ECONOMIC VALUE OF BEE POLLINATION IN CROP PRODUCTION IN THE STATE OF GOIÁS

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ABSTRACT

The pollinating bees provide an essential service to the ecosystem and bring numerous benefits to society, through its role in food production and conservation of biological diversity. Tooth material respects this economic valuation of this service. Thus, this study aims to estimate the economic value of pollination by bees in agricultural crops in the State of Goiás. To estimate the value used the method based on market prices of crops, combining with the method based on production function of the soybean, tomato, beans cotton, coffee, orange and sunflower between the years 2000 to 2012. The production gains from pollination by bees in total economic value to \$14 billion dollars. As pollinating bees contribute about R\$ 1.07 billion dollars a year. Bees are essential for pollination of agricultural crops, showing considerable increase in agricultural production and consequent increase in economic gain productions.

KEYWORDS: conservation; sustainable production; environmental services.

VALORAÇÃO ECONÔMICA DA POLINIZAÇÃO POR ABELHAS EM CULTURAS AGRÍCOLAS NO ESTADO DE GOIÁS

RESUMO

As abelhas polinizadoras fornecem um serviço essencial ao ecossistema e trazem inúmeros benefícios à sociedade, por meio do seu papel na produção de alimento e na conservação da diversidade biológica. Dente os aspectos relevantes esta a valoração econômica deste serviço. Assim, o presente estudo tem como objetivo estimar o valor econômico da polinização por abelhas em culturas agrícolas no Estado de Goiás. Para estimar o valor foi utilizado o método baseado em preços de mercado das culturas, conciliando com o método baseado na função de produção das culturas da soja, tomate, algodão, feijão, café, laranja e girassol entre os anos de 2000 a 2012. Os ganhos de produção oriundos da polinização por abelhas em

valor econômico totalizam-se 14 bilhões de dólares. As abelhas polinizadoras contribuem com cerca de 1,07 bilhões de dólares ao ano. As abelhas são fundamentais na polinização das culturas agrícolas, evidenciando considerável aumento da produção agrícola e consequente aumento no ganho econômico das produções.

PALAVRAS-CHAVE: conservação; produção sustentável; serviços ambientais.

INTRODUCTION

The benefits of pollinators in agriculture consist of ecosystem services, also known as environmental services, and the bees the main pollinators of nature (CALDERONE, 2012; GIANNINI et al, 2015). These services are represented by the conditions and processes by which the natural ecosystems and species that constitute offer benefits to human populations (DAILY, 1997).

Pollinators provide an essential service to the ecosystem and bring numerous benefits to society, through its part in the food production and conservation of biological diversity. In many cases, the reduced crop production or fruits are deformed resulting from insufficient pollination and not the lack of inputs agrochemicals (IMPERATRIZ-FONSECA & NUNES-SILVA 2010; GIANNINI et al., 2012). Even in cultures self-pollination occurs, for example, coffee, canola and soybean, there is a considerable increase in the production of fruits and seeds after the occurrence of pollination bees native or introduced (GARRATT et al., 2013). The productivity gains ranging from 14 to 50% for coffee (KLEIN et al., 2003; DE MARCO & COELHO, 2004), and for canola 53 to 55% (DURÁN et al., 2010; ROSA et al., 2011).

Several methodologies have been developed, collected and reviewed to quantify the environmental services of pollinators in several crops (GARIBALDI et al., 2011; VAISSIERE et al., 2011). Emphasizes the need to understand and quantify the economic impact on agricultural production resulting from the pollinating action. This can contribute to the proper management of crops for the introduction of bees and species conservation (MELO-SILVA et al., 2013; KLEIJN et al., 2015). With all this aimed to estimate the economic value of pollination by bees in agricultural crops in the state of Goiás.

MATERIAL AND METHODS

Estimated the value of pollination gain in agricultural crops by market prices for each crop and production function. These two methods are adapted to regional rating scale, according to the methodology of Food and Agriculture Organization (GALLAI & VAISSIÈRE, 2009).

Among the crops of Goiás State, seven cultures were selected that has the pollination gain effects reported in the literature (Table 01). The selected cultures were: soy (*Glicine max* L.); tomato (*Solanum lycopersicum* L.); cotton (*Gossypium herbaceum* L.); coffee (*Coffea arabica* L.); bean (*Phaseolus vulgaris* L.); sunflower (*Helianthus annuus* L.) and orange (*Citrus* spp.). Annual productions (PROD) of each culture in the periods from 2000 to 2013 were obtained using data from the Institute Mauro Borges of Statistics and Socioeconomic Studies (2015).

TABLE 1. Productivity gains of crops due to the increase in pollination by bees.

Crop	Authors	Productivity gains (GP) (%)		
		Mean	Minimum	Maximum
Soybean	CHIARI et al. (2005) MILFONT et al. (2013)	33.86	6.34	61.38
Tomato	MELO-SILVA et al. (2013)	50.21	-	50.21
Cotton	PIRES et al. (2014)	18.44	-	18.44
Coffee	KLEIN et al. (2013) DE-MARCO & COELHO (2004)	32	14	50
Bean	MORETI & SILVA (1994)	9.51	2	17.02
Sunflower	MORETI et al. (1996) PAIVA et al. (2002)	56.56	27.12	86
Orange	GAMITO & MALERBO-SOUZA (2006) TOLEDO et al. (2013)	33	30	36

TABLE 2. Quantity produced (tonnes) in the State of Goiás by crop for the years 2000-2013.

Year	Soybean	Tomato	Cotton	Coffee	Bean	Sunflower	Orange
2000	4.092.934	712.448	254.476	-	200.415	-	-
2001	4.052.169	742.182	326.150	10.731	221.742	-	119.954
2002	5.405.589	951.410	301.255	12.022	235.418	-	115.813
2003	6.319.213	1.016.188	305.187	10.746	289.172	-	116.969
2004	6.091.676	871.945	469.794	14.235	209.835	-	113.057
2005	6.983.860	776.430	432.045	16.022	280.461	12.383	113.040
2006	6.017.719	759.620	202.914	19.105	268.478	9.187	111.270
2007	5.937.727	802.030	296.553	19.133	253.668	26.994	113.600
2008	6.604.805	1.249.525	286.750	19.129	220.449	26.955	127.466
2009	6.809.187	1.427.144	227.307	18.802	261.929	6.718	122.288
2010	7.252.926	1.120.135	180.404	22.835	288.816	16.674	135.485
2011	7.703.982	1.440.961	425.825	19.411	311.837	11.667	121.866
2012	8.398.891	1.157.078	352.514	19.598	336.304	25.705	131.919
2013	8.913.069	1.317.607	205.167	16.285	294.027	5.677	128.975

Prices (P) of crops (per tonne) in different years (2000-2013) were obtained from different bases of Brazilian quotes data such as Center for Advanced Studies in Applied Economics – CEPEA - ESALQ/USP (2015) for soybeans, cotton, coffee, tomatoes (years 2005, 2006, 2007 and 2008); AGROLINK (2015) for bean-carioca and orange (type for industrial processing, used by the lower value) the National Supply Company - CONAB (2015) p for sunflower and Goiás State Supply Centers - CEASA-GO (2015) for tomatoes (annual Conjunctures the years 2008-2013) (Table 3). All values were sought for the Goiás State and/or Goiânia. When local values were not found were used national values to the value of production.

TABLE 3. Values (in dollars) per ton of annual crop 2000-2013.

Value (USD/Ton)	Soybean ¹	Tomato ²	Cotton ¹	Coffee ¹	Bean ³	Sunflower ⁴	Orange ⁵
2000	318.76	-	206.46	2.740.83	-	-	44.93
2001	396.6	-	195.31	1.968.17	-	-	163.57
2002	555.21	-	654.08	2.159.33	-	-	195.61
2003	679.16	-	393.21	2.896.61	905.5	512.83	200.94
2004	707.76	1.045.22	383.77	3.619.72	1.185.17	487.67	154.78
2005	523.1	1.019.13	551.1	4.710.41	1.230.67	418.17	190.34
2006	471.89	872.17	904.74	4.162.72	1.191.67	435	252.72
2007	577.7	1.103.04	279.09	4.203.71	1.815.67	471	274.55
2008	770.69	1.651.00	822.33	4.334.82	2.553.33	548.83	239.67
2009	783.77	950	263.02	4.380.98	1.258.67	513.33	129.64
2010	667.24	890	415.23	5.183.65	1.790.83	616	316.16
2011	774.75	1.705.00	450.75	8.244.67	1.487.33	723.17	371.26
2012	1.100.71	1.957.00	354.16	6.554.01	2.602.33	842.67	164.99
2013	1.088.90	2.421.00	448.45	4.813.56	3.177.17	537.50	158.82

¹Source CEPEA; ²CEPEA/CEASA-GO; ³Agrolink – bean-carioca in Goiás; ⁴CONAB;

⁵CEPEA – Orange for industry - domestic market SP – CEPEA.

For tomato production in the years 2000-2003, coffee in 2000, and beans between 2000 to 2002 were not found values of marketed products. Thus, for these crops will be an underestimate. As for the sunflower, between the years 2000 to 2003 there was no production recorded for the state of Goiás. Targeting more stable currencies, and to improve gains comparisons in other regions, the real amounts were translated into US dollars, according to the value of the dollar in the period of marketing of crops. Values were searched for in the Brazilian Central Bank.

To gain setting in culture production have been used since the work performed (Table 3). In cultures with different production gains for pollination by bees, we used a median value of the different results for the estimate (GP). To define the values the following equations were used:

$$V_{totali} = V_{ano1} + V_{ano2} + \dots + V_{anoi}$$

$$V_{ano} = PROD * GP * P$$

V_{totali} – The production value of pollination gain throughout the study period.

V_{ano} – Value of the production gain of pollination per year.

PROD - Crop production by year ton (ton).

GP – Production of pollination gain established in scientific publication (0-1, representing the percentage gain or GP/100).

P – Culture ton price in the year (USD).

RESULTS AND DISCUSSION

Total production of the seven crops evaluated in the 2000-2013 period consisted of 14 billion and 900 million dollars which are directly related to the action of bees to pollinate crops. On average, in recent years, pollinators may help with pollination of about R \$ 1 billion and 70 million dollars per year (Table 4).

Among the crops, the greatest economic value generated by the pollination is for the soybean crop, since it presents 33.8% gain in production for pollination, combined with the high soybean production in Goiás State. Thus the economic values for soybean pollination are at 10 billion dollars over the 13 years evaluated. For the tomato crop, high production in Goiás State and the importance of pollination in the productive growth of the crop, the tomato is the second most representative, generating revenues of around \$ 3.9 billion. Considering the production of the seven cultures together just over 30% of what is produced is currently due to pollination by bees (average of earnings in studies of Table 3 and Figure 2).

FIGURE 1. Economic gain of pollination by bees in agricultural crops each year in the State of Goiás.

FIGURE 2. Economic gains of pollination by bees between the years 2000-2013 by crop in the State of Goiás.

GIANNINI et al. (2015) analyzing 141 crops worldwide, they found that 85 are dependent on pollinators. In this dependent relationship, the authors estimate that 30% of the total productions are due to pollinators, representing approximately \$ 12 billion. The same authors emphasize the cultivation of soy, as in this work, that even

with a modest dependence on pollination; soy has great values in general terms about the effect of pollination (representing values of 5.7 billion). In absolute values of tons of food produced in agriculture, the soybean crop is 77% of the food produced by pollination, because this is the most produced crop in Goiás State combined with a good pollination gain (33.86%) (Figure 3).

It is important to highlight that none of the seven cultivated species evaluated in this work has dependence of pollination bees, and the pollination is always on increased production condition (AIZEN et al., 2009). Thus it is emphasized that agricultural production can be increased by appropriate management of bees and improving conditions that affect them, such as proper handling of pesticides and conservation of bees habitats (remaining forest fragments) (IMPERATRIZ-FONSECA & NUNES-SILVA, 2010; ROCHA, 2012; GRANDOLFO et al., 2013).

FIGURE 3. Gain percentage of pollination by the total tons produced in the State of Goiás.

The estimates presented, even with values in the billions, are underestimated values, since not all agricultural production is officially declared (family production, production in backyards, urban gardens, etc.). It is emphasized that many other crops that depend on pollinators are not presented in this valuation, such as passion fruit (*Passiflora* spp.), pumpkins, cucumbers, watermelons (*Cucurbitaceae*), in others not highlighted due to lack of official information on production in Goiás State. PEREIRA-VIERA et al. (2010) emphasized that for the yellow passion fruit (*Passiflora edulis* Sims) in Minas Gerais, Brazil, using the economic-environmental valuation technique of avoided cost, an amount of R\$ 33.777,85, referring to the three years of the yellow passion fruit cultivation. According to the authors, this amount represents expenses that farmers would have to manually pollinate passion flowers.

This work is the quantification of production from pollination in quantitative aspects, but without considering the qualitative aspects of pollination by bee's action. Several studies have shown improved quality in size, shape and amount of soluble solids of fruits come from flowers pollinated by bees, as in the case of tomatoes (MORANDIN et al., 2001; MELO-SILVA et al., 2013), strawberry (WITTER et al., 2012), apple (GARRATT et al., 2013; BIZOTTO & SANTOS, 2015) and others, and these aspects are not considered in the economic valuation of pollination.

Among the values per action of the bees, nothing is returned directly in the financial aspect, as political of conservation and management of bees, aiming at the improvement and maintenance of these ecosystem services. Currently, the ecosystem service of pollination performed by bees is still an inadequate argument for the bee species are protected and preserved (KLEIJN et al., 2015).

There are few studies in some areas of knowledge that can contribute in economic value to the agricultural production and construction of conservation measures for native bees. Among these studies, it is essential to understand the specific behavior of several species of native bees, such as types of nest; social behavior or not; nesting; power; foraging behavior (flight distance, type of food resources) and pollination (pollination by vibration and other behaviors). These studies as well as cover social bees should include solitary bees (*Exomalopsis* spp; *Centris* spp; *Epicharis* spp.; Halictidae), which has great contribution to agricultural crops (RAW, 2000; SANTOS & NASCIMENTO, 2011; BURKART et al., 2011; MELO-SILVA et al., 2013).

Studies on management of species of native bees are necessary and the use of the same as pollinators of agricultural crops in greenhouses and / or in open fields are able to increase production and save manpower for other activities. Beside becoming an alternative to the ex situ conservation of the species of native bees and potential for production of bee products (honey, propolis and royal jelly) (KREMEN & MILES, 2012; GIANNINI et al., 2012).

The natives bees (*Melipona* spp., *Tetragonisca* spp., *Frieseomelitta* spp., *Exomalopsis* spp.) and/or introduced (*Apis mellifera* L.), as well as the pollination of native vegetation, are essential in the pollination of crops, representing the largest providers of the sayings environmental services related to pollination. Such importance reflects a considerable increase in agricultural production and consequent increase in economic gain productions.

TABLE 4. Economic gains (in dollars) due to pollination by bees to different cultures in the State of Goiás.

	Soybean	Tomato	Cotton	Coffee	Bean	Sunflower	Orange	Total
2000	241.360.171.95	-	52.932.80	-	-	-	-	241.413.104.75
2001	231.496.690.37	-	4.997.301.13	2.875.210.89	-	-	2.754.537.08	242.123.739.48
2002	347.762.118.79	-	5.045.512.50	2.842.768.51	-	-	2.558.316.94	358.208.716.74
2003	472.121.123.78	-	7.189.382.47	3.236.072.36	8.090.150.39	-	2.519.889.58	493.156.618.58
2004	498.925.202.84	156.390.950.27	11.362.546.44	5.635.184.05	8.082.832.01	-	1.973.559.69	682.370.275.31
2005	508.022.674.18	163.169.205.09	8.347.086.63	9.918.393.03	13.480.603.35	1.202.819.84	2.916.015.91	707.056.798.03
2006	441.419.901.50	152.715.100.42	4.989.691.37	11.683.326.06	13.968.066.36	1.037.682.88	4.260.081.51	630.073.850.10
2007	596.213.789.82	228.016.321.56	7.834.563.29	13.211.686.72	22.484.062.90	3.691.390.76	5.283.323.73	876.735.138.77
2008	939.312.998.53	564.502.538.15	8.133.111.77	14.460.954.80	29.172.914.53	4.560.084.31	5.494.100.84	1.565.636.702.92
2009	904.694.982.95	340.810.489.69	5.519.566.89	13.196.435.15	15.696.620.68	976.517.87	2.619.124.85	1.283.513.738.09
2010	930.866.414.18	284.351.604.23	78.470.48	21.517.497.03	27.942.291.72	3.300.160.01	8.029.929.53	1.276.086.367.18
2011	1.206.500.150.91	736.428.205.58	25.551.271.36	30.572.767.09	26.331.770.08	2.848.856.55	8.913.348.29	2.037.146.369.85
2012	1.601.434.218.44	581.662.380.52	11.777.968.14	21.027.910.72	42.579.716.69	6.267.727.65	3.674.608.06	2.268.424.530.23
2013	1.523.063.000.04	742.312.120.77	7.863.130.33	11.625.717.85	41.174.029.84	799.875.53	3.132.924.77	2.329.970.799.13
Total	10.443.193.438.29	3.950.358.916.28	108.742.535.60	161.803.924.25	249.003.058.55	24.685.115.39	54.129.760.80	14.991.916.749.16

CONCLUSION

Pollination by bees on crops: soybeans, coffee, sunflower, tomato, beans, orange and cotton in the State of Goiás, generates economic value exceeding 14 billion dollars.

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