can benefit other ecosystem services (e.g., floral strips can be beneficial for pollination and natural pest control; Albrecht et al., 2020; Egan et al., 2020), and strategies could be easily extended to cover a range of ecosystem services (e.g., knowledge transfer could incorporate several environmental topics). To incorporate this change, significant adaptations would be necessary for steps 1 and 2 as the methods to assess the importance and economic contribution of different ecosystem services are inherently variable. However, steps 3 and 4 could easily be adapted by reviewing the literature on environmental strategies and practices for the ecosystem service of interest and then adapting the interview and survey questions.

This tool aims to encourage agricultural businesses to implement positive action for pollinators by providing a clear process to create effective strategies. However, such methodological tools alone may not guarantee widescale implementation, and therefore, further research is needed to understand effective approaches for encouraging industries to take action. Increased governmental support or intervention may be necessary in some cases, as it is often the preferred choice for private companies (CBI Economics, 2022). However, considering the economic benefits businesses can gain from pollinator protection, softer approaches that raise awareness and highlight the importance of pollinators may also be effective. Additional research in targeted areas, such as quantifying the additional production benefits resulting from pollination (e.g., production stability and waste reduction) and understanding how different actors in the supply chain will be affected by pollinator losses, may also be required to provide further evidence to encourage businesses to act.

AUTHOR CONTRIBUTIONS

Keira Dymond: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing—original draft, visualization. **Juan L. Celis-Diez:** Writing—review and editing. **Carl Lymna-Dennis:** Conceptualization. **Valeska Rojas-Bravo:** Investigation, Writing—review and editing. **Jaime Martínez-Harms:** Writing—review and editing. **Simon G. Potts:** Conceptualization, Writing—review and editing. **Michael P. D. Garratt:** Conceptualization, Writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data has not been deposited in a repository as most of the data is included in the manuscript or supplementary material. In the case of the human subject data, it was not deemed suitable to deposit, however, this data could be made available on request. For all human subject data, ethical clearance was given by the University of Reading, Ethical Committee 2021. Participation was voluntary and all participants were made aware of how their data would be used before the surveys/interviews commenced.

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SUPPORTING INFORMATION

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