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ANALYSIS

Economic valuation of the vulnerability of world agriculture confronted with pollinator decline

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A B S T R A C T

There is mounting evidence of pollinator decline all over the world and consequences in many agricultural areas could be significant. We assessed these consequences by measuring 1) the contribution of insect pollination to the world agricultural output economic value, and 2) the vulnerability of world agriculture in the face of pollinator decline. We used a bioeconomic approach, which integrated the production dependence ratio on pollinators, for the 100 crops used directly for human food worldwide as listed by FAO. The total economic value of pollination worldwide amounted to €153 billion, which represented 9.5% of the value of the world agricultural production used for human food in 2005. In terms of welfare, the consumer surplus loss was estimated between €190 and €310 billion based upon average price elasticities of – 1.5 to – 0.8, respectively. Vegetables and fruits were the leading crop categories in value of insect pollination with about €50 billion each, followed by edible oil crops, stimulants, nuts and spices. The production value of a ton of the crop categories that do not depend on insect pollination averaged €151 while that of those that are pollinator-dependent averaged €761. The vulnerability ratio was calculated for each crop category at the regional and world scales as the ratio between the economic value of pollination and the current total crop value. This ratio varied considerably among crop categories and there was a positive correlation between the rate of vulnerability to pollinators decline of a crop category and its value per production unit. Looking at the capacity to nourish the world population after pollinator loss, the production of 3 crop categories – namely fruits, vegetables, and stimulants - will clearly be below the current consumption level at the world scale and even more so for certain regions like Europe. Yet, although our valuation clearly demonstrates the economic importance of insect pollinators, it cannot be considered as a scenario since it does not take into account the strategic responses of the markets.

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1. Introduction

The production of 84% of crop species cultivated in Europe depends directly on insect pollinators, especially bees (Williams, 1994). And Klein et al. (2007) found that 87 crops, that is 70% of the 124 main crops used directly for human consumption in the world, are dependent on pollinators. Insect pollination is both an ecosystem service and a production practice used extensively by farmers all over the world for crop production. It is an ecosystem service in that wild pollinators, in particular wild bees, contribute significantly to the pollination of a large array of crops (Kremen et al., 2002; Morandin and Winston, 2005; Greenleaf and Kremen, 2006; Winfree et al., 2007, 2008). And it is also a management tool in that honeybees, bumblebees and a few other bee species are purchased or rented by farmers in many countries to supplement the local pollinator fauna (McGregor, 1976; Olmstead and Wooten, 1987; Robinson et al., 1989; Free, 1993; Dag et al., 2006). Thus the economic benefit of insect pollination is clear for farmers and the market of colony rental is now well developed and organized for honey bees in the United States of America (Sumner, and Boriss, 2006) and Europe (Carreck et al., 1997) as well as for bumble bees all over the world (Velthuis and van Doorn, 2006). This practice also suggests that there is already not enough wild pollinators to insure adequate pollination of all crops throughout the year in these countries. Yet the abundance and diversity of wild bees as well as the abundance of honeybees are now declining and some species are clearly at risk (Biesmeijer et al., 2006; National Research Council, 2007; Olroyd, 2007; Stokstad 2007). The current decline of insect pollinator populations emphasizes the need to better assess the potential loss in terms of economic value that may result from this trend and the possible ultimate disappearance of pollinators, and to estimate the level of vulnerability of the world agriculture to insect pollinators.

Two main ways have been used to date to assess the monetary value of pollinators. The first one consists in simply assessing the total value of insect-pollinated crops. This approach has been used at a national scale in the USA (Martin, 1975; Levin, 1984; Metcalf and Metcalf, 1992) as well as on a world scale (Costanza et al., 1997; Pimentel et al., 1997). Since the production of most crops is only partially reduced in the absence of insect pollinators, a second more refined approach to improve the previous estimate has been to introduce a dependence ratio that takes into account the real impact of insect pollinators on crop production. This dependence ratio enables the calculation of the production loss in case of a complete disappearance of pollinators, and the economic value of insect pollination service is assimilated with the corresponding loss of crop value. Thus the monetary assessment is directly related to reported values of the dependence of crop production on the level of insect pollination and, in this paper, it will be called a bioeconomic approach. This type of assessment has also been done at national and larger scales (France — Borneck and Bricout, 1984; Hungary — Benedek, 1983; Switzerland — Fluri and Frick, 2005; United Kingdom — Carreck and Williams, 1998; USA — Robinson et al., 1989, Morse and Calderone, 2000, Losey and Vaughan, 2006; 12-member-states European Community — Borneck and Merle, 1989). Unfortunately, these studies have used a wide range of dependence ratios for the same crops (Table 1). Indeed, these ratios were estimated based largely on personal communications and interpretation of review material, such as McGregor (1976) and Free (1993), which do not provide dependence ratios. None of the bioeconomic studies to date have evaluated the impact of insect pollinators at the world scale, nor did they make a geographical analysis of the impact of pollinators in terms of the possible vulnerability of agriculture or examined the potential impact of pollinator loss on production compared with the consumption structure.

Our first objective was to quantify the economic loss that could result from the total disappearance of insect pollinators on world agricultural output and we based our calculations on the dependence ratios recently published for the crops used directly for human food (Klein et al., 2007). Due to the many crop species and the heterogeneity of the structure of the agricultural production, the vulnerability to pollinator decline is likely to vary widely among the different continents and regions. Our second objective was therefore to provide a measure of the vulnerability of the regional and world agriculture when confronted to the decline, or even the total disappearance, of insect pollinators. Finally our third objective

Table 1 – Heterogeneity of the dependence ratios reported for the production of some selected crops in regards to insect pollination (extrema are underlined)

Crop species	Common name	Borneck and Bricout (1984)			Robinson et al. (1989)	Southwick and Southwick (1992)	Morse and Calderone (2000)	Klein et al. (2007)		
		Min	Max	Mean				Min	Max	Mean
Fruits										
Fragaria × ananassa	Strawberry	0.100	0.200	<u>0.150</u>	<u>0.4</u>	0.30	0.2	0.1	0.4	0.25
Malus domestica	Apple	0.100	0.200	<u>0.150</u>	<u>1.0</u>	0.80	1.0	0.4	0.9	0.65
Vitis vinifera	Grape	0.001	0.010	0.006	0.1	<u>0.15</u>	0.1	0.0	0.0	<u>0.00</u>
Nuts										
Amygdalus communis	Almond	0.100	0.200	<u>0.150</u>	<u>1.0</u>	0.90	1.0	0.4	0.9	0.65
Vegetables										
Cucumis melo	Melon (incl. cantaloupe)	0.100	0.200	<u>0.150</u>	0.8	0.70	0.9	0.9	1.0	<u>0.95</u>
Mean				0.120	0.66	0.57	0.64			0.50