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Towards pollination accounts in Brazil

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Abstract

Pollination of commercially important plant species is one of the most studied ecosystem services due to its economic significance and direct link to marketable products. Beyond its economic role, pollination acts as a mobile link connecting ecosystems and regulating the reproduction and genetic structure of plant populations, thus shaping ecosystem structure and function. As pollinators are essential for the crossbreeding of most flowering plants, they play a key role in maintaining ecosystem integrity. In Brazil, numerous academic studies and technical reports have addressed pollination services, yet challenges persist in compiling official ecosystem service accounts. This paper discusses the country's progress in developing pollination ecosystem accounts, emphasizing issues such as the selection of products to analyze, knowledge gaps regarding pollinator dependence and its variability, the importance of non-timber forest products (NTFPs)—especially in northern Brazil—and the need for spatially explicit data on agriculture and pollinators. Using municipal data on agricultural and extractivist production from 1996 to 2023, the study identifies an increasing trend in pollination dependence, driven by crops like soy, coffee, orange, and açaí. Regional differences are notable, with the North and Northeast showing higher pollination relevance due to greater reliance on extractivism and permanent crops. To improve ecosystem accounting, timely and high-quality data are essential. Advances include updates in the Twelfth Agricultural Census to refine information on crop location, production value, and managed pollinator use; improved land use monitoring; and ecosystem type mapping aligned with IUCN standards and studies regarding Biodiversity data available in Brazil and Threatened species of pollinators, aiming to improve the knowledge on pollinator distribution, abundance, and conservation status. A database on dependency data is being developed in collaboration with the academic community to better account for regional variability on pollination dependence. These developments are critical for building comprehensive, accurate pollination ecosystem service accounts in Brazil.

Introduction

Pollination plays a critical role in the maintenance of plant populations, which are the base of the food chain of most terrestrial ecosystems, contributing to their stability and the maintenance of biodiversity, and playing a fundamental role in the sustainability of agricultural and extractive systems. For plants of commercial relevance, it is one of the most studied ecosystem services due to its economic importance and direct link with marketable products.

In addition to its economic role, pollination acts as a link that connects ecosystems and regulates the reproduction and genetic structure of plant populations, thereby shaping ecosystem function. As pollinators are essential for the crossbreeding of most flowering plants, they are also pointed out as crucial in maintaining the integrity of terrestrial ecosystems.

Starting from the conceptual and methodological reference of SEEA-EA (System of Environmental Economic Accounting - Ecosystem Accounting - United Nations, 2024) The pollination service is described as a regulation and maintenance service[1], directly linked to natural ecosystems and agricultural systems (Turner *et al.*, 2007; Bergamo *et al.*, 2021), promoting food production (provision service) and improving its physical properties, as well as fostering values related to traditional knowledge (cultural service) (Klein *et al.*, 2007; Klatt *et al.*, 2014; Freitas and Silva, 2015; IPBES, 2016; Katumo *et al.*, 2022; CBD, 2018).

Understanding regulation and maintenance services as a result of the ability of ecosystems to regulate biological processes and thus maintain environmental conditions beneficial to the environment and society, the presence of bees and other insects is an important indicator of the environmental quality of ecosystems, since when the condition of the ecosystem deteriorates, the maintenance capacity of pollinators decreases. The supply of pollinators is an example of an element considered in the evaluation of the state of ecosystems, which can be temporally evaluated, to monitor changes in ecosystem conditions through the assessment of biophysical indicators. The reduction of food sources and nesting sites, the intensive occupation of land, the use of pesticides and the fragmentation of natural landscapes are factors that contribute to the decline of bee and other insect populations.

Looking at the economic dimension, it is important to point out that the ecosystem service of pollination can be present in different stages of the production chain, depending on the product. In some cases, the benefit derived from the service translates into a direct increase in final production, for example, when the product sold is a fruit or seed of a species dependent on biotic pollination. In other cases, when the main product, which is marketed to the final consumer, is derived from a vegetative organ of the plant, such as the bulb (in the case of onions), the stem

[1] CICES V5.2 (Common International Classification of Ecosystem Services)- Pollination services are the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy. This may be recorded as a final or intermediate service.

fibers (in flax), the root (in cassava) or the leaves (in yerba mate), pollination can have an indirect contribution to the production of seedlings or seeds, that may be transported and purchased by the producer as an input (Oliveira *et al.,* 2008).

For agricultural activity, the pollination process is directly associated with crop yield, both by the quantitative and qualitative dimensions of production. However, to estimate the monetary valuation of the pollination service, it is necessary to estimate its contribution to the value of the production of crops that have different dependency rates.

Starting from the identification of the crop dependency rates of a country or region to the identification of the contribution of ecosystem services to each crop, it is possible to build a reference for the potential demand for pollination. The dimensioning of the dependency ratio thus serves as a marker, which can be used to estimate the potential loss of production value due to the disappearance of animal pollinators (Gallai *et al.,* 2009).

For environmental accounting, studies on dependency ratios can be described as complementary thematic studies for valuing the environmental economic accounts of ecosystems.

Thus, the present study aimed to analyze the trends in the direct contribution of animal pollination to agricultural and extractive production in Brazil, based on the Municipal Agricultural Production (PAM) and Plant Extraction and Silviculture Production (PEVS) Surveys of the Brazilian Institute of Statistics and Geography (IBGE), in the period from 1975 to 2023. The article also discusses the national progress in the development of pollination ecosystem accounts, highlighting both the advances and the challenges that still exist — such as the selection of products to be considered, the gaps in knowledge about regarding pollinator dependence and its variability, and the relevance of non-timber forest products (NTFPs). The study also points out ways to overcome these gaps and comments on ongoing initiatives within the scope of the IBGE that will contribute to the development of Ecosystem Accounts on pollination services in Brazil.

Advances in pollination service accounting

Despite the challenges in the implementation of Environmental Ecosystem Accounting for pollination services, some examples of progress can be described. One of these come from the analysis focused on the monetary valuation of the animal pollination service in Mexico, developed within the scope of the Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) Project, a joint initiative of the European Union and the United Nations.

Based on the National Agricultural Survey of Mexico (ENA), the study, which focuses on the importance of contributing to agricultural production and the well-being of the population, evaluates how pollination carried out by animals contributes with agricultural production in the country. The data reveal that, although the value varies between municipalities, pollination represents a significant portion of the country's agricultural production. The research also

examined the relationship between the provision of pollination services and proximity to natural habitats, suggesting that the conservation of these habitats is essential to ensure the continuity of the provision of this ecosystem service (Galindo and Basurto, 2021).

Alvisilver *et al.* (2017) quantified the value of ecosystem services by analyzing the impact of ecosystem changes – such as the removal of one hectare of forest – on production and profit in seven countries: China, Costa Rica, Ethiopia, Kenya, South Africa, Sweden and Tanzania. The study highlighted challenges in the availability, coverage and quality of data, as well as in the definition of spatial units and the need to consider the condition of ecosystems, and not just their presence, to understand the supply of pollinators and their cover in agricultural areas. In the study, the authors reinforce the role of healthy forests as a habitat for pollinators and the impact on the reduction of pollinators by the distance between preserved forests and agricultural areas.

Another study, developed under the European Parliamentary Research Service, on pollinator protection estimated that insects benefit more than 84% of crops in Europe (European Union, 2021), reinforcing that knowing the distribution of pollinators is essential to estimate their availability and, consequently, ensure the maintenance of the habitats that sustain them to ensure the continuous supply of the service (Leonhardt, 2013).

The work by Porto et al, (2020) carried out an assessment of the dependence of world agricultural production on pollination by classifying countries based on agricultural production dependent and not dependent on animal pollinators. The study shows that, despite the growing global advances in the estimates of the pollination service of the most economically relevant crops, there is a lack of data on commercial crops of regional and local importance, essential for the food security of populations, particularly in developing countries. The study proposes the use of multiple approaches to overcome the lack of information by analyzing different ecological and socioeconomic contexts. These approaches aim to provide data for both mechanized farmland that serves global markets, and small-scale horticulture that supports local subsistence economies.

In Brazil, a study developed by Moreira *et al.* (2024) for the State of São Paulo presented an important contribution to the methodological structuring of the valuation of the ecosystem service of pollination based on the concepts of supply, flow, and demand. To this end, they started from (a) spatial analysis, with satellite image mapping of agricultural areas and native vegetation; (b) spatial indicators of pollinator provision and crop dependency and (c) model integrating pollinator data, landscape ecosystem characteristics and crop requirements. Starting from this analytical construction, it is possible to describe consistent methodological steps for the advancement of pollination service accounting, aligned with SEEA-EA, both in the dimension of service valuation and in the construction of indicators of ecosystem condition.

Brazilian context

Agriculture plays a central role in the Brazilian economy (IPEA, 2023), contributing significantly, directly and indirectly, to the country's Gross Domestic Product (GDP). The vast

territorial extension, combined with the diversity of soils and climates, favored Brazil's transition from being a food importer to one of the main agricultural producers and exporters in the world (Mores *et al.*, 2022; FAO, 2023).

In the academic and technical sphere, several studies have addressed pollination services in Brazil, although there are still challenges in the preparation of consolidated official accounts on these services. Initiatives, research groups and projects have reinforced the country's role in pollinator conservation, as summarized by Wolowski *et al.* (2019) and Imperatriz-Fonseca (2012). These efforts have not only sought to fill knowledge gaps but also sensitize society and public policy makers about the importance of conserving pollinator diversity.

Some of the main Brazilian initiatives were summarized by Wolowski *et al.* (2019). Highlights include the meeting "Conservation and Sustainable Use of Pollinators in Agriculture, with an Emphasis on Bees" (which resulted in the São Paulo Declaration in 1998), the International Initiative for the Conservation and Sustainable Use of Pollinators (IPI) and its national version (IBP), the Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (PROBIO, 2003-2004), in addition to the Pollinators of Brazil Project, launched in 2010. In 2012, Brazil became a signatory to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which published, in 2016, the Thematic Diagnosis on Pollination, Pollinators and Food Production. The country also created the Brazilian Platform for Biodiversity and Ecosystem Services (BPBES), which launched the Thematic Report on Pollination in partnership with the Brazilian Network of Plant-Pollinator Interactions (REBIPP). REBIPP brings together researchers from multiple institutions who work in different initiatives related to basic and applied research on pollination, including the monitoring of the international coalition Promote Pollinators (https://promotepollinators.org), established within the scope of the CBD.

Giannini *et al.* (2015) estimated that the economic contribution of pollinators is equivalent to about 30% (approximately US$12 billion) of the total value of the annual agricultural production of dependent crops (about US$45 billion). More recently, the Thematic Report on Pollination, Pollinators and Food Production in Brazil (Wolowski *et al.*, 2019) estimated that, in 2018, the value of the ecosystem service of pollination (by bats, moths, wasps, butterflies, flies, beetles, and bees) for food production in the country is around R$ 43 billion annually based on the value of production and dependency rates of 44 crops for which this information was available.

In 2021, in a study funded by the Center for Synthesis in Biodiversity and Ecosystem Services (SinBiose), Bergamo *et al.* (2021) mapped the importance of pollinators for agriculture in all Brazilian municipalities. The main contribution of the study was to identify where native vegetation restoration efforts can generate the greatest benefits for both biodiversity and agricultural production.

Expanding the taxonomic and spatial coverage of data on the degree of dependence of different crops on pollination is still a significant challenge (Gianinni *et al.*, 2015; Wolowski *et al.*,

2019). Most of the studies are concentrated in the Southeast and Northeast Regions - 36% and 26% according to Wolowski *et al.* (2019) – which can lead to inappropriate generalizations between pollination and agriculture at the national level. In addition, there is a risk of neglecting key pollinator species in other regions, potentially essential for local crops. In addition, varieties of the same crop may have distinct floral morphologies that influence this dependence or require specific pollinators (Garratt, *et al.*, 2016;).

IBGE's approach on the topic of pollination

To start the development of a system of environmental pollination accounts in Brazil, the IBGE published in July 2025 a study entitled "Contribution of Pollinators to agricultural and extractive production in Brazil" (IBGE, 2025). In this study, we used data on the production of agricultural crops and those from the activity of plant extractivism compiled annually for each Brazilian municipality by the IBGE, through two surveys: PAM and PEVS.

Produção Agrícola Municipal - PAM (Municipal Agricultural Production) is an annual and continuous survey that, since 1975, has compiled statistical information on the quantity produced, planted and harvested area, average yield and value of agricultural production. The survey Produção da Extração Vegetal e Silvicultura – PEVS (Production of Plant Extraction and Silviculture) is also annual and continuous and, since 1986, it has compiled statistical information on the quantity and value of production resulting from the harvesting of native plant resources and planted forests, with the municipality as the collection unit. The total existing area and the harvested area of forest plantations are also objects of the survey. Data collection for the PAM and PEVS is conducted using standardized questionnaires completed by key stakeholders in each municipality, such as agricultural sector technicians, large-scale producers, agricultural and industrial establishments, and organizations representing the agricultural and extractive sectors (IBGE, 2018).

In the field of agricultural statistics, IBGE also conducts the Agricultural, Forestry, and Aquaculture Census, which covers a broader range and greater variety of products than PAM and PEVS but is carried out every ten years. This periodicity limits its use for analyzing annual trends, which is the focus of this initial study. In the future, data from the Agricultural Census are expected to be used to complement the accounts.

Timber and forestry products were excluded from the analyses, since no product from these sectors is directly related to the ecosystem service of pollination. The other products were classified as pollination-dependent or non-pollination-dependent, considering only the direct contribution of pollination. That is, the influence of pollinators on the formation of fruits and seeds that are sold to the final consumer and recorded in the surveys, excluding indirect impacts, such

as the production of seedlings or seeds of crops in which vegetative parts of the plant are economically exploited. Thus, products such as cassava, onions, or yerba mate were considered non-dependent, even if the reproduction of the species involves pollination for seed production.

The dependency ratios used in this study were obtained from Siopa *et al*. (2024). For species not listed in this source, the values were obtained from Wolowski *et al*. (2019) or Klein *et al*. (2007) and, for some products from extractivism, Sabino *et al*. (2022) and De Medeiros *et al*. (2019). Some species known not to be dependent on pollinators, which were not included in the lists mentioned above, were classified using other sources, such as pineapple (Queiroga et al., 2023) and pecan/European walnut (Fronza et al., 2018). Based on the average dependency rates, the products were grouped into four classes of dependence on animal pollination (Klein et al., 2007).

In total, data were compiled from 89 products, of which 32 were products from temporary crops and 35 from permanent crops from PAM, and 28 products from PEVS, six of which are common to both surveys (açaí, rubber, cashew nuts, yerba mate, heart of palm and annatto). Dependency rates were obtained for 86 products, and the remaining 3 (oiticica, tucum and tungue) were classified as having unknown dependence.

The influence of pollination services at national, regional and municipal levels throughout the historical series of agricultural and extractive production in Brazil was explored, contrasting the tendencies between the pollinator dependency groups. The variables analyzed were harvested area, quantity produced and value of production of each product, from PAM, and the quantity produced and value of production from plant extraction, from PEVS.

To consolidate the information into a single metric, an Indicator of Pollinator Contribution to Production Value was calculated. The production value was obtained by multiplying the agricultural output by the average price paid to producers. This indicator was then estimated by weighting the production value of each product by its level of dependence on animal pollination for the period from 1996 to 2023[2] (Fig. 1), for different accounting areas: Municipality, State and the Federal District, Major Region, Brazil. Exclusively for the year 2023, the indicator was also computed for the 6 terrestrial Brazilian Biomes (IBGE, 2019), using a correspondence table of the main biome of each municipality available for this year (IBGE, 2024).

To account for uncertainties in the dependence estimates, three alternative values of the indicator were calculated for each year: using the mean, the minimum, and the maximum dependence values assigned to each product. For products with unknown levels of pollination

[2] Between the late 1980s and early 1990s, Brazil went through a period of monetary instability, and hyperinflation reaching 40% per month in 1994. To avoid erroneous interpretations caused by price fluctuations, we opted to start the monetary analysis from 1996.

dependence, an assumed average of 50% was applied, with 0% and 100% used as the minimum and maximum values, respectively, to reflect the uncertainty.

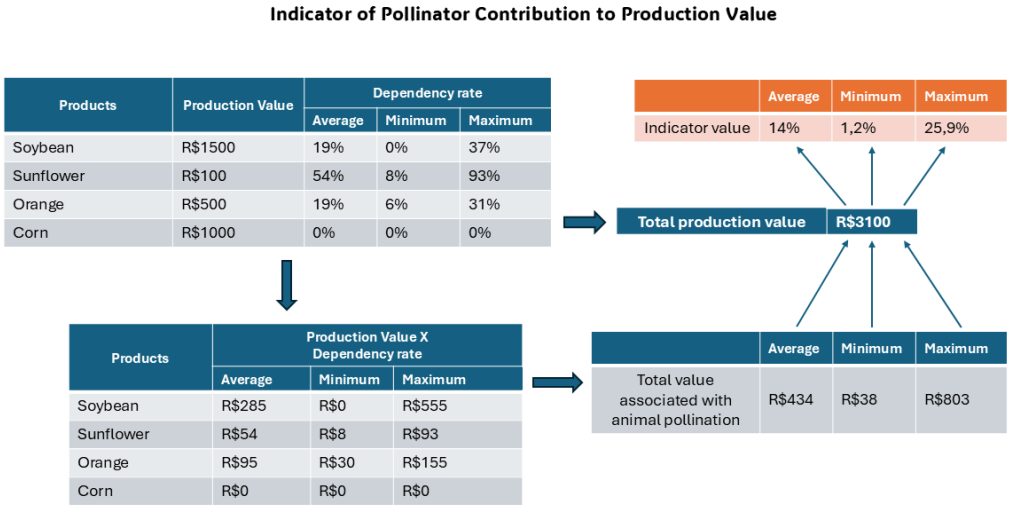


Figure 1 – Hypotethical example showing how the Indicator of Pollinator Contribution to Production Value is computed for each analysed area.

The Brazilian municipalities were then classified according to their values of the Contribution of Pollinators to Production Value into five groups - no contribution (indicator value equal to 0), up to 5%, 6 to 25%, 26 to 65% and more than 65%. The proportion of municipalities with data in each class was compared between the years 1996 and 2023, considering the total production and each of the modes of production (temporary crop, permanent crop, and wild crop harvesting).

It is important to highlight that this indicator does not represent a direct estimate of the economic value of the pollination service, as it does not consider variations in pollinator supply or possible pollination deficits. However, it reflects the distribution of pollination-dependent products and their participation in the total value of production in each geographic area, enabling spatio-temporal analyses of the contribution of this service to national agricultural and extractive production.

The summary results of the study are presented below. The complete information can be obtained at (all materials in Portuguese):

Full text:

https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=2102189

Data from the Indicator of Pollinator Contribution to Production Value:

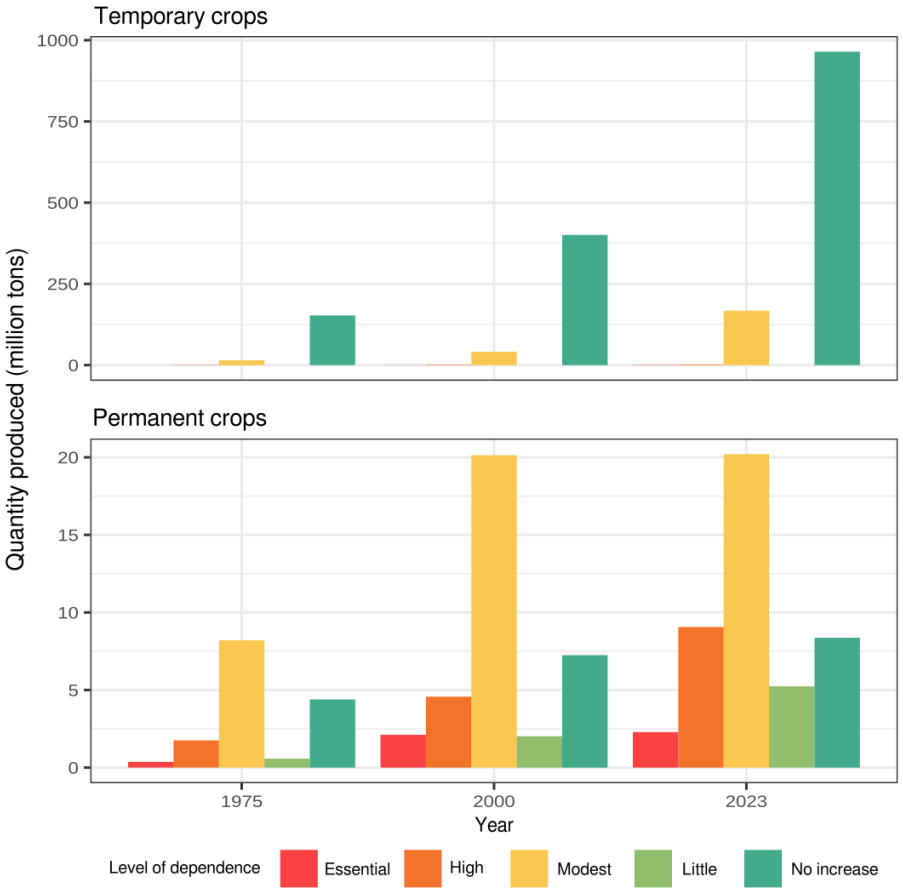
https://sidra.ibge.gov.br/pesquisa/contas-economicas-ambientais/contribuicao-dos-polinizadores/tabelas

Data from Municipal Agricultural Production (PAM): https://sidra.ibge.gov.br/pesquisa/pam/tabelas.

Data on Plant Extraction Production and Silviculture: https://sidra.ibge.gov.br/pesquisa/pevs/tabelas/brasil/2023.

Results

Among the 89 products analyzed, 48.3% depend, to some degree, on animal pollination. Temporary agricultural crops show a strong predominance of products with modest dependence, represented mainly by soybeans and without dependence, represented mainly by sugarcane. Among the products of permanent cultivation and extractivism, the dependency rates are more varied, with expressive values of products of all dependency classes (Fig. 2). Products with a large volume of production in these categories are coffee, cocoa and various fruits, such as oranges, açaí, mangoes and grapes.



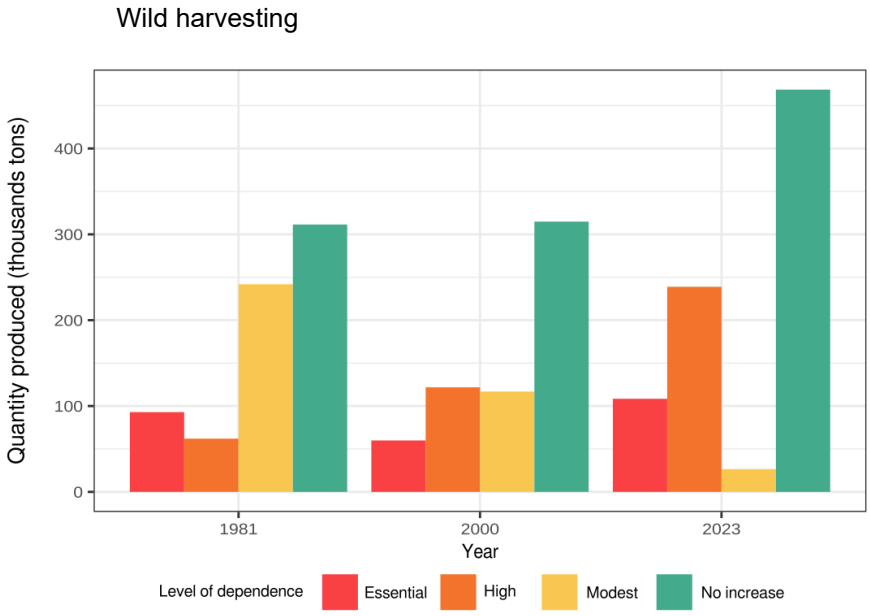


Figure 2 – Quantity produced according to the pollinator dependency levels.

Pollination contributes considerably to the value of Brazilian agricultural and extractive production (Fig. 3). It is estimated that its contribution varies between 5 and 25% of the total, that is, animal pollination may be contributing with up to a quarter of the gross value obtained from Brazilian agricultural/extractive production. In 2023, the average value of the Indicator of Pollinator Contribution to Production Value was 16.14%, showing growth in relation to 1996 (14.4%).

Considering the mode of production, for temporary crops, the average indicator changed from 7.3% in 1996 to 12.0% in 2003. For permanent crops, it went from 36.4% to 38.7%. Extractive production was the modality in which the contribution of pollinators grew the most proportionally in the period analyzed, from 21.8% in 1996 to 47.2% in 2023.

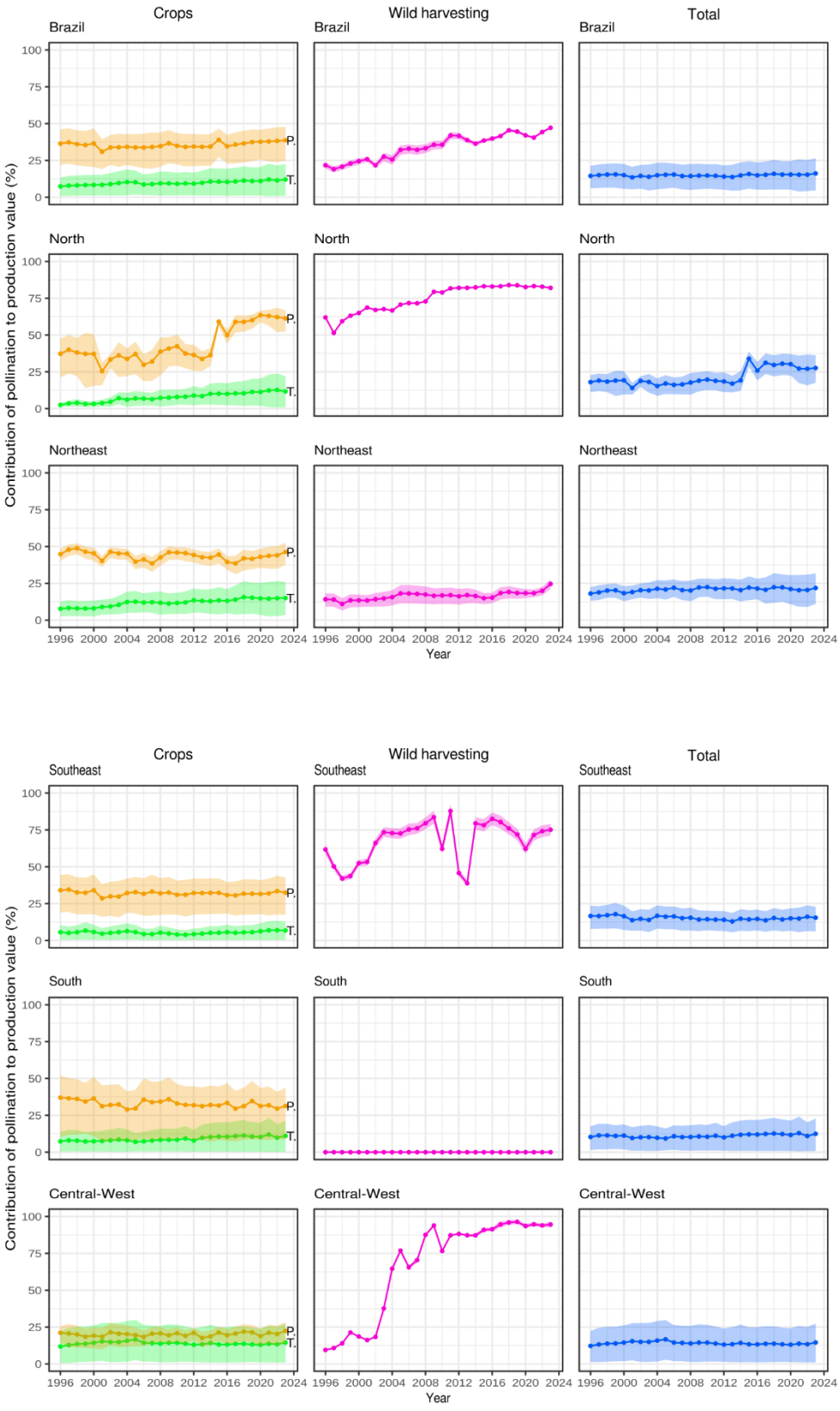


Figure 3 – Time series of the Indicator of Polination Contribution to Production Value, total of the country and values by Great Region and production mode (P – permanent crops, T – temporary crops).

Thus, the action of animal pollinators has an important impact on agricultural and extractive production in Brazil and this percentage has grown in recent years. Regionally, it is possible to observe that the average values of the indicator increased in 4 of the 5 regions of the country (Figure 2), even with great variation between the main products cultivated and extracted in each of them. Although the average contribution of pollination to the value of production is generally between 10 and 20% in total, there are marked differences depending on the composition of the predominant crops in each region and considering each type of crop separately, quite significant impacts of pollination are observed between permanent and extractive crops in some regions (Fig. 3).

Among the agricultural and extractive products dependent on pollination with the highest production value, soybeans are the main product in all regions. But there is variation in the remaining products of each region (Fig. 4). The North region, where the Amazon forest is located, has a high contribution of pollination both for the cultivation of permanent products and for extractivism. Açaí is traditionally a product from wild crop harvesting in the North region. In the last few decades, it began to be cultivated in permanent crops, and in 2023 already is among the 5 pollinator-dependent products with the highest production value in the North region. The Northeast region stands out in the production of fruits, such as mangoes, cocoa and grapes, and a considerable part is exported to other countries[3].

[3] Export percentages consulted in https://abrafrutas.org/dados-estatisticos/

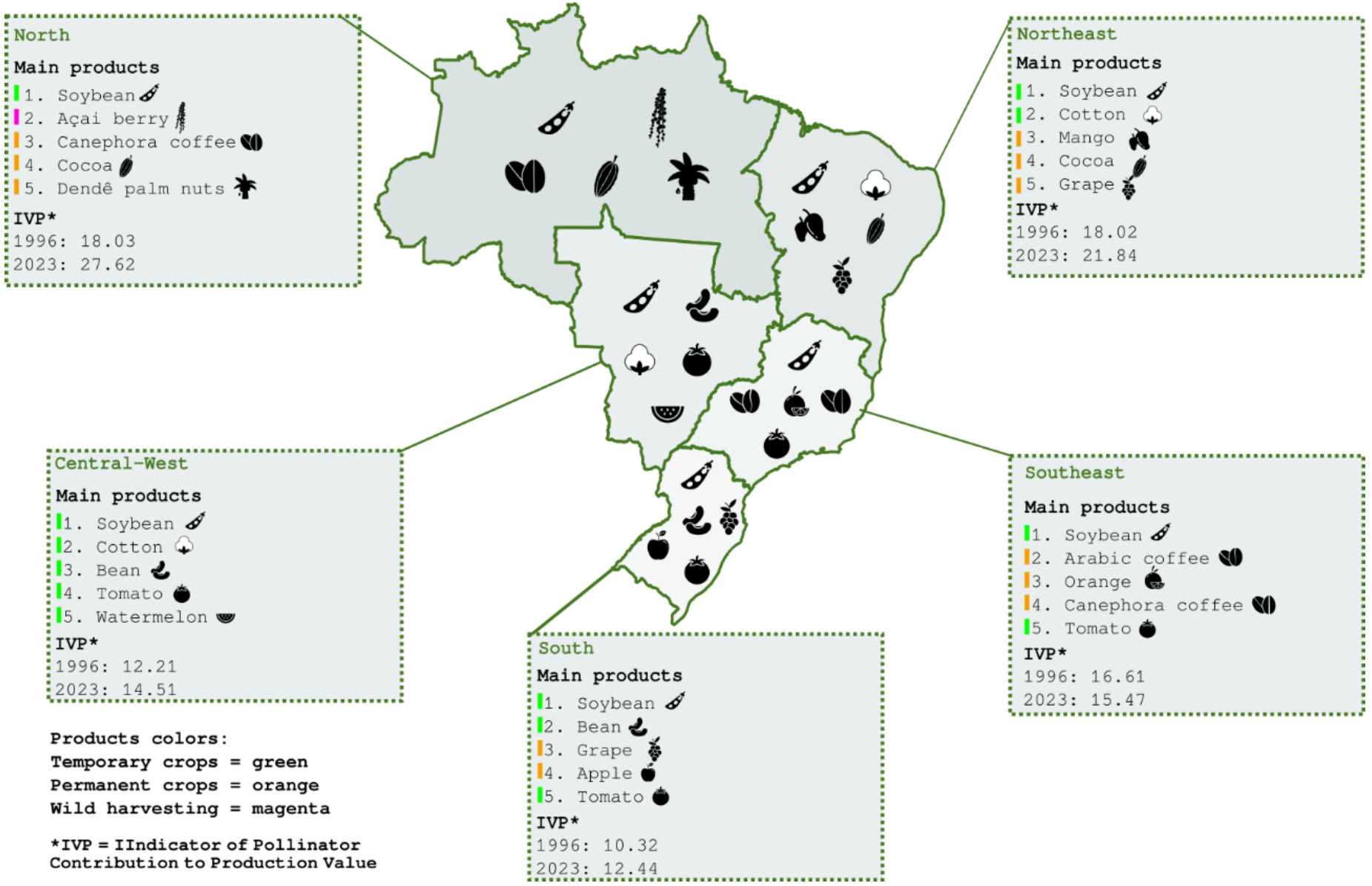
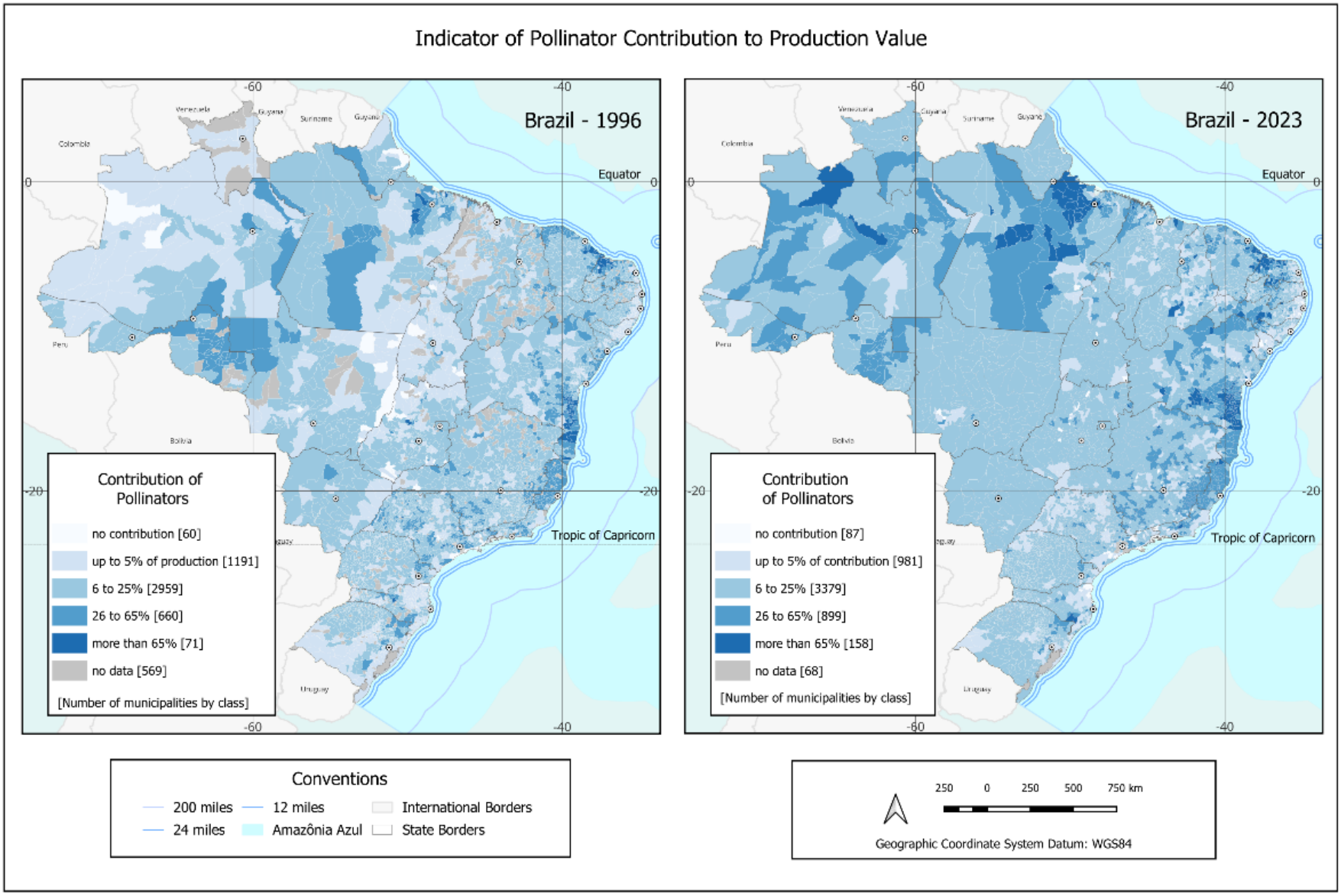


Figure 4 – Infographic showing highlighted products from each Great Region and values of the Indicator of Pollinator Contribution to Production values in 1996 and 2023.

The importance of animal pollination manifests itself in different ways and at different scales, benefiting the national and regional economy, and the economy of municipalities, communities and families that depend directly or indirectly on this ecosystem service. At the municipal level, its relevance is reflected both in income generation and in food security and in the sustainability of local production systems and varies according to the size, economic profile and types of predominant crops.

The analyzed data showed that most Brazilian municipalities benefit from pollination for agricultural and extractive production and this proportion has been increasing (Map 1). Although the proportion of municipalities that do not benefit from pollination grew between 1996 and 2023 (representing 1.2% in 1996 and 1.6% in 2023) and that of municipalities with a contribution of up to 5% decreased (24.1% in 1996 and 17.8% in 2023), significant increases occurred in the proportions of municipalities with a contribution from pollination in the value of production greater than 5% (74.7%, in 1996, and 80.6% in 2023).



Map 1 – Indicator of Pollinator Contribution to Production Value of the Brazilian Municipalities, 1996 and 2023.

Next steps

Considering the important demand for pollination in the country, the availability of data and the transversal nature of this ecosystem service, the elaboration of ecosystem accounts focused on pollination represents not only an important step, but also a strategic advance for the consolidation of SEEA-EA in Brazil. The compilation of these accounts requires progress in measuring both the potential for service supply and the flows realized in the areas where economic activity develops. Below are some initiatives in progress within the scope of the IBGE that will contribute to overcoming these challenges.

In Brazil, the Ministry of Science, Technology and Innovation, in partnership with UN Environment (UNEP) and with support from the Global Environment Facility (GEF), developed the Brazilian Biodiversity Information System (SiBBr), which acts as the national node of GBIF (Global Biodiversity Information Facility) and adopts international standards for sharing species occurrence data. In collaboration with SiBBr, IBGE evaluated the quality and coverage of these records (IBGE, 2023), identifying advances and limitations regarding taxonomic, spatial, and temporal completeness. More complete records — with identification of the species, date and geographic coordinates — can be applied in Ecological Niche Models (e.g. Perennes *et al.* 2021) to estimate the potential distribution of pollinators from environmental and landscape variables. These models provide fundamental inputs to generate spatial indicators of pollination supply, subsidizing the elaboration of pollination accounts within the scope of environmental economic accounts.

Data on the conservation status of species are routinely produced by the Ministry of the Environment and Climate Change (MMA), following the global methodology defined by IUCN. Between 2020 and 2022, the Chico Mendes Institute for Biodiversity Conservation (ICMBio), the agency linked to the MMA responsible for the evaluation of fauna species, prepared the National Action Plan for the Conservation of Pollinating Insects, contemplating integrated actions by civil society and government institutions, to promote the conservation of habitats and the recovery of populations 56 taxa at risk of extinction[4]. Since 2020, the IBGE, in partnership with ICMBio and the National Center for Flora Conservation of the Botanical Garden Research Institute of Rio de Janeiro (the institution responsible for assessing the risk of extinction of flora species) has been producing accounts of threatened species, synthesizing this data for Brazilian fauna and flora. The initial publication was released in 2020 (IBGE, 2020), and in 2022, the tables were updated based on the official lists published by the MMA (IBGE, 2022).

Another relevant effort was the comparison between the IUCN Ecosystem Functional Groups (EFG) and the national classes of Vegetation and Land Cover and Land Use (IBGE, 2021). The study evaluated the proportions of conceptual and spatial comparability in the territory,

[4] More information available in: www.gov.br/icmbio/pt-br/assuntos/biodiversidade/pan/pan-insetos-polinizadores (in portuguese)

highlighting the limitations related to the thematic resolution of national classes, especially in agricultural ecosystems.

Throughout 2023 and 2024, collaborations with the University of Melbourne and IUCN resulted in the development of a guide for the classification of agricultural and forestry ecosystems in the IUCN global ecosystem typology (IUCN, 2025), which includes guidelines for the classification of some relevant crops in Brazil (e.g. banana) that have intermediate characteristics between two EFGs.

For a better representation of the land cover and land use classes, IBGE is currently working on improving its land cover and land use mapping, incorporating new technologies for orbital image classification and strengthening partnerships with other government institutions. The mapping that is being developed seeks to improve the representation of territorial features by incorporating the analysis of time series of large volumes of orbital data with the application of artificial intelligence and machine learning techniques. The methodology also involves the construction of a robust database of point samples for classifier training and field validation stages, to ensure better accuracy of the final map and better representation of the country's regional and environmental diversity.

IBGE has sought collaboration with the academic community to develop innovations for ecosystem accounts. In the case of the pollination service, the participation of IBGE researchers in the INPol project stands out, a research group funded by the National Institutes of Science and Technology Program (INCT), which fosters multi-institutional and interdisciplinary networks dedicated to scientific research in strategic themes and to facing major national challenges. Among the expected products of this collaboration, which began in 2023, are: (a) the development of a regionalized database for crop dependence data on pollinators; and (b) a joint technical publication establishing the criteria for inclusion of scientific studies in this database. Both products will be important to improve the accuracy of dependency estimates, given the high regional variation in the demand for pollination service and the uncertainties associated with dependency rates, which point to the need for more field experiments with standardized criteria that allow estimating specific rates for different regions or agricultural varieties.

From INPol, questions were also proposed in the questionnaire of the 12th Census of Agriculture, Aquaculture and Silviculture, whose field collection is expected to take place soon. Questions were proposed about beekeeping (European or native) in agricultural establishments, in addition to the use of managed pollinators for pollination supplementation, broken down by crop produced in the establishment. This information will make it possible to assess, both from the point of view of beekeepers and farmers, the prevalence and distribution of the use of managed bees for pollination purposes, providing statistics on the economic aspects of this use and pointing out regions and crops where ecosystem service provided by wild bees is probably not sufficient anymore.

The 12th Agricultural Census also is planning important methodological innovations that will be invaluable for the accounts of the pollination ecosystem service, such as spatially explicit information about plots and crops, provision of pollination services to third parties, expenses with inputs, production value of a wide list of products and seeds, adoption of sustainable agricultural practices and use of pesticides.

It is expected that the integration of the initiatives presented here - associated with inter-institutional partnerships and academic collaboration - will enable advances in ecosystem accounting, with the pollination service as a point of consolidation for this improvement in Brazil.

Questions for the London Group

What is your country's experience with pollination accounts?

Which data sources are available, and which are not?

How to deal with and communicate uncertainties in estimates?

What kind of questions can be added to traditional statistical surveys to boost the compilation of pollination or other ecosystem accounts?

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