



International Journal of Agricultural Sustainability

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tags20

# Two enabling factors for farmer-driven pollinator protection in low- and middle-income countries

Stefanie Christmann, Aden Aw-Hassan, Yasemin Güler, Hasan Cumhur Sarisu, Marc Bernard, Moulay Chrif Smaili & Athanasios Tsivelikas

**To cite this article:** Stefanie Christmann, Aden Aw-Hassan, Yasemin Güler, Hasan Cumhur Sarisu, Marc Bernard, Moulay Chrif Smaili & Athanasios Tsivelikas (2021): Two enabling factors for farmer-driven pollinator protection in low- and middle-income countries, International Journal of Agricultural Sustainability, DOI: <u>10.1080/14735903.2021.1916254</u>

To link to this article: https://doi.org/10.1080/14735903.2021.1916254

© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



6

Published online: 28 Apr 2021.

Submit your article to this journal 🕝



View related articles 🗹



View Crossmark data 🗹



OPEN ACCESS Check for updates

## Two enabling factors for farmer-driven pollinator protection in low- and middle-income countries

Stefanie Christmann<sup>a</sup>, Aden Aw-Hassan<sup>b</sup>, Yasemin Güler<sup>c</sup>, Hasan Cumhur Sarisu<sup>d</sup>, Marc Bernard<sup>e</sup>, Moulay Chrif Smaili<sup>f</sup> and Athanasios Tsivelikas<sup>a</sup>

<sup>a</sup>ICARDA, Rabat, Morocco; <sup>b</sup>Independent Consultant, Edmonton, Canada; <sup>c</sup>Directorate of Plant Protection Central Research Institute (CRIPP), Ankara, Turkey; <sup>d</sup>Fruit Research Institute (MAREM), Isparta, Turkey; <sup>e</sup>German Federal Office for Agriculture and Food (BLE), Bonn, Germany; <sup>f</sup>National Institute for Agricultural Research (INRA) Kenitra, Morocco

### ABSTRACT

Reward-based wildflower strips are the most common approach for pollinator protection in high-income countries. Low- and middle-income countries cannot afford this practice. A promising pilot study in Uzbekistan introduced an alternative approach, Farming with Alternative Pollinators, focusing on farmers as target group, marketable habitat enhancement plants and a method-inherent incentive: higher income per surface achieved already in the first year. We hypothesized that higher income would be a replicable enabling factor across continents, but a knowledge-raising campaign would be necessary in many low- and middle-income countries. We assessed the replicability of the incentive with a small number of farmers in 2015-2016 in Morocco but focused on assessing if farmers have sufficient knowledge to recognize wild pollinators and use this approach. We conducted 766 interviews using a standardized questionnaire with randomly selected smallholder farmers in three culturally different farming societies of lowand middle-income countries (Morocco, Turkey and Benin). Farming with Alternative Pollinators induced higher income (75% (2015), 177% (2016)) also in Morocco. The trial and the survey show the indispensability of a knowledge-raising campaign as the second enabling factor. However, based on capacity building, Farming with Alternative Pollinators could have indeed high potential to promote pollinator protection in low- and middle-income countries.

#### **KEYWORDS**

Farmers' knowledge; Farming with Alternative Pollinators (FAP); incentive; motivation; scalable

The manuscript highlights:

- Social science is the key for pollinator protection in the Anthropocene
- Farming with Alternative Pollinators (FAP) increases yields significantly
- The method-inherent incentive promotes farmerdriven pollinator protection
- Farmers in Benin, Turkey and Morocco cannot recognize wild pollinators
- Farmer-driven pollinator protection requires capacity building

### Introduction

A recent analysis of pollinator protection strategies of the European Union found them inadequate as they focus on technical and ecological approaches for land management, but rarely on change of motivation and behaviour (Marselle et al., 2020). 'Environmental degradation ultimately stems from human behavior' (Amel et al., 2017); the 'pollination crisis is a consequence of human actions, short-term priorities, and decisions' (Christmann et al., 2017). In the Anthropocene, human interventions most critically endanger pollinators and thus key agents of terrestrial life in

CONTACT Stefanie Christmann 🖾 s.christmann@cgiar.org 🖃 ICARDA, B.P. 6299, 10112 Rabat, Morocco

© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

many countries. We need protection approaches, which focus on humans and allow all countries including low- and middle-income countries (LIC, MIC) to conserve these species (Christmann, 2020).

The full value of (wild) pollinators is probably not yet recognized even by ambitious valorization studies (Mwebaze et al., 2018). Pollinators are the basis of biodiversity in its three aspects - genetic diversity, diversity of species and of habitats (in terrestrial ecosystems) - agriculture and humankind (Christmann, 2019a; Gallai et al., 2009; Potts et al., 2016). A balanced diet within the planetary boundaries requires pollinator conservation (Chaplin-Kramer et al., 2014; Christmann, 2019b; Chaplin-Kramer et al., 2019). 87% of all flowering plants depend on pollinators for regeneration (Ollerton et al., 2011), consequently all ecosystem services (ES) provided by these 87% of flowering plants depend on pollinators (Christmann, 2019a). Pollinator loss can cause interlinked degradation and later poverty spirals, trigger counterproductive human responses and finally result in a Pollinator-Loss Syndrome (Christmann, 2019a). Climate change can accelerate pollinator decline (Erenler et al., 2020; Gérard et al., 2020; Goulson et al., 2015; Potts et al., 2016), but pollinators are essential for climate change adaptation of plants and ecosystems as cross-pollination enriches genetic diversity (Christmann, 2019a).

Agro-environment schemes (AES) and national protection strategies are available in a number of high-income countries (HIC) e.g. France, Netherlands, United Kingdom and Norway (Christmann, 2019c; Dicks et al., 2016a). The European Union invests billions to subsidize AES (Batáry et al., 2015; De Snoo et al., 2013; McCracken et al., 2015), but even in countries paying farmers for seeding wildflower strips (WFS) for decades, the decline of pollinators progresses (Biesmeijer et al., 2006; Carvalheiro et al., 2013; EU, 2020; Hallmann et al., 2017; Powney et al., 2019; Zattara & Aizen, 2021). Farmers dislike even paid WFS (Kleijn et al., 2019). Farmers' efforts to protect pollinators in agricultural lands remain very limited (Potts et al., 2016). WFS-research assesses impacts mostly on pollinator diversity; impacts on pests and natural enemies are sometimes also assessed, but rarely by the same study and even more rarely farmers' responses are described (Albrecht et al., 2020; Kleijn et al., 2019; Uyttenbroeck et al., 2016). Several authors highlighted that simple payment is not sufficient and that protection of ES or biodiversity depends highly on intrinsic motivation

and aspects stimulating such motivation (Ahnström et al., 2009; García-Llorente et al., 2012; Knapp et al., 2020; Kusnandar et al., 2019; Marselle et al., 2020; Meijer et al., 2015; Mwebaze et al., 2018).

LIC and MIC cannot afford AES for seeding WFS; therefore, more research is needed on enabling factors feasible for these countries. Assessments on the value of pollinators (An & Chen, 2011; Gallai et al., 2009) can trigger motivation to preserve pollinators. The importance of policies (Christmann, 2019c; Cole et al., 2020; Dicks et al., 2016b; EU, 2020; Gemill-Herren et al., 2021) and a structured policy dialogue including worst-case scenario, low-cost crosssector policy instruments and cross-cutting benefits have been highlighted (Christmann, 2020).

However, how to convince farmers? As farms are business entities working for high income, a method with inherent incentive as suggested by Christmann and Aw-Hassan (2012) might indeed be one crucial enabling factor to motivate farmers in particular, if AES are not affordable (Christmann, 2019b; 2019c; Christmann et al., 2017). As farmers usually prefer to use their entire land for production (Christmann et al., 2017), Farming with Alternative Pollinators (FAP) pursues land-sharing by strips of marketable habitat enhancement plants (MHEP; spices, oil seeds, crops, medicinal plants or forage plants) and lowcost materials for nesting- and water support. Particularly in irrigated dry areas, crops can be even more effective than wildflowers to sustain beneficial insects (Tscharntke et al., 2016). The hypothesis of FAP was that the demonstration of the economic value of pollination and pest control can motivate farmers to protect pollinators (Christmann & Aw-Hassan, 2012). The encouraging pilot study in Uzbekistan confirmed both (a) higher income per surface and (b) higher income as effective motivating factor for farmers (Christmann et al., 2017).

However, is the enabling factor *higher income per surface* replicable across countries and continents? The case study from Uzbekistan is the only published field study using FAP by now. Additionally, in case this economic incentive is replicable in Europe or America, is the enabling factor *higher income* also sufficient for farmer-driven pollinator protection in more typical MIC and LIC with mostly lower (school) knowledge? The FAP-pilot project was not conducted in a typical MIC but in the former Soviet country Uzbekistan. Uzbekistan nearly eradicated illiteracy (0.01% of adults above 15 years) (UNESCO, 2020). Even in HIC, farmers' knowledge on pollinators is partly only moderate (Hanes et al., 2013; Hevia et al., 2020; Park et al., 2018). In HIC, higher education levels can be aligned with more knowledge and awareness on pollinators and even more willingness to protect pollinators (Ahnström et al., 2009; Hevia et al., 2020; Mwebaze et al., 2018). In LIC and MIC, farmers' knowledge about pollinators differs a lot from country to country and from region to region within countries, farmers are often not able to recognize wild pollinators as pollinators or leastwise as beneficial (Ali et al., 2020; Elisante et al., 2019; Frimpong-Anin et al., 2013; Hall & Martins, 2020; Kasina et al., 2009; Munyuli, 2011; Rawluk & Saunders, 2019; Smith et al., 2017; Tarakini et al., 2020).

Common lack of knowledge about the importance and value of wild pollinators can result in counterproductive priorities like chemicals and clean fields without weeds and insects instead of safeguarding pollinators as production factor. Wild pollinators are not a private, but a common resource (Christmann, 2019a) and to some extent mobile. A farmer can suspect that neighbours might benefit more from his conservation efforts than the own farm. Why to support free riders? However, if a farmer knows how habitat enhancement pays off for himself already in the first year and for low or no investment, he might enhance habitats in his private land though free riders will benefit as well (Christmann et al., 2017). McCracken et al. (2015) realized strong impacts of social factors and that farmer experiential learning is a key process. The importance of attitudes, values, social learning and networks for agroecological approaches has been highlighted (Ahnström et al., 2009; De Snoo et al., 2013; Knapp et al., 2020; Smith et al., 2019). Field management is a result of farmers' knowledge and values, common behaviour and traditions, individual and group decisions, promotion of chemicals by companies, trainings, policies against land parcelling, use of large-scale farm equipment, labour costs, prices, marketing options and consumer demand. Therefore, more contributions from social scientists to research supporting pollinator protection are recommended (Christmann et al., 2017 De Snoo et al., 2013;; Hall & Martins, 2020; Knapp et al., 2020).

Therefore, we tested if the already identified enabling factor *higher income* would be replicable in a country very distant from Uzbekistan, as agronomical replicability is the precondition for further studies. We used a small grant project in Morocco and – for better comparability with the pilot study in Uzbekistan (Christmann et al., 2017) - the same main crop: cucumber. Cucumber is not consumed daily as in Uzbekistan during the summer, but it is a common crop also in Morocco, several cultivars are available all around the year from production in open fields and greenhouses. Due to observations already during the trials in Morocco, we focused on assessing if a second enabling factor would be needed in more typical LIC and MIC. Therefore, we analysed farmers' knowledge about pollinators and pollination in three culturally differing LIC and MIC with different rates of illiteracy, Morocco, Benin and Turkey, to learn, if farmers would need a knowledge-raising campaign as the second enabling factor to use FAP and benefit from the methodinherent incentive higher income.

### **Methods**

### Assessing the replicability of the enabling factor higher income

In Morocco, national agricultural researchers and extension services had not worked on wild pollinators for more than four decades at least. The Green Morocco Plan (since 2008) is a large governmental agricultural modernization strategy focusing on drip irrigation, crop change from cereals to fruits and vegetables and value chains. Large-scale fields instead of small-parcelled farms are recommended. Wild pollinators and their habitat requirements had not been considered. The project site in Skhirat region is around 25 km south of the capital Rabat and characterized by intensive smallholder farming. All participating farmers were male and between 28 and 51 years old. They owned between 0.75 and 10 ha. All farmers were literate, all learnt agriculture from their fathers or another relative, none of them took part in agricultural trainings. Farmers and fields were visited nearly each week.

The FAP methodology is described in detail (Christmann et al., 2017): FAP fields for smallholders have the main crop in 75% of the area and use 25% for habitat enhancement, whereas in control fields the main crop is planted in the entire area. The impacts of habitat enhancement are measured concerning insect diversity and abundance and net income per surface. Farmers contribute to the selection of MHEP, nesting and water support, they do all agricultural field work and

receive feedback on the impacts. In Morocco, the cucumber cultivars from Uzbekistan are not available, so we used Mydas, Winto, Dephla, Poinsette and Amiral with five replications and the same randomization plan as in Uzbekistan in the 75% zone. The 25% zone of control fields had a local cucumber variety. The farmers agreed on MHEPs partly different from Uzbekistan, in 2015: sunflower, faba bean, coriander, zucchini, mint, watermelon, rosemary, eggplant, green pepper and pumpkin; in 2016 rosemary was deleted and hot pepper added. Nesting support out of local materials (e.g. bundles of hollow stems in used waterbottles, old wood with boreholes, packed bare soil), field size (0.03ha) and distance between fields (at least 2000 m) were as recommended.

Insects were collected four times by transect in 2015 and five times in 2016; each sweep netting transect was conducted for 15 min: one transect around the field 1 m far from the field boundary (at the border of the 25% and the 75% zone) and twice vertical (30 m) in the middle of the field. Two conducted such transects were during the flowering of the main crop in 2015 and three in 2016, one before and one after its flowering, additionally once by malaise trap during flowering of the main crop (48 h; at 15 m length; position of the malaise traps: partly in the 25% zone and partly in the 75% zone) each year. Pests were sampled additionally by the beating method.

For the economic assessments, the number of cucumber fruits was counted and weighed. Investment costs in FAP and control fields are the same in the 75% zones. The income from the 75% zones was assessed by multiplying total weight with market price per kg. The income from the 25% zones of control fields was assessed by total weight multiplied by market price per kg; investment costs were deducted. The income of the 25% zone of FAP fields was computed by multiplying total weight with market price per kg of MHEP minus investment costs and minus 100 MAD (1.5 person days per FAP field) as labour costs for harvesting MHEP, though in our trial farmers harvested themselves.

Concerning the statistical analysis, a linear mixed model was applied to identify significant effects, taking into consideration for each year the fields that were finally assessed. Based on this model the effects of the farming system (i.e. FAP fields (as total) and Control field(s) (as total)), the cultivars, as well as the interaction between farming system and cultivars were considered as fixed effects; while the blocks (i.e. replications within individual fields) nested by each one of the fields assessed were considered as random effects. In the case of significant effects, post hoc comparisons were employed by using Student's t-test, to mark the significant differences.

### *Survey to assess the need of a second enabling factor:* knowledge-raising campaign

The three selected countries have different illiteracy rates: Benin 57.64%, Morocco 26.25% and Turkey 3.85% (UNESCO, 2020). Interviewers used a semi-structured questionnaire including nine questions and some qualitative sub-questions to assess the knowledge of farmers' ex ante of any pollinator project (Figure 1). Farmers were selected randomly. Interviewers used the questionnaire translated to Arabic, Turkish or French. For data evaluation, the responses to qualitative questions were standardized by a coding procedure. Responses to open questions were linguistically analysed and coded according to their concurrence of meanings.

In Morocco, 110 questionnaires were conducted in the Kenitra region (north of Rabat, close to an urban region, farmers shift from cereals to vegetables), 100 in the Sefrou region (Middle Atlas, long tradition of early flowering fruit orchards), 100 in the Settat region (semi-arid, tradition of cereal monocultures) and 97 in Errachidia (traditional oasis with small, diverse fields and date palm), 407 in total. In Turkey, we did a total of 253: 44 in Isparta province (Mediterranean region with fruit orchards), 174 in Konya (Central Anatolia Region growing cereals, fruits and vegetables) and 35 in Ankara province (Central Anatolia Region; vegetables and stone fruits). In Benin, we conducted a total of 106 questionnaires in 5 provinces, 18 in Collines (main crops: maize and cassava), 18 in Albori (maize and cotton), 4 in Atlantique and 52 in Zou (both: maize and oil palm), 14 in Borgou (maize and cotton).

In Turkey, all participants were literate, 49% had attended primary school, 8.3% even university. In Benin, 14% of participants were illiterate, 40% visited high school or college and 5.7% even university. In Morocco, 58% were illiterate and 21% had only primary school, 1% visited university.

Information provided: Pollinators are insects flying from one flower to another to collect nectar and pollen

)istrict					
Number of the questionnaire	Name of the farmer	Education level	How many ha does your farm have?		
Question 1	Which crops did you produce for the last 5 years?				
	Bread wheat	Yes	No		
	Durum wheat	Yes	No		
	Barley	Yes	No		
	Maize	Yes	No		
	Millet	Yes	No		
	Sorghum	Yes	No		
	Rice	Yes	No		
	Potato, sweet potato,	Yes	No		
	Fennel, onion, carrot, beet, cabbage, spinach,	Yes	No		
	green beans, pigeon pea, lettuce, soybean				
	Tomato	Yes	No		
	Eggplant, pepper, chilli pepper, capsicum	Yes	No		
	Melon, watermelon, pumpkin, zucchini, cucumber	Yes	No		
	Strawberry, raspberry	Yes	No		
	Faba bean	Yes	No		
	Spices	Yes	No		
	Apples, peach, apricots, cherry, pear, avocado, guava, mango	Yes	No		
	Orange, lemon, grapefruit, mandarine, papaya	Yes	No		
	Cashew, almond, nuts	Yes	No		
	Groundnut	Yes	No		
	Sugar cane, oil palm, olive	Yes	No		
	Cotton	Yes	No		
	Sesame	Yes	No		
Question 2	Have you ever noticed any problems of pollination?	Yes	No		
	If « yes », which problems ?				
Question 3	Have you ever used honeybees in collaboration with a beekeeper?	Yes	No		
Question 4	Which pollinators do you know?				
Question 5	Have you ever seen pollinator nests in or near your field?	Yes	No		
Question 6	Do you need pollinators for your crops?	Yes	No		
	If « yes», for which crops?	-			
Question 7	Which pollinators do you think is the best?	Honeybees	Other species		
906-67-79-87-65,54) 	Why?				
Question 8	Have you assembled your fields since 2000?	Yes	No		
Question 9	Have you increased the use of insecticides and fungicides since 2000 per ha?	Yes	No		
	If « yes », by how much %?				
	Contract and a finite full second and experiences and the second s	1	1		



### Results

### Enabling factor: higher income

Higher income as an incentive for farmers – and thus replicability of the enabling factor for farmer-driven pollinator protection - was confirmed (Figure 2(A, B)). As in Uzbekistan, the trials were conducted without initial training of farmers on pollinators and pollination, and already the trials unveiled the need to raise the knowledge of farmers in a more typical MIC. In 2015, farmers doubted the value of the experiment as we would not bring honeybee hives to the fields. Additionally, all participating farmers had low interest in the trial as they regard cucumber as a difficult crop due to the high risk of powdery mildew, aphids and thrips. In Morocco, cucumber is not high in demand as in Uzbekistan. In 2015, we started with 6 farmers (4 FAP, 2 control), but FAP-1 farmer did not irrigate the field even after reseeding. FAP-2 farmer had the best field at the beginning with high pollinator diversity and abundance, but 12th May his father visited the field, noticed high abundance of insects and used chemicals 'to protect the crop' (farmer's father). It took about 2 weeks until FAP-2 regained high insect diversity. FAP-3 farmer had a serious problem with his well in the middle of the trial and prioritized crops with a higher market value. FAP-4 and Control-1 farmers collaborated well; FAP-4 farmer contributed many observations. Control-2 farmer had so low cucumber quality (Figure 2(C)) that he could not sell his product and dropped out. Therefore, in 2015, we used only FAP-2-4 and Control-1 for the assessments (Figure 2(A,D,E)).

In 2016, we worked with 4 FAP and 3 control farmers, all farmers performed well. They knew that FAP fields provided better income than control fields in 2015. The better performance of all farmers involved shows the value of the incentive: In the second year, they were more curious and eager to contribute to the trial. In particular, the FAP-farmers proudly informed us about their observations and regarded themselves as recognized stakeholders. They informed friends and relatives on the trials. Visiting farmers realized the difference in abundance and diversity of (flower-visiting) insects between FAP- and common fields at once. Already in 2016, FAP-4 farmer started a FAP-pepper trial on his own (with four MHEP). The investment is low as farmers need seeds for the entire field anyway; already in the first year, farmers earn more, so the barrier to adopt FAP is

low. The FAP-2 farmer from 2015 seeded coriander strips throughout his entire farm in 2016 and following years. FAP farmers from 2016 offered their fields for further trials with other main crops.

In 2015, in total FAP farmers (FAP-2-4) had on average 53.8% higher income per unit area than Control-1 farmer due to better cucumber yields, while the income from 25% zones was nearly equal (Figure 2(A)). FAP fields (FAP-2-4) had on average 6538 cucumber fruits in the 75% zone, whereas Control-1 had 2783 fruits. Based on the 4 project fields of 2015, the 75% zone of FAP fields showed a significant increase of productivity in terms of number of cucumber fruits ( $\alpha$ =0.01) and in terms of total weight ( $\alpha$ =0.01).

In 2016, all fields were highly affected by powdery mildew reducing the total income from all fields. The total net income per surface was on average 156.1% higher from FAP fields than from control fields due to better cucumber yields and relatively high income from MHEP, as they were not affected by powdery mildew (Figure 2(B)). FAP fields had on average 2622 cucumber fruits in the 75% area, control fields on average 1506. Based on the 7 project fields of 2016, the 75% zone of FAP fields showed significant increase of productivity in terms of number of cucumber fruits ( $\alpha$ =0.01) and total weight ( $\alpha$ =0.01), as well as income from cucumber  $(\alpha=0.01)$  and also total net income from fields ( $\alpha$ =0.01). Similar to the 2014-trial in Uzbekistan, which was heavily affected by aphids (Christmann et al., 2017), in 2016 the MHEP buffered against income loss per surface to some extent. Based on farmers' feedback, we recommend only 4 cultivars and 4 replications in the 75% zone for FAP trials to reduce time for harvesting and field books.

The entomological results explain the economic results. In 2015 and 2016 the samplings both by transects (Figure 2(D,F)) and by malaise traps (Figure 2(E,G)) demonstrated that FAP fields had higher diversity, often more than 10 genera of flower visitors including *Osmia, Halictus, Xylocopa, Amegilla, Colletes,* hoverflies, wasps, butterflies and honeybees. The transects also showed more natural enemies (Figure 2(D,F)) than control fields. In particular, coriander attracted high diversity of pollinators (hoverflies, wild bees, wasps and others) and also natural enemies such as seven-spotted ladybird, Adonis' ladybird, hoverflies, mirid bugs, common green lacewing and flower bugs. Whereas, for instance, sunflower attracted mainly bees and



**Figure 2.** Results of field trials. (A) FAP impact on average net income in 2015, Skhirat. (B) FAP impact on average net income in 2016, Skhirat. (C) FAP impact on cucumber quality, Skhirat 23 June 2015. (C1) FAP-2 field had high diversity of pollinators, high number of fruits, cucumbers were straight with fully dark green colour without marks. (C2) Control-2 field had only honeybees and in very low abundance, the (mostly) curved product was not marketable. (C3) Control-1 field had higher abundance of honeybees and slightly higher pollinator diversity than Control-2, but less than the FAP fields; the product was marketable for low price. (D) FAP impact on diversity of wild insects (genus), 2015 (ransects). (E) FAP impact on diversity of wild pollinators (genus), 2015 (malaise traps). (F) FAP impact on diversity of wild insects (genus), 2016 (malaise traps).

before flowering natural enemies like flower bugs and hoverflies. Also, zucchini attracted different wild bees. The beneficial insects frequently moved between MHEP and main crop. Control fields had most of the time only honeybees and after flowering of the main crop no flower visitors anymore, whereas FAP fields sustained a high diversity of flower visitors. This confirms the results from Uzbekistan, where diversity of pollinators, including Osmia, Halictus, Anthidium, Anthophora, Xylocopa, hoverflies, butterflies, and of natural enemies, was higher in FAP fields, while control fields hosted mainly honeybees and rarely natural enemies (Christmann et al., 2017). Different to Uzbekistan, in Morocco wasps were important pollinators as well. Among pests, in particular cotton aphid, western flower thrips and cucurbit beetle had lower abundance in FAP fields than in control fields.

### *In LIC and MIC, FAP requires a second enabling factor:* knowledge-raising campaign

The questionnaires unveiled that in all participating countries, farmers' knowledge about pollination and pollinators is very low, often vague and not sufficient for FAP. FAP introduction without an integrated knowledge-raising campaign might face similar problems as the first trial in Morocco, where farmers were not aware of the value of wild pollinators, the multiple benefits of MHEP and where high insect diversity was partly misunderstood as high pest abundance. In Morocco, Benin and Turkey, farmers do not recognize the diversity of wild pollinators (Figure 3(A)). 57% of participating farmers in Morocco mentioned honeybees as pollinators, 74% in Turkey and 72% in Benin. However, Moroccan farmers rarely recognize flies and bumblebees, only 0.4% mentioned wild bees. In Turkey, only 1.6% mentioned wild bees and 7.6% bumblebees. Farmers list even non-pollinating insects like grasshoppers as pollinators. 76% (Morocco), 38% (Turkey) and 65% (Benin) of farmers never recognized a pollinator nest in or around their farms.

The majority of farmers regards honeybees as more important than wild pollinators (Morocco 99.4%, Turkey 67.5%, Benin 67.9%). Farmers' responses concerning the reasons for this ranking show lack of precise knowledge on pollinators and pollination (Figure 3(B)). Many wild pollinators are more effective in adjusting pollen to the stigma than honeybees; high diversity of wild pollinators enhance fruit sets and yields (Blaauw & Isaacs, 2014; Christmann et al., 2017; Garibaldi et al., 2013). In Morocco, 70% of farmers based their higher ranking of honeybees on the value of honey production. Farmers are not aware that the value of pollination for crop production is much higher than the value of honey.

Question 6B (Figure 1) showed that farmers in Turkey, Morocco and Benin have very blurred understanding which crops need animal-mediated pollination and which do not, crops with 'essential' demand for pollinators (Klein et al., 2007) are recognized as pollinator-dependent only by a few growers of these crops, whereas many pollinatorindependent crops are listed as pollinator-dependent (Table 1). Even farmers able to identify at least some of their pollinator-dependent crops as such, list also pollinator-independent crops. As pollination is an important production factor, farmers might take wrong decisions in the case of bad yields e.g. increasing fertilizer or cutting trees.

21% (Morocco), 30% (Turkey) and 58% (Benin) of participating farmers confirmed pollination problems, but their capacity to identify and describe them was limited (Figure 3(C)). 12.6% of Moroccan farmers (1.8% from Benin) said that flies destroy flowers. Many farmers cannot identify, if the problem is related to lack of pollinators, to human practice (use of chemicals), to plants (disease, low production of flowers) or external factors like lack of water. In total, the responses unveil the need for information on pollination and pollinators.

52% (Morocco), 18.4% (Turkey) and 83% (Benin) of participants increased the size of the fields by ploughing and using former field edges as part of enlarged fields since 2000. 77.4% (Morocco), 54.7% (Turkey) and 91.5% (Benin) of farmers increased the use of chemicals since 2000. According to farmers, they increased chemicals by 43% (Morocco), 48% (Turkey) and 78% (Benin). So, they aggravated threats to pollinators in two important aspects to a high extent, particularly in Benin.

### **Policies**

The Moroccan Ministry for Agriculture and Fishery appointed the national extension service Office National du Conseil Agricole (ONCA) to out scale FAP. Since 2019, staff of the FAP team have been training professional ONCA trainers and providing them with diverse visual materials for farmers (film

![](_page_9_Figure_1.jpeg)

![](_page_9_Figure_2.jpeg)

Figure 3. Farmers knowledge about pollinators and pollination (multiple suggestions possible). (A) Pollinator diversity as recognized by farmers. (B) Reasons, why farmers regard honeybees as more important than wild pollinators. (C) Pollination problems as identified by farmers.

50

		Pollinator dependency according to Klein	Percentage of farmers producing this crop stating that it depends on
Country	Crop	et al. (2007)	pollinators
Morocco	Melon	Essential	5.9
Morocco	Apple	Great	19.5
Morocco	Tomato	Little	17.1
Morocco	Wheat	Independent	4.7
Turkey	Watermelon	Essential	4.5
Turkey	Zucchini	Essential	0
Turkey	Cherry	Great	50.04
Turkey	Apple	Great	10.4
Turkey	Tomato	Little	5.9
Turkey	Olive,	Independent	1.9
	Maize		1.9
	Chickpea		1.9
Benin	Cashew	Great	18.1
Benin	Mango	Great	12.9
Benin	Sesame	Modest	0
Benin	Groundnut	Little	6.7
Benin	Maize	Independent	24.9

Table 1. Farmers have very limited knowledge whether the crops they grow themselves need pollinators or not.

documentaries, PDF-files for ICT, brochures). Based on the experience with FAP in three FAP projects in Morocco and discussion on the advantages of a cross-sector policy mix as described by Christmann (2019c), Morocco joined Promote Pollinators (https:// promotepollinators.org/) on 10 May 2019 and elaborates a national pollinator protection strategy.

### Discussion

The higher diversity and abundance of beneficial insects in FAP fields and the higher net income from FAP than from control fields for the same main crop in both years also in Morocco demonstrated high likelihood that FAP is agronomically replicable across countries and continents. In both pilot FAP projects (Uzbekistan, Morocco), the collaboration with farmers improved in the second year, when farmers knew about the FAP impact on yields. Farmers are aware that the additional income gain depends on their own performance over months, they gain an incentive to learn pollinator protection in a comprehensive way including pollinator-friendly pest control. The method-inherent and performancerelated incentive of FAP is a crucial enabling factor for pollinator protection notably in countries not able to pay rewards. If the value of pollination services would be assessed on field or crop level and communicated to farmers more often, these decision makers would have an incentive to notice pollinators and conserve them. Human behaviour and incentives are crucial factors for pollinator protection (Hall & Martins, 2020; Marselle et al., 2020); however according to Kleijn et al. (2019), only three publications out of around 100 reviewed articles on WFS and environmentally driven habitat enhancement assessed the income gain for farmers. We suggest that the diverse effects of about 20 different MHEP should be analysed in detail in a larger, focused field study by a multidisciplinary team. As we wanted to replicate the trial from Uzbekistan, we used the field shares 75% and 25%; however, we also suggest a study to analyse the maximum size of habitat enhancement zone accepted by farmers and the minimum size needed to sustain pollinators - in particular comparing smallholders and large-scale producers.

Comparing the results of questionnaires in three countries, farmers in Turkey had better formal education than farmers from Benin and Morocco, but the differences concerning knowledge on pollinators and pollination are not considerably higher except concerning pollinator dependency of crops. We, therefore, assume that lessons on pollination and pollinators have not been part of formal education also in Turkey at the time the interviewees have been in school age.

Can farmers care for pollinator conservation, as long as they do not even realize these flying insects as beneficial wild pollinators, as long as they do not recognize their nests and as long as they do not know their habitat requirements? Farmers are often not even able to differentiate the most known pollinators, honeybees, from pests, as reported by Munyuli (2011) from Uganda; in Punjab (Pakistan) even 35% of interviewed farmers mixed them up (Ali et al., 2020). According to Tarakini et al. (2020), many farmers in Zimbabwe are in fear of bees due to stings and have too low knowledge to protect them. Even if a reward-based programme for seeding WFS and seed packages would be available in these three countries, the low knowledge of farmers might most probably counteract pollinator protection, because e.g. high insect abundance can be misunderstood as high pest abundance.

In many LIC and MIC, a second enabling factor, a *knowledge-raising campaign*, might be necessary. To enhance the knowledge of farmers, we recommend PDF files and short films for social media describing (a) what is animal-mediated pollination, (b) pollinator dependency of important main crops in respective countries, (c) pollinator diversity and habitat

requirements, (d) effective MHEP for each season, (e) instructions on the provision of nesting support out of local materials, (f) information on the economic value of crop-pollination versus honey production, (g) economic results of FAP-trials in respective countries, and (h) average figures on reduced pest abundance based on trials in respective countries. This is not costly. We regard capacity building by ICT as an important enabling factor for farmerdriven pollinator protection in LIC and MIC. We also suggest farmer trainings, Farmer-Field-Schools and enhanced education of agricultural advisors. Christmann (2019c) recommends further measures to enhance the knowledge of the entire population, (a) curriculum change in primary or secondary schools to integrate lessons on pollinators and pollination, (b) regular broadcasts on pollinators in national mass media, (c) a yearly contest for the best performing community for promotion as ecotourism site. We also recommend yearly campaigns to enhance school gardens, parks, gardens of administrative bodies, villages, hiking ways etc. for pollinators. We regard all these tools as part of the enabling factor knowledgeraising campaign.

### Conclusions

Our results show that (1) a method-inherent and performance-related incentive based on the economic interests of farmers, and (2) enhancing farmers' capacity to benefit from and protect pollinators are two key enabling factors for pollinator protection particularly in countries unable to pay AES. Instead of protection understood as an outcome of subsidized technical enhancement of fields (more pollinatorfriendly agriculture), we suggest focus more on the triangle of knowledgeable humans deciding on plantpollinator networks, on farmer-friendly and farmerdriven pollinator protection. We need to adapt pollinator protection to the conditions of the Anthropocene (Christmann, 2019c, 2020; Hevia et al., 2020; Kusnandar et al., 2019).

### Acknowledgements

We acknowledge funding by The German Federal Ministry for Economic Collaboration and Development (BEAF [81182268]; ITAACC [81197814]) and the Federal Ministry for the Environment, Nature Protection and Nuclear Safety within the International Climate Initiative (IKI [17\_IV\_065]), the collaboration with the NGO African Innovation Services (AFRIS) and the support by Dr. Axel Ssymank concerning identification of syrphids.

### **Disclosure statement**

No potential conflict of interest was reported by the author(s).

### Funding

This work was supported by Federal Ministry for the Environment, Nature Protection and Nuclear Safety; The German Federal Ministry for Economic Collaboration and Development.

### Notes on contributors

*Stefanie Christmann*, ICARDA, is specialized on environmental governance. She developed Farming with Alternative Pollinators (FAP).

Aden Aw-Hassan is economist, led the program for socio-economical research at ICARDA and is pensioned.

Yasemin Güler is expert for wild pollinators based in Turkey.

Hasan Cumhur Sarisu is expert for fruit trees in Turkey.

*Marc Bernard* developed different extension services for agricultural advisors, e.g. in Benin.

*Moulay Chrif Smaili* is expert on natural enemies and pests from Morocco.

Athanasios Tsivelikas is expert on Gene Banks, but contributes to the FAP team mainly concerning statistics.

#### References

- Ahnström, J., Höckert, J., Bergea, H. L., Francis, C., & Skelton, P. (2009). Farmers and nature conservation: What is known about attitudes, context factors and actions affecting conservation? *Renewable Agriculture and Food Systems*, 24(1), 38–47. https://doi.org/10.1017/S1742170508002391
- Albrecht, M., Kleijn, D., Williams, N., Tschumi, M., Blaauw, B., Bommarco, R., Campbell, A., Dainese, M., Drummond, F., Entling, M., Ganser, D., De Groot, A., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., ... Sutter, L. (2020). Global synthesis of the effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield. *Authorea, April 06*. https://doi.org/10. 22541/au.158618502.29242370
- Ali, M., Sajjad, A., Farroqi, M. A., Bashir, M. A., Aslam, M. N., Nafees, M., Aslam, N. M., Adnan, M., & Ali, K. A. (2020). Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agro-ecosystem of punjab, Pakistan. Saudi Journal of Biological Sciences, 27(1), 189–194. https://doi. org/10.1016/j.sjbs.2019.07.001
- Amel, E., Manning, C., Scott, B., & Koger, S. (2017). Beyond the roots of human inaction: Fostering collective effort toward ecosystem conservation. *Science*, 356(6335), 275–279. https://doi.org/10.1126/science.aal1931

- An, J. D., & Chen, C. W. (2011). Economic value of insect pollination for fruits and vegetables in China. Acta Entomologica Sinica, 54(4), 443–450.
- Batáry, P., Dicks, L. V., Kleijn, D., & Sutherland, W. J. (2015). The role of agri-environment schemes in conservation and environmental management. *Conservation Biology*, 29(4), 1006–1016. https://doi.org/10.1111/cobi.12536
- Biesmeijer, J. C., Roberts, S. P., Reemer, M., Ohlemüller, R., Edwards, M., Peeters, T., Schaffers, A. P., Potts, S. G., Kleukers, R., Thomas, C. D., Settele, J., & Kunin, W. E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, *313*(5785), 351–354. https://doi.org/10.1126/science.1127863
- Blaauw, B. R., & Isaacs, R. (2014). Flower plantings increase wild bee abundance and the pollination services provided to a pollinator-dependent crop. *Journal of Applied Ecology*, *51*(4), 890–898. https://doi.org/10.1111/1365-2664.12257
- Carvalheiro, L. G., Kunin, W. E., Keil, P., Aguirre-Gutiérrez, J., Ellis, W. N., Fox, R., Groom, Q., Hennekens, S., Landuyt, W. V., Maes, D., Van de Meutter, F., Michez, D., Rasmont, P., Ode, B., Potts, S. G., Reemer, M., Roberts, S. P. M., Schaminée, J., WallisDeVries, M. F., & Biesmeijer, J. C. (2013). Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. *Ecology Letters*, *16*(7), 870–878. https://doi.org/10.1111/ele.12121
- Chaplin-Kramer, R., Dombeck, E., Gerber, J., Knuth, K. A., Mueller, N. D., Mueller, M., Ziv, G., & Klein, A.-M. (2014). Global malnutrition overlaps with pollinator-dependent micronutrient production. *Proceedings of The Royal Society Biological Sciences*, 281, 1799. https://doi.org/10.1098/rspb.2014.1799
- Chaplin-Kramer, R., Sharp, R. P., Weil, C., Bennett, E. M., Pascual, U., Arkema, K. K., Braumann, K. A., Bryant, B. P., Guerry, A. D., Haddad, N. M., Hamann, M., Hamel, P., Johnson, J. A., Mandle, L., Pereira, H. M., Polasky, S., Ruckelshaus, M., Shaw, M. R., Silver, J. M., ... Daily, G. C. (2019). Global modeling of nature's contribution to people. *Science*, *366*(6462), 255– 258. https://doi.org/10.1126/science.aaw3372
- Christmann, S. (2019a). Do we realize the full impact of pollinator loss on other ecosystem services and the challenges for any restoration in terrestrial areas? *Restoration Ecology*, 27 (4), 720–725. https://doi.org/10.1111/rec.12950
- Christmann, S. (2019b). Climate change enforces to look beyond the plant – the example of pollinators. *Current Opinion in Plant Biology*, 56, 162–167. https://doi.org/10.1016/j.pbi. 2019.11.001
- Christmann, S. (2019c). Under which conditions would a wide support be likely for a multilateral environmental agreement for pollinator protection? *Environmental Science and Policy*, 91 (1), 1–5. https://doi.org/10.1016/j.envsci.2018.10.004 doi:10. 1016/j.envsci.2018.10.004
- Christmann, S. (2020). Pollinator protection strategies must be feasible for all nations. *Nature Ecology & Evolution*, 4(7), 896–897. https://doi.org/10.1038/s41559-020-1210-x
- Christmann, S., & Aw-Hassan, A. (2012). Farming with Alternative Pollinators (FAP) – an overlooked win-win-strategy for climate change adaptation. *Agriculture, Ecosystems and Environment*, 161, 161–164. https://doi.org/10.1016/j.agee. 2012.07.030
- Christmann, S., Aw-Hassan, A., Rajabov, T., Khamraev, A. S., & Tsivelikas, A. (2017). Farming with Alternative Pollinators increases yields and incomes of cucumber and sour cherry.

Agronomy for Sustainable Development, 37(4), 24. https://doi.org/10.1007/s13593-017-0433-y

- Cole, L. J., Kleijn, D., Dicks, L. V., Stout, J. C., Potts, S. G., Albrecht, M., Balzan, M. V., Bartomeus, I., Bebeli, P. J., Bevk, D., Biesmeijer, C. J., Chlebo, R., Dautarté, A., Emmanuouil, N., Hartfield, C., Holland, J. M., Holzschuh, A., Knoben, N. T. J., Kovács-Hostyánszki, A., ... Scheper, J. (2020). A critical analysis of the potential for EU common agricultural policy measures to support wild pollinators on farmland. *Journal* of Applied Ecology, 57(4), 681–694. https://doi.org/10.1111/ 1365-2664.13572
- De Snoo, G. R., Herzon, I., Staats, H., Burton, R. J., Schindler, S., van Dijk, J., Lokhorst, A. M., Bullock, J. M., Lobley, M., Wrbka, T., Schwarz, G., & Musters, C. J. M. (2013). Toward effective nature conservation on farmland: Making farmers matter. *Conservation Letters*, 6(1), 66–72. https://doi.org/10.1111/j. 1755-263X.2012.00296.x
- Dicks, L. V., Viana, B., Bommarco, R., Brosi, B., Arizmendi, M. D. C., Cunningham, S. A., Galetto, L., Hill, R., Lopez, A. V., Pires, C., Taki, H., & Potts, S. G. (2016b). Ten policies for pollinator. *Science*, 354(6315), 975–976. https://doi.org/10.1126/ science.aai9226
- Dicks, L., Vaughan, M., & Lee-Mäder, E. (2016a). Developing incentives for farmers to support pollinators: Contrasting approaches from Europe and the United States. In B. Gemill-Herren (Ed.), *Pollination services to agriculture* (pp. 216–234). Earthscan.
- Elisante, F., Ndakidemi, P. A., Arnold, S. E. J., Belmain, S. R., Gurr, G. M., Darbyshire, I., Xie, G., Tumbo, J., & Stevenson, P. C. (2019). Enhancing knowledge among smallholders on pollinators and supporting field margins for sustainable food security. *Journal of Rural Studies*, 70, 75–86. https://doi.org/ 10.1016/j.jrurstud.2019.07.004
- Erenler, H. E., Gillman, M. P., & Ollerton, J. P. (2020). Impact of extreme events on pollinator assemblages. *Current Opinion in Insect Science*, 38, 34–39. https://doi.org/10.1016/j.cois. 2020.01.007
- EU. (2020). European Court of Auditors (2020). Protection of wild pollinators in the EU — Commission initiatives have not borne fruit. Special report 15. Pp. 61. Retrieved November 5, 2020, from https://www.eca.europa.eu/Lists/ECADocuments/ SR20\_15/SR\_Pollinators\_EN.pdf
- Frimpong-Anin, K., Kwapong, V., & Gordon, I. (2013). Cocoa farmers' awareness of pollination and its implication for pollinator-friendly practices. *Research and Reviews in Biosciences*, 7(12), 504–512.
- Gallai, N., Salles, J. M., Settele, J., & Vaissière, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted to pollinator decline. *Ecological Economics*, 68(3), 810–821. https://doi.org/10.1016/j. ecolecon.2008.06.014
- García-Llorente, M., Martín-López, B., Iniesta-Arandia, I., López-Santiago, C. A., Aguilera, P. A., & Montes, C. (2012). The role of multi-functionality in social preferences toward semi-arid rural landscapes: An ecosystem service approach. *Environmental Science and Policy*, 19–20, 136–146. https:// doi.org/10.1016/j.envsci.2012.01.006
- Garibaldi, L., Steffan-Dewenter, I., Winfree, R., Aizen, M. A., Bommarco, R., Cunningham, S. A., Kremen, C., Carvalheiro, L. G., Harder, L. D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N. P., Dudenhöffer, J. H.,

Freitas, B. M., Ghazoul, J., Greenleaf, S., ... Klein, A. M. (2013). Wild pollinators enhance fruit Set of crops regardless of honey Bee abundance. *Science*, *339*(6127), 1608–1611. https://doi.org/10.1126/science.1230200

- Gemill-Herren, B., Garibaldi, L. A., Kremen, C., & Hien, T. N. (2021). Building effective policies to conserve pollinators: Translating knowledge into policy. *Current Opinion in Insect Science*, 46, 64–71. https://doi.org/10.1016/j.cois.2021.02.012
- Gérard, M., Vanderplanck, M., Wood, T., & Michez, D. (2020). Global warming and plant–pollinator mismatches. *Emerging Topics in Life Sciences*, 4(1), 77–86. https://doi.org/10.1042/ ETLS20190139
- Goulson, D., Nicholls, E. K., Botias, C., & Rotheray, E. L. (2015). Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science*, 347(6229), 1255957. https://doi. org/10.1126/science.1255957
- Hall, D. M., & Martins, D. J. (2020). Human dimensions of insect pollinator conservation. *Current Opinion in Insect Science*, 38, 107–114. https://doi.org/10.1016/j.cois.2020. 04.001
- Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D., & de Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PloS One*, *12*(10), e0185809. https://doi.org/10. 1371/journal.pone.0185809
- Hanes, S. P., Collum, K. K., Hoshide, A. K., & Asare, E. (2013). Grower perceptions of native pollinators and pollination strategies in the lowbush blueberry industry. *Renewable Agriculture and Food Systems*, 30(2), 124–131. https://doi. org/10.1017/S1742170513000331
- Hevia, V., García-Llorente, M., Martínez-Sastre, R., Palomo, S., García, D., Miñarro, M., Pérez-Marcos, M., Sanchez, S. A., & González, J. A. (2020). Do farmers care about pollinators? A cross-site comparison of farmers' perceptions, knowledge, and management practices for pollinator dependent crops. *International Journal of Agricultural Sustainability*, *19*(1), 1– 15. https://doi.org/10.1080/14735903.2020.1807892
- Kasina, M., Kraemer, M., Martius, C., & Wittmann, D. (2009). Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of Apicultural Research*, 48 (2), 126–133. https://doi.org/10.3896/IBRA.1.48.2.07
- Kleijn, D., Bommarco, R., Fijen, T. P. M., Garibaldi, L. A., Potts, S. G., & van der Putten, W. H. (2019). Ecological intensification: Bridging the Gap between Science and practice. *Trends in Ecology & Evolution*, 34(2), 154–166. https://doi.org/10.1016/ j.tree.2018.11.002
- Klein, A., Vaissière, B., Cane, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of The Royal Society Biological Sciences*, 274(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721
- Knapp, J. K., Phillips, B. B., Clements, J., Shaw, F. F., & Osborne, J. L. (2020). Socio-psychological factors, beyond knowledge, predict people's engagement in pollinator conservation. *People and Nature*, 3(1), 204–220. https://doi.org/10.1002/pan3.10168
- Kusnandar, K., Brazier, F. M., & van Kooten, O. (2019). Empowering change for sustainable agriculture: The need for participation. *International Journal of Agricultural Sustainability*, 17(4), 271–286. https://doi.org/10.1080/ 14735903.2019.1633899

- Marselle, M. R., Turbe, A., Shwartz, A., Bonn, A., & Colléony, A. (2020). Addressing behavior in pollinator conservation policies to combat the implementation gap. *Conservation Biology*, https://doi.org/10.1111/cobi.13581
- McCracken, M. E., Woodcock, B. A., Lobley, M., Pywell, R. F., Saratsi, E., Swetnam, R. D., Mortimer, S. R., Harris, S. J., Winter, M., Hinsley, S., & Bullock, J. M. (2015). Social and ecological drivers of success in agri-environment schemes: The roles of farmers and environmental context. *Journal of Applied Ecology*, *52*(3), 696–705. https://doi.org/10.1111/ 1365-2664.12412
- Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. International Journal of Agricultural Sustainability, 13 (1), 40–54. https://doi.org/10.1080/14735903.2014.912493
- Munyuli, T. (2011). Farmers' perceptions of pollinators' importance in coffee production in Uganda. *Agricultural Sciences*, 2(3), 318–333. https://doi.org/10.4236/as.2011.23043
- Mwebaze, P., Marris, G. C., Brown, M., MacLeod, A., Jones, G., & Budge, G. E. (2018). Measuring public perception and preferences for ecosystem services: A case study of bee pollination in the UK. *Land Use Policy*, *71*, 355–362. https://doi.org/10. 1016/j.landusepol.2017.11.045
- Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*(3), 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x
- Park, M. G., Joshi, N. K., Rajotte, E. G., Biddinger, D. J., Losey, J. E., & Danforth, B. N. (2018). Apple grower pollination practices and perceptions of alternative pollinators in New York and pennsylvania. *Renewable Agriculture and Food Systems*, 35 (1), 1–14. https://doi.org/10.1017/S1742170518000145
- Potts, S. G., Imperatriz-Fonseca, V. L., Ngo, H.T., Aizen, M. A., Biesmeijer, J. C., Breeze, T.D., Dicks, L. V., Garibaldi, L. A., Hill, R., Settele, J., & Vanbergen, A. J. (2016). Safeguarding pollinators and their values to human well-being. *Nature*, 540 (7632), 220–229. https://doi.org/10.1038/nature20588
- Powney, G. D., Carvell, C., Edwards, M., Roger, M., Roy, H., Woodcock, B., & Isaac, N. J. B. (2019). Widespread losses of pollinating insects in Britain. *Nature Communications*, *10*(1), 1018. https://doi.org/10.1038/s41467-019-08974-9
- Rawluk, A., & Saunders, M. (2019). Facing the gap: Exploring research on local knowledge of insect-provided services in agroecosystems. *International Journal of Agricultural Sustainability*, 17(1), 108–117. https://doi.org/10.1080/ 14735903.2019.1567244
- Smith, B. M., Chakrabarti, P., Chatterjee, A., Chatterjee, S., Dey, U. K., Dicks, L. V., Giri, B., Laha, S., Majhi, R. K., & Basu, P. (2017). Collating and validating indigenous and local knowledge to apply multiple knowledge systems to an environmental challenge: A case-study of pollinators in India. *Biological Conservation*, 211, 20–28. https://doi.org/10.1016/j.biocon.2017.04.032
- Smith, K. S., Ostrom, M., McMoran, D., & Carpenter-Boggs, L. (2019). Connecting new farmers to place, agroecology, and community through a bilingual organic farm incubator. *Journal of Agriculture, Food Systems, and Community Development, 9*(A), 111–124. https://doi.org/10.5304/jafscd. 2019.091.030
- Tarakini, G., Chemura, A., & Musundire, R. (2020). Farmers' knowledge and attitudes toward pollination and bees in a maize-

producing region of Zimbabwe: Implications for pollinator conservation. *Tropical Conservation Science*, *13*, 1–13. https://doi.org/10.1177/1940082920918534

- Tscharntke, T., Karp, D. S., Chaplin-Kramer, R., Batáry, P., DeClerck, F., Gratton, C. Hunt, L., Ives, A., Jonsson, M., Larsen, A., Martin, E. A., Martínez-Salinas, A., Meehan, T. D., O'Rourke, M., Poveda, K., Rosenheim, J. A., Rusch, A., Schellhorn, N., Wanger, T. C., ... Zhang, W. (2016). When natural habitat fails to enhance biological pest control – five hypotheses. *Biological Conservation*, 204, 449–458. https://doi.org/10.1016/j.biocon.2016.10.001
- UNESCO. (2020). Retrieved May 2, 2020, from www.uis.unesco. org/country/
- Uyttenbroeck R., Hatt, S., Paul, A., Boeraeve, F., Piqueray, J., Francis, F., Danthine, S., Frederich, M., Dufrêne, M., Bodson, B., & Monty, A. (2016). Pros and cons of flower strips for farmers. A review. *Biotechnology, Agronomy, Society and Environment, 20*(S1), 225–235. https://doi.org/10.25518/1780-4507.12961
- Zattara, E. E., & Aizen, M. A. (2021). Worldwide occurrence records reflect a global decline in bee species richness. One Earth, 4(1), 114–123. https://doi.org/10.1016/j.oneear.2020. 12.005