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Biodiversity Economics: The Value of Pollination Services to Egypt

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Abstract

Pollinator populations are under severe pressure worldwide because of man-made intensification in land use, including the use of pesticides and fertilizers. The majority of wild and crop plants are fully or partially dependent on pollinators for their reproduction. Loss of pollinators has already caused measurable declines in the populations of many wild plants in Europe. Many Egyptian crops are fully or partially dependent on pollinators for their yields, and data exist on the market values of Egyptian crops. We therefore use these to estimate the 2004 costs to the Egyptian economy of a catastrophic loss of pollinators. The annual cost to the Egyptian economy of losing its pollinators would be approximately LE 13.5 billion ($2.4 billion), 3.3% of the 2003 GDP.

Keywords: ecosystem services, biodiversity economics

Introduction

Our lives are heavily dependent upon the planet's biodiversity and the ecological systems that it supports. The many products (e.g. raw materials such as timber) and services (e.g. climate regulation) provided by these ecosystems are not only essential to our own survival but also to the functioning of the Earth's life-support system (Millenium Ecosystem Assessment 2005). Due to the difficulty of placing a realistic monetary worth on ecosystems, their services are not given adequate importance when making policy decisions (van Jaarsveld *et al.* 2005). Agriculture in particular has many obvious dependencies on natural services provided by the ecosystem. Ironically, however, agriculture is one of the main driving forces behind the decline of biodiversity (UNEP 2007).

Pollination is a prime example of a supporting service that is being negatively affected by agricultural practices, as well as by other factors such as global warming and urbanisation (Klein *et al.* 2007). Pollination is essential to most plants for reproduction, including commercial crops. This ecosystem function is provided by many wild pollinator species. There have been worldwide declines in pollinator diversity (Dias *et al.* 1999, Klein *et al.* 2007), with declines identified in at least one region or country on every continent (except Antarctica), including the UK and Netherlands in Europe (Biesmeijer *et al.* 2006). The types of pollinators in decline include wild bees (social and solitary), domesticated honeybees, hoverflies, butterflies, bats, hummingbirds and other small mammals. The causes of these declines in pollinator biodiversity are almost certainly related to changes in landuse (Klein *et al.* 2007). Pollinators require local floral diversity and nesting sites in order to persist in the unnatural environment of farmed land, but loss of natural habitat (usually related to land use practices) prevents this. Agricultural intensification leads to loss and fragmentation of natural pollinator habitat, while climate change, introduction of alien plants and competition with non-native fauna adds to the pressure placed on pollinator populations.

Without the service provided by pollinators, many plant species would be driven to extinction, and cultivation of many modern crops would be impossible. Many crops are wholly dependent on cross-pollination (such as melons and squash) by pollinators, while other crops show significant yield increases when cross-pollinated instead of self-pollinated (such as

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apples, tomatoes and cotton). It has been estimated that pollination is responsible for as much as 30% of agricultural food production (UNEP 2007), and in some cases pollination services may contribute as much or more to yields than fertilisers. Due to its ability to dramatically improve yields, the economic value of natural pollination worldwide is thought to be between US$65 and US$70 billion each year (Dias *et al.* 1999). Inadequate pollination can not only reduce yields, but may also delay them and be the reason for inferior fruit production. Domesticated honeybees remain the world's most important pollinators (Klein *et al.* 2007), but even they are declining and disappearing for no obvious reason (BBC 2007). Without wild pollinator species, current levels of agricultural productivity are under threat.

The International Pollinators Initiative (Dias *et al.* 1999) was adopted by the Convention on Biological Diversity because of the perceived threat to such a valuable ecosystem service. However, action by politicians and decision-makers is hampered by a lack of estimates of the true value of this ecosystem service. Several methods have been proposed that try to give a monetary value to ecosystem services, none of them perfect (de Groot *et al.* 2002, Chee 2004). Direct market valuation is the exchange value that services have in trade. While straightforward, the value is only what the product is worth to a buyer, and omits other less direct values of the services (de Groot *et al.* 2002). However, it is simple to understand and clear to apply, especially for pollination where the value of the product is often available. Stimulated by a recent review on experimental evaluations of the impact of pollination on crops (Klein *et al.* 2007), we use here the Direct Market Valuation approach to estimate the economic value of pollination to the Egyptian economy.

Materials & Methods

Egypt's main arable output covers 70 different plants, including non-consumed field crops (such a cotton), fruits, nuts and vegetables. These plants differ in their reliance on pollinators for successful fruit and seed setting, from full dependence (e.g. watermelon, melon, custard apples) to total independence (e.g. date, grape, maize, olive). The review by Klein *et al.* (2007) places the available information for each crop into one of four categories of the impact of pollinator loss on yield: essential (reduction of >90%), high (40-90% loss), modest (10-40%), little (0-10%) and none (0%). For calculation, we used the midpoint of these ranges: 95, 65, 25, 5 and 0 respectively. Although these are approximations, when summed over all the types of Egyptian crops, the final figure is likely to be a reasonable estimate.

Klein *et al.* (2007) was based on a worldwide review rather than an Egyptian-specific one, and it would be very useful to have an equivalent review of Egyptian pollination studies: alas, such a review does not exist. The estimated reductions represent the average loss in yield obtained in all the various experiments carried out on any one crop type anywhere in the world. The figures might well be different under Egyptian conditions, but until the relevant experiments and review have been done, we do not know. The overall message is, however, unlikely to be very different with Egypt-specific values for the impact of pollinator loss.

The total values of each of the Egyptian crops was obtained from the publication by the Economic Affairs Sector (2006) of the Ministry of Agriculture. This gives values either overall, or split by season or by land type (old or newly developed areas): we used the overall values.

The use of each crop, and therefore the impact of pollinator loss, varies. Thus some crops produce vegetative growth that is consumed: pollinators affect seed production for the next generation in those crops that are grown from seed each year. For crops that are grown vegetatively, the impact of pollinators is more long-term, but no less serious. For example, a standard fodder crop in Egypt is barseem (i.e. alfalfa), which can be cropped for six years before needing to be renewed from seed. However, alfalfa is well-known for its seed production being dependent on wild-bee pollinators because honeybees are especially poor:

semi-domesticated solitary bees (*Megachile rotundata*), on the other hand, do the job very well. Here we simply multiplied the value of the crop by the proportion of the yield that would be lost if pollinators were absent. Over the long term, we regard this as justifiable.

Results

The results (Table 1) are dominated (46%) by the impact of pollinator loss on alfalfa, predicted to cause annual losses of more than LE 6 billion (more than US $ 1 billion). It is true that even if seed production were reduced, this might not affect the production of the fodder itself. However, in the long term, there would be a substantial impact. For valuable crops, such as melons, pollinator loss would also have a huge economic impact, an annual loss of almost LE 1.9 billion (US $ 333 million).

Overall, according to these calculations, almost LE 13.5 billion (US $ 2.4 billion) would be lost every year. Since Egypt's GDP in 2003 was LE 411 billion (UNESCO 2007), this represents about 3.3% of GDP.

Table 1: Monetary losses based on the average yield reduction that would be the consequence of loss of pollinators in Egypt for the crop production of 2004. There are approximately 5.7 LE to each $US. Pollination losses are taken from Klein et al (2007); crop values from Economic Affairs Sector (2006).

Commodity	Latin name	Pollination effect	Pollination loss %	Value (m LE)	loss (m LE)	Notes
Field crops						
clover, alfalfa	*Trifolium* spp, *Medicago sativa*	seeds	65	9429.0	6128.9	estimated % loss: dependent on seeds in long term
Cotton	*Gossypium* spp	parts eaten	25	3131.3	782.8	
Fodder (not alfalfa)	various	seeds	25	313.9	78.5	estimated % loss
Lufa	*Luffa aegyptiaca*	seeds	65	109.8	71.4	probably 95% but some selfing occurs
Sunflower	*Helianthus annuus*	parts eaten	25	96.5	24.1	
Linseed, Flax, Straw	*Linum usitatissimum*	seeds	5	111.9	5.6	
Safflower seed	*Carthamus tinctoria*	parts eaten	5	46.0	2.3	
Kenaf	*Hibiscus cannabinus*	parts eaten	65	2.7	1.8	probably needs pollinators
Egyptian lupin	*Lupinus albus*	seeds	5	11.4	0.6	mainly selfing
Sugar Beet	*Beta vulgaris vulgaris*	seeds	0	357.6	0	
Barley	*Hordeum* spp	independent	0	228.2	0	
Rice	*Oryza* spp	independent	0	6678.6	0	
Sugar Cane	*Saccharum officinarum*	independent	0	2191.1	0	
Sorghum	*Sorghum* spp	independent	0	1001.8	0	
Wheat	*Triticum* spp	independent	0	8903.9	0	
Maize/corn/sweetcorn	*Zea mays*	independent	0	7361.4	0	
Fruit crops						
Melon	*Cucumis melo*	parts eaten	95	1031.8	980.2	
Mango	*Mangifera indica*	parts eaten	65	1323.3	860.1	
Apple	*Malus 'domestica'*	parts eaten	65	930.7	605.0	
Cantaloupe	*Cucumis melo*	parts eaten	95	547.7	520.3	
Peach	*Prunus persica*	parts eaten	65	623.3	405.2	
Watermelon	*Citrullus lanatus*	parts eaten	95	399.5	379.5	
Apricot	*Prunus armeniaca*	parts eaten	65	169.0	109.8	
Orange	*Citrus spp*	parts eaten	5	2166.6	108.3	
Banana	*Musa spp*	breeding potential	5	1345.4	67.3	estimated % loss

Fig	*Ficus carica*	parts eaten	25	258.4	64.6	
Pear	*Pyrus communis*	parts eaten	65	91.3	59.4	
Guava	*Psidium guajava*	parts eaten	25	235.9	59.0	
Strawberry	*Fragaria* spp	parts eaten	25	134.6	33.6	
Plum	*Prunus x domestica*	parts eaten	65	47.3	30.7	
Tangerine, Mandarine	*Citrus* spp	parts eaten	5	595.1	29.8	
Lemon, lime	*Citrus* spp	parts eaten	5	296.5	14.8	
Prickly pears (Cactus)	*Opuntia*	parts eaten	25	48.9	12.2	
Custard apple	*Annona* spp	parts eaten	95	10.8	10.3	
Pomegranate	*Punica granatum*	parts eaten	25	39.5	9.9	
Medlar (Loquat)	*Eriobotrya japonica*	parts eaten	65	2.1	1.4	
Sour orange	*Citrus* spp	parts eaten	5	19.2	1.0	
Kaki persimmon	*Diospyros kaki*	parts eaten	5	14.4	0.7	
Grapefruit, Pomelo	*Citrus* spp	parts eaten	5	1.9	0.1	
Olive	*Olea europaea*	independent	0	698.2	0	
Date	*Phoenix dactylifera*	independent	0	1255.1	0	
Grape	*Vitis vinifera*	independent	0	1912.5	0	
Herb crops						
Rosemary	*Rosemarinus officinalis*	breeding potential	65	155.4	101.0	estimated % loss
Marjoram	*Origanum majoranae*	breeding potential	65	58.6	38.1	estimated % loss
Karkadeh	*Hibiscus sabdariffa*	parts eaten	65	51.4	33.4	probably needs pollinators
Coriander	*Coriandrum sativum*	parts eaten	65	48.9	31.8	
Basil	*Ocimum basilicum*	breeding potential	65	38.9	25.3	estimated % loss
Wormwood	*Artemisia* spp	seeds	65	37.1	24.1	estimated % loss
Fenugreek	*Trigonella foenum-graecum*	parts eaten	65	35.1	22.8	estimated % loss
Parsley	*Petroselinum crispum*	breeding potential	65	27.9	18.2	estimated % loss
Cumin	*Cuminum cyminum*	parts eaten	65	24.6	16.0	
Sage	*Salvia* spp	seeds	65	22.9	14.9	estimated % loss
Oregano	*Origanum vulgare*	breeding potential	65	22.9	14.9	estimated % loss
Mint	*Mentha* spp	breeding potential	65	20.5	13.3	estimated % loss
Fennel	*Foeniculum vulgare*	seeds	65	12.4	8.0	
Anise	*Pimpinella anisum*	seeds	65	9.8	6.4	
Dill	*Anethum graveolens*	seeds	25	24.1	6.0	estimated % loss
Caraway	*Carum carvi*	parts eaten	25	17.5	4.4	
Henna	*Lawsonia inermis*	parts eaten	65	2.8	1.8	estimated % loss
Other aromatics	*various*	seeds	25	1.5	0.4	estimated % loss
Coriander, green	*Coriandrum sativum*	seeds	65	0.4	0.3	
Nut crops						
Almond	*Prunus dulcis*	parts eaten	65	201.2	130.8	
Sesame seed	*Sesamum orientale*	parts eaten	25	157.4	39.4	
Peanut, Groundnut	*Arachis hypogaea*	parts eaten	5	437.6	21.9	
Pecan nut	*Carya illinoinensis*	independent	0	3.8	0	
Vegetable crops						
Squash, courgette, pumpkin	*Cucurbita spp*	parts eaten	95	367.4	349.0	
Cucumber	*Cucumis sativus*	parts eaten	65	348.7	226.6	
Tomato	*Lycopersicon esculentum*	parts eaten	5	3797.0	189.8	
Beans, Broad, dry	*Vicia faba*	parts eaten	25	757.9	189.5	
Aubergine (eggplant)	*Solanum melongena*	parts eaten	25	398.4	99.6	

Potato	*Solanum tuberosum*	breeding potential	5	1503.9	75.2	estimated % loss
Beans, Broad, Green	*Vicia faba*	parts eaten	25	172.9	43.2	
Molokhayia	*Corchorus olitorius*	seeds	95	43.6	41.4	grown from seed, and pollination required
Okra	*Abelmoschus esculentus*	parts eaten	25	140.4	35.1	
Onion	*Allium cepa*	seeds	5	580.7	29.0	estimated % loss
Soybean	*Glycine max*	parts eaten	25	87.1	21.8	
Carrot	*Daucus carota*	seeds	65	28.7	18.7	
Snake Cucumber	*Cucumis melo*	parts eaten	65	27.3	17.7	
Sweet peppers	*Capsicum annuum*	parts eaten	5	248.2	12.4	
Artichoke	*Cynara scolymus*	breeding potential	25	35.7	8.9	estimated % loss
Cabbage	*Brassica oleracea capitata*	seeds	5	174.3	8.7	estimated % loss
Beans, dry	*Phaseolus* spp	parts eaten	5	142.6	7.1	
Garlic	*Allium sativum*	breeding potential	5	139.4	7.0	estimated % loss
Beans, green	*Phaseolus* spp	parts eaten	5	137.0	6.8	
Sweet potato	*Ipomoea batatas*	breeding potential	5	88.2	4.4	estimated % loss
Taro	*Colocasia esculenta*	breeding potential	5	72.2	3.6	vegetatively reproduced, but pollination by flies
Radish	*Raphanus sativus*	parts eaten	65	4.9	3.2	annual, and mainly cross-pollinated by insects
Turnip	*Brassica rapa rapifera*	seeds	65	4.8	3.2	
Rocket	*Eruca vesicaria sativa*	seeds	25	11.9	3.0	estimated % loss
Beans, Kidney, Green	*Phaseolus* spp	parts eaten	5	49.8	2.5	
Broccoli, Cauliflower	*Brassica oleracea botrytis*	seeds	5	43.2	2.2	estimated % loss
Capsicum (chilli pepper)	*Capsicum annuum*	parts eaten	5	28.2	1.4	
Onion seed	*Allium cepa*	seeds	5	23.1	1.2	estimated % loss
Beans, Kidney, dry	*Phaseolus* spp	parts eaten	5	19.8	1.0	
Egyptian leek	*Allium ampeloprasum* var. *kurrat*	seeds	5	9.1	0.5	estimated % loss
Celery	*Apium graveolens*	seeds	5	2.3	0.1	estimated % loss
Purslane (Rigla)	*Portulaca oleracea sativa*	seeds	25	0.3	0.1	estimated % loss
Leek	*Allium ampeloprasum* var. *porrum*	seeds	5	0.4	0.02	estimated % loss
Beetroot	*Beta vulgaris vulgaris*	independent	0	0.8	0	
Chard	*Beta vulgaris vulgaris*	independent	0	6.8	0	
Chick pea	*Cicer arietinum*	independent	0	29.5	0	
Lettuce	*Lactuca sativa*	independent	0	42.8	0	
Lentil	*Lens* spp	independent	0	8.8	0	
Pea	*Pisum sativum*	independent	0	184.7	0	
Spinach	*Spinachia oleracea*	independent	0	15.6	0	
				Total potential losses	13446.1	

Discussion

Biological services, while essential for the whole planet's survival and persistence, are often overlooked in a country's economics. Without many of these services, invisibly working in the background, many economies would collapse. An early estimate for the value of pollination services was 0.4% of GDP for the whole world (Costanza *et al.* 1997); in managed pollination, a single solitary bee (*Habropoda*) can be worth \$20 to *Vaccinium* pollination (Kevan & Phillips 2001), and the pollination services provided by nearby forest reserves for coffee plantations amounted to 7% of farm income (Ricketts *et al.* 2004). For comparison in the way in which we have calculated pollination services here, the value of insect ecosystem services to the USA was estimated by Losey & Vaughan (2006) at $58 billion (made up of dung burial 0.4, pollination 3.1, pest control of native herbivores 4.5, and 'recreation' [food for game, fish and wildlife] 50.0). Since the GDP of the USA in 2006 was $13 trillion, this represents only 0.45% of GDP, with pollination services accounting for only 0.02%.

In developing countries, pollinator services are almost certainly more significant in that a greater proportion of the human population is maintained by income provided by agriculture: Egypt is no exception. Crops that are fully dependent on pollinators, such as melons (including watermelons), onions and aubergines (eggplants), are some of the biggest contributors to the Egyptian agricultural market. With declining populations of pollinators, these crops will suffer a dramatic drop in production, and this will have a huge impact not only on the individual producers, but on the whole of Egypt's economy.

The Nile Valley represents an environment with one of the world's longest records of continuously habitation by man. Virtually all natural habitats have disappeared, and many insects must have been already lost before the advent of modern agriculture. 21st-century declines of pollinators on an already-narrowed group of pollinators are likely to be serious. Egypt needs to implement strategies to prevent and reverse declines in pollinator populations. Changing farming techniques (i.e. reducing intensification, conserving pollinator-friendly areas), and enforcing restrictions on pesticide use would go a long way to achieving this. While this sounds an expensive and counter-productive strategy, the potential consequences of not implementing such a change could be far more costly to Egypt's development.

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References

BBC (2007) Bee vanishing act baffles keepers. 27th Feb 2007 on *www.bbc.co.uk/news*

Biesmeijer JC *et al.* (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351-354

Costanza R, D'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Rifkin RG, Sutton O & van den Belt M (1997) The value of the world's ecosystem and natural capital. *Nature* 387: 253-260

Chee YE (2004) An ecological perspective on the valuation of ecosystem services. *Biological Conservation* 120: 549-565

Dias BSF, Raw A & Imperatri-Fonseca VL (1999) International Pollinators Initiative: The São Paulo Declaration on Pollinators. Brasilian Ministry of the Environment, Brasilia, Brazil. *http://www.biodiv.org/doc/ref/agr-pollinator-rpt.pdf*

Economic Affairs Sector (2006) *Study for Estimating National Agricultural Income 2003/4*. Ministry of Agriculture & Land Reclamation, Economic Affairs Sector, Dokki, Giza, Arab Republic of Egypt.

de Groot RS, Wilson MA & Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41: 393-403

Kevan PG & Phillips TP (2001) The economic impacts of pollinator declines: an approach to assessing the consequences. *Conservation Ecology* 5(1): 8

Klein A-M, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C & Tscharntke T (2007) Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society of London* B 274: 303-313

Losey JE & Vaughan M (2006) The economic value of economic services provided by insects. *BioScience* 56(4): 311-323

Millenium Ecosystem Assessment (2005) *Living beyond our means: natural assets and human well-being*. Island Press, Washington, DC

Ricketts TH, Daily GC, Ehrlich PR & Michener CD (2004) Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences* USA 101(34): 12579-82

UNEP (2004) Biodiversity. In: *Global Environmental Outlook 4- environment for development*, pp 157-192. Progress Press Ltd., Malta

UNESCO (2007) GDP of Egypt for 2003. Obtained from *http://portal.unesco.org/ci/en*

الملخص العربي

إقتصاديات التنوع البيولوجى: قيمة خدمات التلقيح الحشرى فى مصر

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تقع الأنواع الحشرية الملقحة للنباتات البرية والزراعات تحت ضغط كبير حول العالم؛ بسبب سوء استخدام الأراضى، والاستخدام الزائد للمبيدات الحشريه والمخصبات. تعتمد أغلبية نباتات المحاصيل والنباتات البرية اعتمادا كليا أو جزئيا علي الملقحات لاستكمال دورة حياتها. و قد أثبتت الدراسات والأبحاث فى أوروبا أن فقد أو قلة عدد الملقحات قد سبب انخفاضاً معنوياً في كثافة وإنتاجية النباتات البريه والزراعات.
تعتمد كثير من المحاصيل والنباتات الإقتصادية المصرية اعتمادا كلياً او جزئياً علي الملقحات لإنتاج أفراد جديدة وزيادة إنتاجية الفدان من تلك المحاصيل. ومن خلال البيانات المتاحة عن بعض أنواع المحاصيل والنباتات الإقتصادية المصرية شاملة كمية الإنتاج السنوية و سعر السوق، وغيرها من المعلومات أمكن تقدير كمية الفقد الاقتصادى الناجم عن فقد الملقحات التى تزور وتساعد تلك الأنواع الهامة للغذاء فى مصر. أثبتت الحسابات أن كمية الفقد السنوى فى الإقتصاد المصرى نظرا لغياب تلك الملقحات يقدر بحوالى 13.5 بليون جنيه فى عام 2004، وهو ما يمثل حوالى 3.3% من الدخل القومى المصرى خلال عام 2003م. يجب بذل أقصى الجهود للحفاظ على تواجد وانتشار النحل البرى والملقحات الأخرى، من خلال استخد ام الأراضى بطريقة أمثل والتقليل من استخدام المبيدات والمخصبات الزراعية؛ لما لها من تأثير ليس فقط على التنوع البيولوجى ولكن على الإقتصاد القومى المصرى.