Socioeconomic data on pollinators

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Abstract

Pollinating insects create economic values by enabling or enhancing fruit set of various crop species and – in the case of managed honey bee colonies – additionally by the production of various hive products, among which honey and beeswax. The extent to which the yield of a given crop is affected by insect pollination depends on a variety of factors. Different ranges for the level of dependence on insect pollination have been defined for leading world crops [1]. Based on this definition and on production data provided by FAO [2], the economic value of crop pollination by insects has been calculated for all current EU member states. The average economic value of crop pollination by insects in the EU from 1991 to 2018 ranged between 7 and 18 billion USD per year, equivalent to 8,1% - 9,9% of the total value of plant production. Insect pollination of apple produced the highest economic value, accounting on the average for 24% of the overall value of crop pollination by insects between 2014 and 2018. High shares were also found for stone fruit, oilseed, cucurbits and tomato. Crop production in the EU member states relies to a different extent on insect pollination. While in some central and southern European regions on the average more than 12% of total agricultural production depended on insect pollination, in some northern European regions, this dependency was equal to or less than 6%. Between 2014 and 2018, on the average 1,4 beehives were kept per ha crop area requiring insect pollination in the EU. In a few central and southern European regions this ratio was 2 to 3 times higher than the EU average and in a range that is commonly considered to be sufficient for pollination of many crops.

Keywords: pollination, honey, beeswax, crops, EU

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Introduction

Pollinating animals create economic values by enabling or enhancing fruit set of various crop species and – in the case of managed honey bee colonies – additionally by the production of various hive products, among which honey and beeswax [1, 3]. The extent to which the yield of a given crop is affected by animal pollination depends on a variety of factors. Different ranges for the level of dependence on animal pollination, predominantly insects in the case of world crop production and exclusively insects in the case of European crop production, have been defined for leading world crops [1]. Based on this definition and on production data provided by FAO [2], the economic value of crop pollination by insects has been calculated for all current EU member states.

Method

Estimates on the economic value of honey and beeswax production as well as on the number of managed honey bee colonies were obtained from data provided by the Food and Agriculture Organization of the United Nations (FAO) and by a local beekeeping association. A rough assessment of the economic value of crop pollination was made by a method proposed by Gallai and co-workers [4], based on pollination dependency ranges for different crops provided by Klein and co-workers [1].

Data on honey (t), wax (t) and agricultural crop production (t, ha) in the EU from 1961 to 2018 was obtained from FAO at country level [2]. Producer prices (USD) for honey, beeswax, and agricultural crops in the EU from 1991 to 2018 were obtained from FAO at country level [2]. The number of managed colonies was obtained from FAO (1961 to 2018) at country level [2] and from the Austrian Beekeepers Federation Biene Österreich (2001-2019) for Austria at regional (NUTS 2) level. The pollination dependency of agricultural crops was obtained from Klein and co-workers [1].

Economic value of pollination for a crop per EU member state per year

The total economic value (EV_{ixy}) of a given crop (i) in a given EU member state (x) in a given year (y) is calculated according to the following formula where Q_{ixy} is the quantity produced of crop i in EU member state x in year y and P_{ixy} is the annual average price of crop i per unit of quantity produced in EU member state x in year y:

$$EV_{ixy} = P_{ixy} \times Q_{ixy}$$

The minimum ($PEVmin_{ixy}$), maximum ($PEVmax_{ixy}$) and average ($PEVavg_{ixy}$) economic value of pollination of a given crop (i) in a given EU member state (x) in a given year (y) is calculated according to the following formulas, where for each crop $i \in [1, I]$, Q_{ixy} is the quantity produced of this particular crop in EU member state x in year y, P_{ixy} is the annual average price of this particular crop per unit of quantity produced in EU member state x in year y, $Dmin_i$ is the minimum and $Dmax_i$ the maximum dependence ratio of crop i on insect pollinators.

$$PEVmin_{ixy} = P_{ixy} \times Q_{ixy} \times Dmin_i$$

$$PEVmax_{ixy} = P_{ixy} \times Q_{ixy} \times Dmax_i$$

$$PEVavg_{ixy} = \frac{PEVmax_{ixy} + PEVmin_{ixy}}{2}$$

The relative economic value of plant pollination ($RPEVavg_{ixy}$) for a given crop (i) in

a given EU member state (x) in a given year (y) is then calculated as the percentage of average economic value of plant pollination for the given year y ($PEVavg_{ixy}$).

$$RPEVavg_{ixy} = \frac{PEVavg_{ixy} \times 100}{EV_{ixy}}$$

Economic value of pollination per crop per year

The total economic value (EV_{iy}) of a given crop (i) in a given year (y) in all EU member states is calculated according to the following formula where for each EU member state $x \in [1, X]$, EV_{ixy} is the economic value of crop i in EU member state x in year y:

$$EV_{iy} = \sum_{x=1}^{X} \left(EV_{ixy}\right)$$

The minimum ($PEVmin_{iy}$), maximum ($PEVmax_{iy}$) and average ($PEVavg_{iy}$) economic value of pollination for a given crop (i) in a given year (y) in all EU member states is calculated according to the following formulas, where for each EU member state $x \in [1, X]$, $PEVmin_{ixy}$ is the minimum economic value of plant pollination for crop i in EU member state x in year y and $PEVmax_{ixy}$ is the maximum economic value of plant pollination for crop i in EU member state x in year y.

$$PEVmin_{iy} = \sum_{x=1}^{X} \left(PEVmin_{ixy}\right)$$

$$PEVmax_{iy} = \sum_{x=1}^{X} \left(PEVmax_{ixy}\right)$$

$$PEVavg_{iy} = \frac{PEVmax_{iy} + PEVmin_{iy}}{2}$$

The relative economic value of pollination ($RPEV_{iy}$) for a given crop (i) in a given year (y) in all EU member states is calculated according to the following formula where $PEVavg_{iy}$ is the average economic value of pollination for a given crop (i) in a given year (y) in all EU member states and EV_{iy} is the total economic value of a given crop (i) in a given year (y) in all EU member states.

$$RPEV_{iy} = \frac{PEVavg_{iy} \times 100}{EV_{iy}}$$

The average relative economic value of pollination ($RPEV_{i,2014-2018}$) for a given crop (i) in all EU member states for the years 2014 to 2018 is calculated according to the following formula where $RPEV_{iy}$ is the relative economic value of pollination for a given crop (i) in a given year (y) in all EU member states:

$$RPEV_{i,2014-2018} = \frac{\sum_{y=2014}^{2018}\left(RPEV_{iy}\right)}{5}$$

Economic value of pollination per EU member state per year

The total economic value of crop production (EV_{xy}) in a given EU member state (x) in a given year (y) is calculated according to the following formula where for each crop $i \in [1, I]$, EV_{ixy} is the total economic value of crop i in EU member state x in year y:

$$EV_{xy} = \sum_{i=1}^{I} \left(EV_{ixy}\right)$$

The minimum ($PEVmin_{xy}$), maximum ($PEVmax_{xy}$) and average ($PEVavg_{xy}$) economic value of crop pollination in a given EU member state (x) in a given year (y) is calculated according to the following formulas, where for each crop $i \in [1, I]$,

$PEVmin_{ixy}$ is the minimum economic value of plant pollination for crop i in EU member state x in year y and $PEVmax_{ixy}$ is the maximum economic value of plant pollination for crop i in EU member state x in year y.

$$PEVmin_{xy} = \sum_{i=1}^{I}\left(PEVmin_{ixy}\right)$$

$$PEVmax_{xy} = \sum_{i=1}^{I}\left(PEVmax_{ixy}\right)$$

$$PEVavg_{xy} = \frac{PEVmax_{xy} + PEVmin_{xy}}{2}$$

The relative economic value of crop pollination ($RPEV_{xy}$) for a given EU member state (x) in a given year (y) is calculated according to the following formula where $PEVavg_{xy}$ is the average economic value of crop pollination for a given EU member state (x) in a given year (y) and EV_{xy} is the total economic value of crop production for a given EU member state (x) in a given year (y).

$$RPEV_{xy} = \frac{PEVavg_{xy} \times 100}{EV_{xy}}$$

The average relative economic value of crop pollination ($RPEV_{x,2014-2018}$) for a given EU member state (x) for the years 2014 to 2018 is calculated according to the following formula where $RPEV_{xy}$ is the relative economic value of crop pollination for a given EU member state (x) in a given year (y):

$$RPEV_{x,2014-2018} = \frac{\sum_{y=2014}^{2018}\left(RPEV_{xy}\right)}{5}$$

Economic value of pollination per year

The total economic value of crop production in all EU member states (EV_y) in a given year (y) is calculated according to the following formula where for each crop $i \in [1, I]$ and for each EU member state $x \in [1, X]$, EV_{ixy} is the total economic value of crop i in EU member state x in year y:

$$EV_y = \sum_{x=1}^{X}\sum_{i=1}^{I}\left(EV_{ixy}\right)$$

The minimum ($PEVmin_y$), maximum ($PEVmax_y$) and average ($PEVavg_y$) economic value of crop pollination in all EU member states in a given year (y) is calculated according to the following formulas, where for each crop $i \in [1, I]$ and for each EU member state $x \in [1, X]$, $PEVmin_{ixy}$ is the minimum economic value of plant pollination for crop i in EU member state x in year y and $PEVmax_{ixy}$ is the maximum economic value of plant pollination for crop i in EU member state x in year y.

$$PEVmin_y = \sum_{x=1}^{X}\sum_{i=1}^{I}\left(PEVmin_{ixy}\right)$$

$$PEVmax_y = \sum_{x=1}^{X}\sum_{i=1}^{I}\left(PEVmax_{ixy}\right)$$

$$PEVavg_y = \frac{PEVmax_y + PEVmin_y}{2}$$

The average ($RPEVavg_y$), minimum ($RPEVmin_y$) and maximum ($RPEVmax_y$) relative economic value of crop pollination in all EU member states in a given year (y) is calculated according to the following formulas where $PEVavg_y$, $PEVmin_y$ and $PEVmax_y$ are the average, minimum and maximum economic value, respectively, of

crop pollination in all EU member states in a given year (y) and EV_y is the total economic value of crop production in all EU member states in a given year (y).

$$RPEVavg_y = \frac{PEVavg_y \times 100}{EV_y}$$

$$RPEVmin_y = \frac{PEVmin_y \times 100}{EV_y}$$

$$RPEVmax_y = \frac{PEVmax_y \times 100}{EV_y}$$

Pollinated area

The total area of cultivated crops for which the dependency on insect pollination according to Klein [1] is greater than 0, subsequently referred to as pollinated crops (PA_{xy}) in a given EU member state (x) in a given year (y) is calculated according to the following formulas, where the pollinated crop $i \in [1, I]$ and A_{ixy} is the total area of a pollinated crop i in EU member state x in year y.

$$PA_{xy} = \sum_{i=1}^{I} (A_{ixy})$$

The number of beehives per total area of pollinated crops (BPA_{xy}) for a given EU member state (x) in a given year (y) is calculated according to the following formula where B_{xy} is the total amount of beehives kept in a given EU member state (x) in a given year (y) and PA_{xy} is total area of pollinated crops in a given EU member state (x) in a given year (y).

$$BPA_{xy} = \frac{B_{xy}}{PA_{xy}}$$

The average number of beehives per total area of pollinated crops ($BPA_{x,2014-1018}$) for a given EU member state (x) for the years 2014 to 2018 is calculated according to the following formula where BPA_{xy} is the number of beehives per total area of pollinated crops for a given EU member state (x) in a given year (y):

$$BPA_{x,2014-2018} = \frac{\sum_{y=2014}^{2018} (BPA_{xy})}{5}$$

Results and Discussion

What is the economic value of crop pollination by insects in the EU?

The extent to which the yield of a given crop is affected by insect pollination depends on a variety of factors.

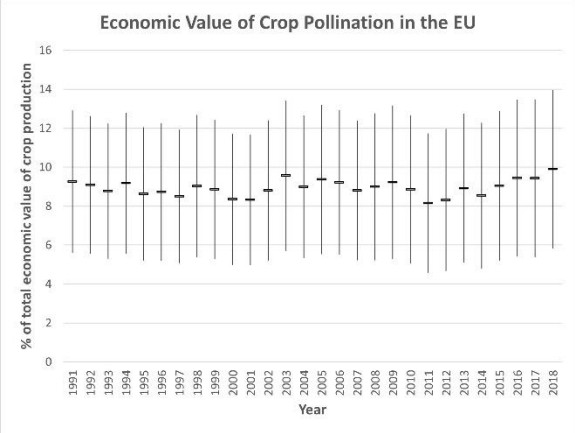


Figure 1. Average ($RPEVavg_y$, horizontal bar), minimum ($RPEVmin_y$, lower whisker) and maximum ($RPEVmax_y$, upper whisker) relative economic value of crop pollination by insects [%] in all EU member states. Source: [4, 1, 2].

Different ranges for the level of dependence on insect pollination have been defined for leading world crops [1]. Based on this definition and on production data provided by FAO [2], the economic value of crop pollination by insects has been calculated for all current EU member states. The average economic value of crop pollination by insects in the EU from 1991 to 2018 ranged between 7 and 18 billion USD per

year, equivalent to 8,1% - 9,9% of the total value of plant production in the EU member states (Figure 1). This corresponds to earlier results obtained by Gallai et al. 2009 [4]. For comparison, EU total GDP was 15,965 trillion USD and gross value added of agriculture, forestry and fishing was 257 Billon USD in 2018 [5].

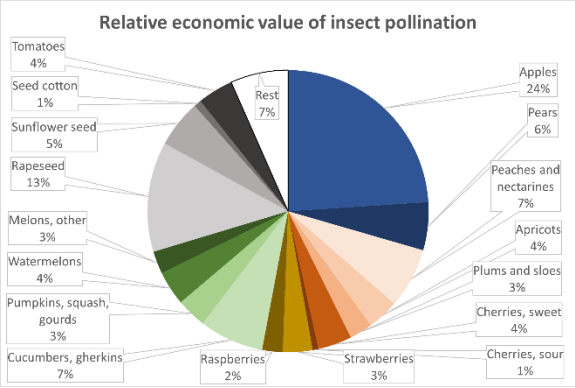


Figure 2. Average relative economic value [%] of pollination by insects ($RPEV_{i,2014-2018}$) for different crops (blue shades: pip fruits; brown shades: stone fruits; olive shades: berries; green shades: cucurbits; grey shades: other important field crops; white: rest) in all EU member states for the years 2014 to 2018. Source: [4, 1, 2].

For which EU grown crops do pollinators create the highest economic value?

Some crops depend to a greater extent on insect pollination than others. Some achieve higher producer prices than others. Some produce more than others. Moreover, production and prices are subject to fluctuations. In the years 2014 to 2018, the economic value of insect pollination for apple accounted for 24% of the overall value of crop pollination by insects. For stone fruits, including peaches, nectarines, apricots, plums, sloes, and cherries, this share was around 18%. The same share applied to oilseed, including rapeseed and sunflower. Cucurbits, including melons, cantaloupes, watermelons, pumpkins, squash, gourds, cucumbers, and gherkins accounted for 10% (Figure 2).

To which extent do EU member states depend on insect pollination?

In the years 2014 to 2018, the economic value of insect pollination in the EU accounted on average for 8,8% of the overall value of crop production. Crop production in the EU member states, however, relies to a different extent on insect pollination, depending on the amount and type of crops being grown in the various regions.

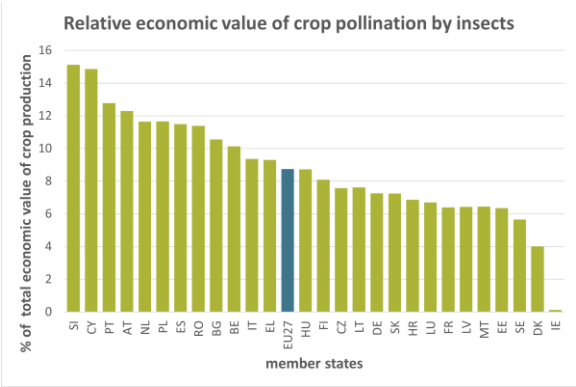


Figure 3. Average relative economic value [%] of crop pollination by insects ($RPEV_{i,2014-2018}$) for EU member states (green bars) and for the EU (blue bar) for the years 2014 to 2018. Source: [4, 1, 2].

While in central and southern European regions such as Slovenia, Cyprus, Portugal and Austria, more than 12% of total agricultural production depended on insect pollination, in northern European regions such as Estonia, Sweden, Denmark and Ireland, this dependency was equal to or less than 6% (Figure 3).

Is the number of beehives kept in the EU sufficient for crop pollination?

In addition to professional pollination services, honey bee colonies kept by EU beekeepers provide free pollination service to agriculture. The extent of this free service depends on the number of beehives kept in each region and to some extent on the size

of beekeeping operations. No information exists on the spatial distribution of beehives in relation to agricultural crops requiring pollination by insects. However, analysis of the amount of honey bee colonies kept in each EU member state in relation to the cultivated are of crops requiring pollination by insects was possible and showed marked differences. In the years 2014 to 2018, on average 1,4 beehives were kept per ha crop area requiring insect pollination. In Cyprus, Slovenia, Croatia, Austria, and Greece this ratio was 2 to 3 times higher than the EU average. For some EU member states, no or no plausible data for beehives was available in the FAO database [2].

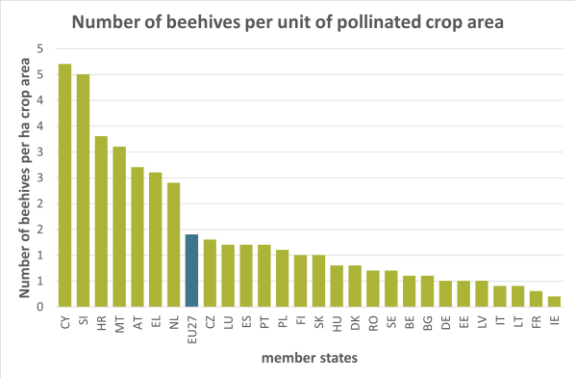


Figure 4. The average number of beehives per total area [beehives ha^{-1}] of pollinated crops requiring pollination by insects ($BPA_{x,2014-1018}$) for EU member states (green bars) and for the EU (blue bar) for the years 2014 to 2018. For some EU member states no (IE, MT, NL, DK) or no plausible (LV) data for beehives was available in the FAO database. Source: [4, 1, 2].

The number of beehives required for pollination varies greatly among crops, but roughly more than 2 beehives per ha are usually considered to be required to ensure sufficient crop pollination [3]. Figure 4 gives a summary of the main content of this dataset, comprising tables on livestock (Livestock), production of crops, honey, and beeswax (Production), producer prices for crops, honey, and beeswax (Prices) and pollination dependency of crops (Pollination). In particular data on beehives, production of and producer prices for honey and beeswax are either lacking or are obviously incorrect, allowing only a limited number of analyses.

Conclusions

Pollination by insects contributes significantly to agricultural crop production. The average economic value of crop pollination by insects in the EU from 1991 to 2018 ranged between 7 and 18 billion USD per year, equivalent to 8,1% - 9,9% of the total value of plant production. Insect pollination of apple produced the highest economic value, accounting on average for 24% of the overall value of crop pollination by insects between 2014 and 2018. High shares were also found for stone fruit, oilseed, cucurbits, and tomato. Crop production in the EU member states relies to a different extent on insect pollination. While in some central and southern European regions on average more than 12% of total agricultural production depended on insect pollination, in some northern European regions, this dependency was equal to or less than 6%. Between 2014 and 2018, on the average 1,4 beehives were kept per ha crop area requiring insect pollination in the EU. In some central and southern European regions this ratio was 2 to 3 times higher than the EU average. The analyses have shown that data availability and data quality on the social and economic significance of pollinators, even on honey bees, are generally poor. Great efforts will be required to close this gap.

Table 1. Summary of the main content of the dataset. Data Source: FAO (2), Austrian beekeeping federation (Biene Österreich). n.a.: not applicable. Further description see text.

	Livestock		Production		Prices		Pollination	
	total	range	total	range	total	range	total	range
total entries	1818	n.a.	158077	n.a.	52337	n.a.	54	54 crops
years	59	1961-2019	58	1961-2018	28	1991-2018	n.a.	n.a.
areas	33	AT, AT11, AT12, AT13, AT21, AT22, AT31, AT34, AT33, AT34, BE, BG, CY, CZ, DE, EE, EL, ES, FI, FR, HR, HU, IT, LT, LU, LV, NL, PL, PT, RO, SE, SI, SK	27	AT, BE, BG, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SE, SI, SK	27	AT, BE, BG, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SE, SI, SK	n.a.	n.a.
elements	1	live animals	2	area harvested, production quantity	1	annual value	n.a.	n.a.
items	1	beehives	127	123 crops, honey, beeswax	115	111 crops, honey, beeswax	n.a.	n.a.
units	1	number	2	t, ha	2	SLC/t, USD/t	1	percent from, percent to

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