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EXTENSION OF KNOWLEDGE BASE
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TOWARDS SUSTAINABLE CROP POLLINATION SERVICES
MEASURES AT FIELD, FARM AND LANDSCAPE SCALES

POLLINATION SERVICES FOR SUSTAINABLE AGRICULTURE

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MEASURES AT FIELD, FARM AND LANDSCAPE SCALES

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Chapter 14

Common approach for socio-economic valuation of pollinator-friendly practices

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REASON FOR THE PRACTICE

Rationale

With increasing recognition of the centrality of ecosystem services in agricultural production, the need for placing a value on these services has also increased in order to provide a value- or "evidence"-based argument for their maintenance and enhancement. There are different ways to define and measure value, of which monetary is only one. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) notes that: "in keeping with the general anthropocentric notion of 'nature's benefits to people', one might consider a benefit to be an ecosystem's contribution to some aspect of a good quality of life, where a benefit is a perceived thing or experience of value," (IPBES, 2013).

In the definition provided by the IPBES Conceptual Framework, the "value" is multi-dimensional and cannot be properly estimated with only one variable. This is one of the bases of the multi-dimensional aspect of the protocol for socio-economic valuation of pollination-friendly landscapes presented here.

Commonly, valuation estimates have focused on the benefits of pollination to crop production and do not include all the benefits that pollinators provide to the economy. A region´s wealth includes the financial, physical, natural, human and social capital that enhances development and sustainable rural livelihoods. Therefore, comparing the influence of practices (or landscapes) that are pollinator-friendly versus practices that are unfriendly, using all of these measures of capital would be a more robust approach to putting a value on pollinator changes, and allows quantification of the synergies and trade-offs associated to pollinator enhancement.

This chapter presents a protocol for determining the socio-economic value of pollinator-friendly versus -unfriendly practices that can be implemented at different spatial levels (for example, farms or landscapes). The scope is comprehensive and includes both small- and large-scale farming systems; indeed, the comparison between these systems can be of great interest. The results of the application of this protocol may interest both producers and decision-makers wishing to answer, for example, questions such as: are differences in the socioeconomic assets of the producers associated with friendly or unfriendly practices? Can a group of socioeconomic variables predict the number of pollinator-friendly practices applied by producers? Which assets should be promoted to enhance the number of pollinator-friendly practices? Are there trade-offs or synergies among different assets (for example, biodiversity and crop production)?

Context

The valuation of ecosystem services is an increasingly important issue at international, national and regional levels. Some examples of global initiatives that address this issue at an international level are The Economics of Ecosystems and Biodiversity (TEEB) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). At the national level, countries are interested in valuing ecosystem services to provide financially based evidence for the conservation and management of services that are important not only for humans, but also for the wider environment. Initiatives such as Payments for Environmental Services (PES) are in place to address this matter. At the regional level, in 2012 a regional workshop was held on "Mainstreaming Ecosystem Services Approaches into Development: Application of Economic Valuation for Designing Innovative Response Policies" for senior level decision-makers from regions of South and Southeast Asia. This workshop was organized by the United Nations Environment Programme (UNEP), in close cooperation with the ASEAN Centre for Biodiversity (ACB).

Insect pollination has been shown to improve fruit and vegetable yields, as well as oil, seed and nut crops (Klein *et al.*, 2007). Gallai *et al.* (2009) estimated that, for 2005, the global economic value of pollination was USD 215 billion or 9.5 percent of global food production value. Clearly, a convincing argument for the monetary value of pollination services exists; however, it needs to be further supported.

Addressing the economic valuation of pollination services – essential for crop production – has been undertaken through different perspectives and at different levels (local to global). For example, the Handbook for Participatory Socio-Economic Valuation of Pollinator-Friendly Practices (FAO, 2012)[1] looks at valuation at the local level; it is a guide to help farmers evaluate the benefits and costs of applying pollinator-friendly practices. It looks not only at the economic, but also at the social value of these practices. FAO's Tool for Valuation of Pollination Services at National Level, using producer price and crop production data, is supported by the Guidelines for the Economic Valuation of Pollination Services at National Scale[2] (Gallai and Vaissière, 2009).

HOW TO IMPLEMENT IT

There are five basic steps to implement this protocol:

Summary of the steps for valuation of agricultural landscapes

1. Experimental design: define a contrast;
2. Multiple dimensions of socio-economic value: define at least three variables per asset;
3. Define the method (feasibility) for obtaining information for each variable (questionnaires, Geographic Information System (GIS), databases);
4. Statistical analyses;
5. Inform decision-makers.

1 http://www.fao.org/3/a-i2442e.pdf
2 http://www.fao.org/3/a-at523e.pdf

Step 1. Experimental design: Define a contrast

Based on satellite images and landscape features, characterization of the experimental plots will help to identify and select contrasting study sites (Table 1). For example, these can be landscapes dominated by crop monocultures (pollinator-unfriendly) versus those planted with several crop species (friendly); or low (unfriendly) versus high (friendly) habitat diversity (Garibaldi *et al.*, 2011; Kennedy *et al.*, 2013). An aspect to bear in mind is that areas providing resources for wild bees usually also provide them for managed pollinators (e.g. honeybees). In general, the following aspects define a pollinator-friendly site (i.e. higher species richness of flower visitors):

- high complexity (diversity, heterogeneity) of habitats (different types of habitats)
- high habitat quality (not only natural)
- low or no use of pesticides
- high within-field plant biodiversity (e.g. ruderal plants)

Table 1.

Example of site general characterization in order to select contrasting study sites

Main primary activity	i.e., Main crop grown.
General characteristics of the landscape	e.g. What are the other crops grown? What is the typology of the natural habitat surrounding the landscape? Is there livestock present? If so, what kind? What are the primary pollinators (e.g. Africanized honeybees, stingless bees, midges).
Scale	Describe the landscape and scale (e.g. each landscape is a drainage basin of approximately 5 x 5 km^2).
Scope	Describe the scope, e.g. rural landscapes with more than 10 percent of "x" crop and less than 10 percent of urban area.
Friendly versus unfriendly	Complexity of habitats, agricultural practices.

In statistical terms, there are at least two treatments (friendly versus unfriendly) with several replicates each. The number of replicates depends on the desired precision, selected confidence, and the variability among landscapes (Anderson *et al.*, 2008). Replicate numbers can be determined through standard statistical procedures (Anderson *et al.*, 2008); based on our experience, we recommend at least 10 replicates per treatment (i.e. at least 20 landscapes as a minimum for the assessment).

> This section provides a framework to value different practices; therefore, the user needs to choose the most useful (relevant) contrast for their specific objectives (e.g. landscapes providing resources for honeybees versus those that do not provide resources).

The design implies an observational experiment in contrast to manipulative experiments (Hulbert, 1984). In manipulative experiments, the treatments (pollinator-friendly versus -unfriendly designs) are randomly assigned to the experimental units (e.g. farms or landscapes). These experiments have the ability to establish causal relations (i.e. the effects of treatments on response variables); however, they are usually not feasible (nor ethical) in many circumstances, such as in our case. Manipulative studies, therefore, are rarely employed in socio-economic valuations. On the other hand, observational experiments can be set up in real-world rural landscapes, through the evaluation of statistical associations between treatment and response variables (not necessarily causal). Our design allows evaluation if the socio-economic value of pollinator-friendly practices is different from that of the pollinator-unfriendly practices. The design does not, however, tell us if higher socio-economic value is a result of the agroecological design (e.g. pollinator-friendly practice); or the reverse (e.g. a higher socio-economic value determines a higher capacity to implement a pollinator-friendly design); or a win-win scenario (e.g. positive feedback between agroecological design and socio-economic value). The information provided by this protocol is of great importance for policy implementation. For example, it will allow us to detect if landscapes with more natural capital share less financial capital and, therefore, correct the financial deficit by payment for ecosystem services programmes (Zheng *et al.*, 2013).

> The general idea is to choose farms (or landscapes) that differ greatly in the degree to which they support pollinator richness, based on *a priori* knowledge and GIS information (Step 1). This information can be updated with field data and questionnaires (Steps 2 and 3) to create a quantitative index of the number of pollinator-friendly practices applied in each farm (or landscape). This index is usually more informative in analysis (Step 4) and in guiding decision-making (Step 5).

Step 2. Multiple dimensions of socio-economic value: Define at least three variables per asset

The sustainable livelihoods (SL) framework (also known as the “rural livelihoods” framework) has been implemented for many years in rural areas (DFID, 1999; Nelson *et al.*, 2010), including FAO assessments (Baumann, 2002; Cleary *et al.*, 2003; Seshia and Scoones, 2003; Tayyib *et al.*, 2007). The SL framework accounts for the multi-dimensional socio-economic value of agricultural practices by considering five livelihoods assets:

- **Human capital**: individuals’ skills, health (including mental health), nutrition and education that contribute to the productivity of labour and capacity to manage land (Nelson *et al.*, 2010).

- **Natural capital:** land productivity counting climate, water and biological resources that contribute to current and future agricultural productivity, including wildlife, wild foods and fibers, biodiversity and environmental services.
- **Financial capital:** stocks of financial resources to which households have access, including cash, incomes, access to other financial resources (credit and savings) and overall wealth that influences the ability to generate income.
- **Physical capital:** infrastructure, transport, roads, vehicles, secure shelter and buildings, water supply and sanitation, energy, communications, tools and technology, equipment for production, seeds, fertilizers, pesticides, traditional technology.
- **Social capital:** reciprocal claims on others by virtue of social relationships, social bonds that facilitate cooperative action, and social bridging and linking together; and which ideas and resources are accessible (networks and connections, relations of trust and mutual support, formal and informal groups, common rules and sanctions, collective representation, mechanisms for participation in decision-making, leadership).

The SL provides a general framework that must be modified, adapted and made appropriate to local circumstances and priorities (objectives).

Step 3. Define the method (feasibility) to obtain information for each variable (questionnaires, GIS, databases)

Once the contrast has been defined, the relevant variables must be selected, data sources must be identified and instruments for the collection of data must be prepared and administered. Gathered data will conform the database to be analysed (see Step 4: Statistical analyses).

a) Variables selection: Adapt the framework to the specific conditions of your system

Choose at least three variables per asset. In particular, we are looking for variables with a direct relation to pollinator-friendly practices (whether they are a result of the agroecological design or determinants of practices adoption; see Step 1: Experimental design). Different variables may be selected for different regions and socio-economic conditions. Researcher judgment and previous knowledge of the study context are important for selecting which variables are considered the most important within each asset, and to determine how to measure them. Below is a non-exhaustive list of variables and examples of elements for each asset described in the SL framework that you can include in the questions. New variables should be added to the list and the unit of analysis should be adapted to best fit your assessment.

Table 2.

List of non-exhaustive variables of human capital, which can be included in the questions

CAPITAL	SAMPLE QUESTIONS
Educational level	What is the highest level of education reached? Responses will be measured using ordinal variable with the following values: (1) primary school completed or attended; (2) 1-4 years high school completed; (3) 5-6 years high school completed; (4) trade apprenticeship or technical qualification completed; and (5) university or other tertiary completed (Tayyib *et al.*, 2007; Nelson *et al.*, 2010; Antwi-Agyei *et al.*, 2012). To measure this variable at the landscape level, calculate the percentage of each value or select the percentage of the value considered most relevant (for example, the percentage of the producers that have attained levels 4 or 5).
Health status	Has any member of this household been ill (i.e. in need of hospital treatment) in the last six months? Do you have local medical assistance (i.e. within the landscape)? (Antwi-Agyei *et al.*, 2012). (*Prediction: pollinator-friendly landscapes may increase health because of lower agrochemical use. This may be measured directly by other methods, e.g, irritation, report of illness because of pesticide use.*) To measure this variable at the landscape level, calculate the percentage of households with ill members and the aggregate access to health care.
Nutritional outcome	Yearly energetic value of primary and secondary production.
Dietary diversity	Vitamins, antioxidants, minerals, essential amino acids and nutrients of primary and secondary production (e.g. using USDA data for nutritional composition of crops) (Eilers *et al.*, 2011).
Number of households	Record the number of households present in the site.
Labour status	Percentages of employed, unemployed and/or inactive inhabitants (Tayyib *et al.*, 2007).
Status in employment (A)	Percentages of self-employed or employed persons.
Status in employment (B)	Percentages of full- or part-time employment (Plagányi *et al.*, 2013).
Livelihood diversification	Main livelihood activities in terms of their contribution to household income.
Pollination knowledge	Percentage of farmers that know: which insects visit the production area; what a pollinator is; the importance of pollinating insects for crops.
Beekeeping experience	Percentage of farmers that have beekeeping experience. Average number of years of beekeeping experience.

Table 3.

List of non-exhaustive variables of natural capital, which can be included in the questions

CAPITAL	SAMPLE QUESTIONS
Number of pollinator-friendly practices	Compose an index that measures the number of pollinator-friendly practices applied in the landscape. The index will have positive values for the pollinator-friendly practices (e.g. holdings having beehives for pollination services in the productive area; having forage in the form of native bush or other crops or conservation areas; increasing pollinator accessibility to crops through, for example, presence of water containers). It will have negative values for practices that are detrimental to pollinators (e.g. use of chemical products; destroying wild pollinator colonies in the productive area; monoculture systems).
Landscape complexity	Several standard indices are available for land-use composition (richness, evenness and diversity of landscapes) and configuration (patch area and edge, patch shape complexity, core area, contrast, aggregation, subdivision, isolation). "Patch-based metrics (i.e. for categorical map patterns or patch mosaics) fall into two general categories: (1) those that quantify the composition of the map without reference to spatial attributes; and (2) those that quantify the spatial configuration of the map, requiring spatial information for their calculation. "Each category contains a variety of metrics for quantifying different aspects of the pattern. It is incumbent upon the investigator or manager to choose the appropriate metrics for the question under consideration" (Mcgarigal, 2013; see also Kennedy *et al.*, 2013). It is important to define the range in which the complexity is measured, because the effect of the variables is scale-dependent.

CAPITAL	SAMPLE QUESTIONS
Wildlife	Proportion of natural (or semi-natural) habitat, and their diversity. Possibly highly correlated with complexity (depends on the index).
Crop biodiversity	Number of crops.
Ecosystem services	Services provided by agricultural landscapes not necessarily related to primary or secondary production (e.g. aquifer recharge, water quality improvement, carbon fixation, reduction of soil erosion). It is suggested that two "key" ecosystem services should be chosen. There should be a relation between the chosen service and pollination provision.

Table 4.

List of non-exhaustive variables of financial capital, which can be included in the questions

CAPITAL	SAMPLE QUESTIONS
Profit per crop per hectare	Income versus costs. Kg ha^{-1} produced per crop, kg ha^{-1} sold per crop (produced - sold = consumed), main costs (fertilizers, etc.), price at which it is sold (Grieg-Gran and Gemmill-Herren, 2012).
Access to credit	Percentage of farmers that have access to credit for their agricultural activities (Antwi-Agyei *et al.*, 2012).
Ownership of livestock	Percentage of farmers that have livestock or poultry. List the types and number of livestock (Antwi-Agyei *et al.*, 2012).
Remittances received	Percentage of farmers that received remittances from family or friends in the last year (Antwi-Agyei *et al.*, 2012); or average (median) value of remittances received.
Abroad work	Percentage of farmers that work abroad from their farms. Percentage of the aggregate income generated in the landscape represented by the work abroad the farms.
Income from tourism	Current or potential income on farms that include these activities (e.g. farm hotel, agro-ecotourism). Indicators can include data from farms or municipalities, e.g. tourist flow; number of hotels; number of restaurants; number of tourist agencies; number of rental car companies; number of events (congresses, meetings, symposiums) per year; currency revenues from tourism; presence of thematic and/or ecological parks and natural reserves.

Table 5.

List of non-exhaustive variables of physical capital, which can be included in the questions

CAPITAL	SAMPLE QUESTIONS
Ownership of honeybee hives	Percentage of holdings that own beehives or numbers of hives relative to the number of farms.
Irrigation facilities	Percentage of farms that have access to irrigation facilities.
Agricultural machinery	Percentage of farms that use machinery in the productive cycle. Average expenditure on machinery.
Fertilizers	Average expenditure in the use of fertilizers.
Pesticides	Average expenditure in the use of pesticides (Tayyib *et al.*, 2007). Percentage of farmers that apply pesticides.
Economically active population	Percentage of people of working age in the landscape, disaggregated by gender.
Workers	Average or median number of working days per year and percentage of holdings with family/hired workers (Grieg-Gran and Gemmill-Herren, 2012).
Infrastructure	Availability of roads, ports.

Table 6.

List of non-exhaustive variables of social capital, which can be included in the questions

CAPITAL	SAMPLE QUESTIONS
Number of groups or associations present in the landscape (relative to the number of farms)	Membership of a group provides an indication of a linking form of social capital, the horizontal connections between socially similar groups through which ideas, resources and opportunities flow (Nelson *et al.*, 2010; Antwi-Agyei *et al.*, 2012).
Tenure system	Percentage of farmers by type of arrangements for access to farming activities (e.g. owner, partner, occupant, employee).
Partners	Average number of non-family partners running farm business. This variable provides an indicator of the linking form of social capital, the kind of local social capital that provides support in difficult times and enables individuals to take advantage of opportunities (Nelson *et al.*, 2010).
Services from outside	Percentage of farmers that hire services from outside the landscape (e.g. for harvesting). Cost of hiring services from outside the landscape.
Availability of extension service	Number of days per year that a professional from an extension service is available in the landscape for technical assistance or other activities.
Access to Internet	Internet access availability. Internet access is an indicator of the linking form of social capital – vertical connections that provide access to ideas and resources between economically and socially differentiated groups (Nelson *et al.*, 2010).
Production and commercialization organization	Percentage of farmers that produce/commercialize in a collective way.

b) Data sources

Data can be obtained from regular questionnaires performed by governmental agencies, GIS databases and questionnaires specially prepared for this purpose. Bear in mind that when preparing your questionnaire, questions will need to be formulated in an inquisitive but polite fashion. Responses that have ranges instead of details of exact values are recommended to reduce non-response. Additionally, a pilot sampling is very important to refine the questions, trying to implement it in heterogeneous sites (i.e. pollinator-friendly and pollinator-unfriendly sites). Asking more (but not too many) questions than those you are going to analyse is a good practice, in order to later select the best variables. Administering the questionnaire should not take more than 30 minutes per farmer. Remember human ethics.

c) Data collection

The sample of survey respondents should be selected randomly from GIS data (this data needs to be gathered and assembled) and should allow aggregate statistics (mean, variance, skewness, equity, etc.). Questionnaires should be applied to the decision-maker or person with knowledge of how the farm operates. Ideally, half of the responses should come from women to allow for gender comparisons or, when this is not possible, through community organization (i.e. women not related directly to farm activities). Here the researchers may find different groups within the community to compare (i.e. beekeepers and farmers). Face to face interviews are recommended in order to reduce non-response. Researcher trustfulness and empathy are also important in collecting answers that are more reliable; in many places, some local governmental professionals advise the farmers and already know them. They should be involved and can be of help in contacting the farmers. The information gathered can be useful for future programmes – for example, to pay the farmers for ecosystem service delivery, so they can be incentivized to respond the questionnaires (Zheng *et al.*, 2013).

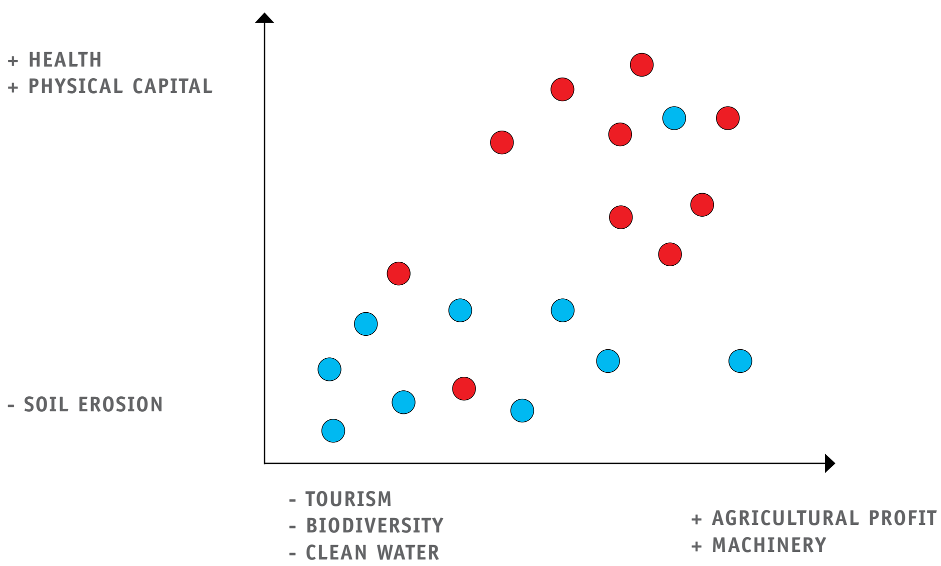
The entire survey process should take as much as one month in total, considering the selection of conceptually relevant variables and the 20 sites and data analyses in GIS.

Step 4. Statistical analyses

Information gathered from the different variables (in Step 3) should be integrated through standard multivariate statistics (e.g. principal component analyses, correspondence analyses). Multivariate statistics are powerful and provide useful information for socio-economic analysis, instead of a general index. In this way, the co-variation among different conceptually relevant variables can be understood (Figure 1). It is important to note that, for example, if one asset has very low values it can limit sustainable livelihoods even when the other assets have very high values. Therefore, the balance among all assets is important.

Figure 1.

Example of a possible result from a principal component analysis



Step 5. Inform decision-makers

Knowing the socioeconomic value of agricultural practices can make an important contribution to decision-making processes and the design of subsequent interventions. For example, this value can indicate which type of asset (human, social, physical, financial or natural) should be strengthened in order to enhance pollinator-friendly practices in a region.

It could also provide a solid argument for conservation in cases where no negative relation between natural capital and economic revenue of the producers is found. That suggests that it is possible to conserve and promote nature and pollinators without losing economic benefits (i.e. absence of trade-offs between natural and financial capital). Moreover, pollination could even support the productivity of some crops (i.e. synergies between natural and financial capital may exist). Thus, the assessment results can provide solid arguments for conservation in both cases: that is, in the absence of trade-offs and the presence of synergies between natural and financial capital.

SUCCESSFUL EXAMPLES OF APPLICATION

Example 1: Coffee

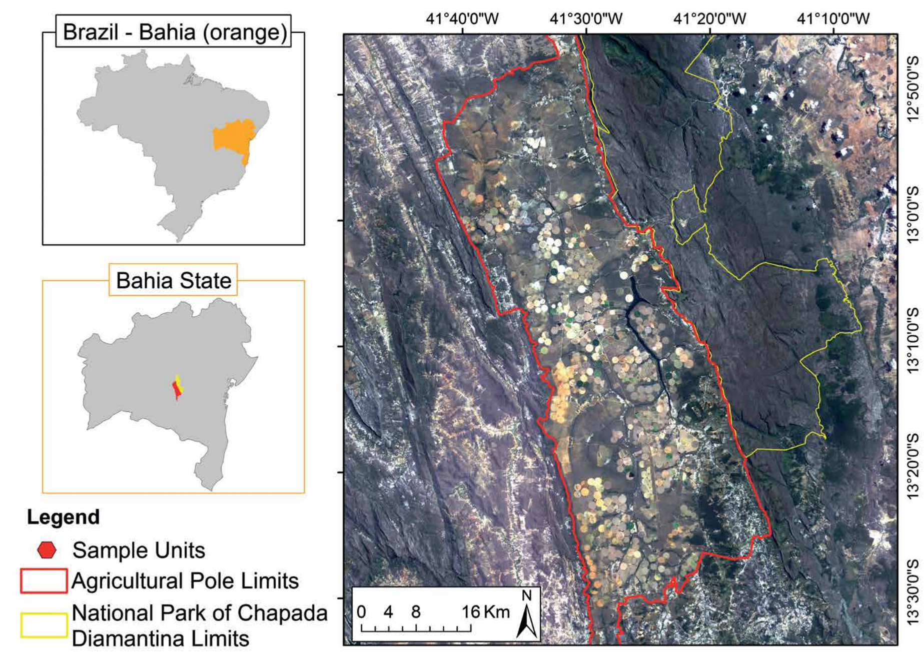
The protocol for assessing the socio-economic value of pollination at the landscape scale was applied on coffee farms in Bahia, Brazil. Assessing this value can enable the identification of opportunities, risks and threats in order to propose actions that lead to more sustainable and “pollinator-friendly farms”, i.e. farms that use practices that intend to increase the abundance and diversity of natural pollinators through the enhancement of diverse floral resources, farm land heterogeneity, reduced- or non-use of synthetic insecticides, among others (Garibaldi *et al.*, 2014; Hipólito *et al.*, 2016).

Step 1: Experimental design

Study sites included areas of intense agriculture and production of coffee, potatoes, tomatoes and strawberry, among others, but also bordered one of the National Parks of Chapada Diamantina in Brazil (Figure 2). The region is markedly dominated (80 percent) by small (< 20 ha) coffee farms, but there are also medium (20 - 200 ha) and large farms (> 500 ha) corresponding, in total, to over 2 000 farmers (Seagri, 2002) on 11 250 ha of cultivated coffee (IBGE, 2013).

Figure 2.

Map of the agricultural area of Chapada Diamantina in Bahia, Brazil



The yellow and red lines demonstrate the borders of the National Park of Chapada Diamantina (yellow) and the agricultural region (red)

Table 7.

Characterization of friendly and unfriendly coffee landscapes in Chapada Diamantina, Bahia, Brazil

Main primary activity	Coffee
General characteristics of the land-scape	Potato and coffee are the main crops in the region, although others such as tomato and passionflower can be found; semi-natural habitats, many streams, some livestock, wild and Africanized honeybees, etc.
Scale	Each landscape is an area of 2 000 m ratio.
Scope	In each landscape coffee farms varies from 1 to 110 ha, and from 15 percent to 93 percent of natural areas.

Characteristics that define landscape	**Pollinator friendly**	**Pollinator unfriendly**
Beehives	Native or *Apis mellifera*	No
Pesticide use	No use or only when necessary (low use)	High
Weed control	Partial manual weeding	Total weeding
Organic certificated	Yes	No
Hedges	Present	Absent
Crop richness	Presence of non-coffee crops (product diversification)	Only coffee present, i.e. monoculture

Steps 2 and 3:
Selecting variables and defining the method for obtaining information of each variable

A standardized questionnaire was elaborated and tested face-to-face with 12 of the 29 farmers who responded to the final questionnaire. Some questions that were too general or inadequate were excluded. The final questionnaire included approximately five questions per type of capital. For statistical analyses, variables included not only those from the questionnaires, but also variables obtained by GIS, such as the percentage of natural areas around the farms (Table 3). This allowed more reliable data given that, sometimes, producers that own more than one farm don't have all the information for each one, or do not know the percentage of natural areas around the farms (small farmers).

Table 8.

Selected variables for coffee landscapes analysis

VARIABLES	HOW TO MEASURE IT?	WHY MEASURE IT?/ SOME IMPORTANT CONSIDERATIONS
HUMAN CAPITAL		
Education level	What is your highest educational level?	More formally educated farmers could practice more friendly practices.
Management capacity	What are your functions on the land?	Undoubtedly this is a difficult variable to measure, but it should assess and respect that farmers have different managing capacities, some of which may derive not just from their formal education (as noted above) but how they apply it; equally, farmers with no formal education often have high capacity to manage and innovate on their farms.
Family structure	How many people in your family work on activities directly related to the farming activities?	Knowing the family structure and number of people contributing to total income may also reveal the number of women working the land, since not many are formally responsible for the farm.
NATURAL CAPITAL		
Conservation	Percentage of natural area in the 200m area around the farm	This is a variable that has been shown to be highly contributory to pollination services. If the farmer does not have the information, it can be easily gathered by GIS.
Conservation	Do you implement the governmental requisite of forest reserve?	To correlate with GIS information and analyse if forest reserves are close to the coffee farm and can maintain ecologic processes (pollination).
FINANCIAL CAPITAL		
Profit per crop per ha	How many crops per hectare? What is the amount of production per hectare?	Some caveats on determining this: in coffee production this is related to the area, however, we do not always found the same number of plants in a given area, so both are important.

VARIABLES	HOW TO MEASURE IT?	WHY MEASURE IT?/ SOME IMPORTANT CONSIDERATIONS
Other income	Is farming your main occupation? Do you have another employment? Receive any other income? (e.g. government benefits, retirement).	To assess the farmer's dependence on the income generated by agricultural activities.
Area	What is the total farm area planted with coffee?	Important to measure production based on the total planted area.
PHYSICAL CAPITAL		
Irrigation	What type of irrigation do you practice (e.g. flooding, drip, sprinkler)?	Knowing the type of irrigation implemented may be important to consider the possible impacts on the environment or production.
Production system	Do you have any machinery? Which fertilizers and how much of these is utilized? Do you use herbicides?	To consider the machinery and technology used in agricultural activities. In addition, certain tools, techniques and/or technologies can affect pollinator activity in the field.
Improvements	What kind of farm improvements do you have to make to increase coffee sales? (e.g. investment in post-harvest equipment such as machines for drying coffee, or for coffee selection)	To consider the equipment that may raise the value of the product and thus, benefit the sales.
SOCIAL CAPITAL		
Associations	Are you a member of any association?	To evaluate social associations that can generate new ideas and opportunities.
Extension	Do you interact with professionals from extension services? If so, which extension services and how many times (per year)?	Extension services may bring benefits to farmers in the form of technical assistance or other activities that lead to higher productivity.
Sales	How do you sell your products? (alone, with partner)	Partners may lead to higher probability of selling the products.

Step 4: Statistical analyses

Generalized Linear Models (GLM, Poisson error distribution) were used in this study, although the data generated for the analysis should be carefully examined in order to properly choose the statistical analysis as well as the data distribution (normal, poison, binomial, among others). Thus, analysis can vary depending on the data. In a general sense (and a suggestions, as multivariate analysis such as the Non-Metrical Multidimensional Scaling techniques can be quite flexible considering its assumptions), the data generated by the components of multivariate analysis can be used in these studies when it is interesting to extract the information of multiple variables in one. The new composed variable can be followed by a GLM (generalized linear model) to identify which variables best explain the use of friendly practices. We suggest that an expert evaluate what is the best analysis for the generated data.

Results

In this study, pollinator-friendly and -unfriendly landscapes were represented by a gradient ranging from no pollinator-friendly practices (value = 0) to a maximum level of pollinator-friendly practices (value = 5; Figure 3).

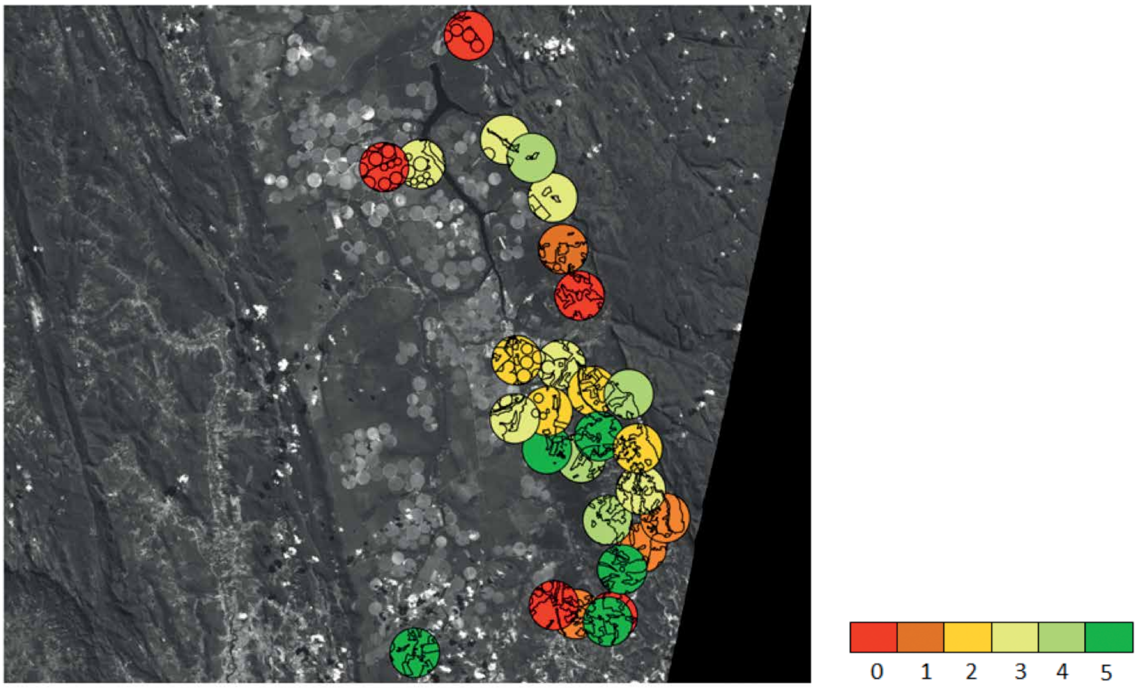
The most important variables to predict the number of pollinator-friendly practices applied by producers were management capacity (human capital), production per hectare (financial), area (financial), conservation (natural), education (human) and commercialization (social).

Pollinator-friendly practices encountered in the different farms were also related to the biodiversity of flower visitors, reinforcing its importance as a variable to consider in order to improve pollination services in coffee farms (Figure 4).

Findings highlight the possibility of generating win-win scenarios between biodiversity, production and producers' profitability.

Figure 3.

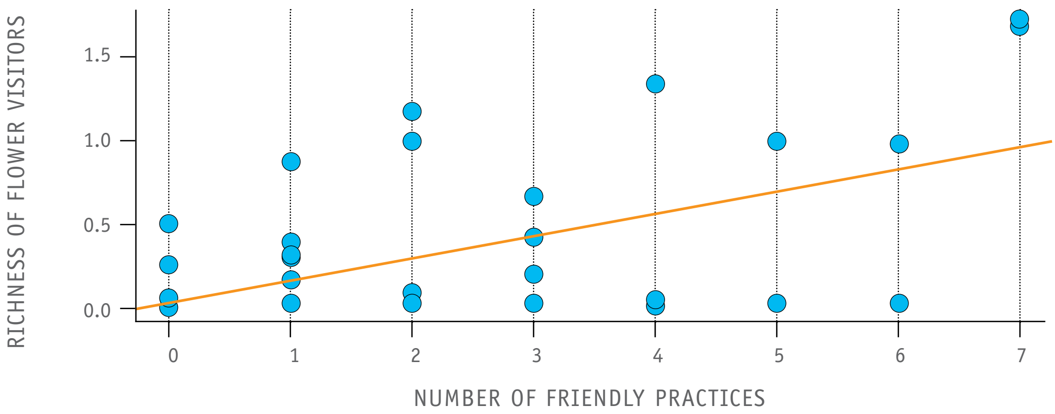
General overview of friendly and unfriendly landscapes of coffee in Chapada Diamantina, Bahia, Brazil



Colors and numbers refer to the number of pollinator-friendly practices from none (zero) to five

Figure 4.

Relationship between the number of friendly practices and visitor's richness in coffee landscapes in Chapada Diamantina, Bahia, Brazil



R=0.3147, p<0.001

Example 2: Cashew

This protocol has also been applied to cashew fields in the States of Ceará, Piauí and Río Grande do Norte in Brazil, between June 2011 and February 2012. The survey targeted 162 producers and the sample was stratified by the area allocated to cashew production (< 5 ha; 5-20 ha; 20-100 ha; >100 ha).

The number of 'pollinator-friendly practices' was a quantitative variable based on producers' responses to the following questions: (a) Do you have managed pollinators in the productive area? (b) Is there any forage available for pollinators (in the form of native bush or other crops)? (c) Do you use chemical products on your farmland? (d) How do you manage beehives and what do you do with the wild colonies in the productive area? and (e) Do you contribute to increasing pollinators' accessibility to crops (for example, through the presence of water containers in the productive area)?

Findings highlight the positive socioeconomic value of pollinator-friendly practices. Results show that the producers' experience in beekeeping is important to enhance the number of pollinator-friendly practices applied, emphasizing the benefits of promoting human capital among producers (Garibaldi and Dondo, 2015).

Example 3: Cotton

The protocol has also been applied to cotton farms in Brazil. The survey targeted 100 producers in three municipalities (Apodi, Janduís and Nova Descoberta).

The number of 'pollinator-friendly practices' was a quantitative discrete variable based on producers' answers to the following questions: (a) Do you have conservation areas on your property? (b) What do you do with wild plants in the productive area? (c) Do you have beehives for pollinator services? (d) Do you use chemicals? (in general; but also in particular for the flowering period); (e) Do you implement any alternative disease control method? and (f) Is your production a monoculture?

Findings highlight the positive socioeconomic value of pollinator-friendly practices (Garibaldi and Dondo, 2015). Results show that landscapes with more pollinator-friendly practices are associated with higher natural, financial, physical and social assets. Additionally, the number of pollinator-friendly practices increased when producers implemented an organic culture system and had beehives for pollination services on their properties (both physical assets). Overall, for this crop, the pollinator-friendly practices were positively related to four of the five assets. These results suggest that the conservation of natural capital is not related to lower financial outputs (i.e. agronomic yields and income can be increased through sustainable pathways that do not destroy the natural capital).

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