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Economic value of pollination services on crops in Benin, West Africa

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ABSTRACT

Pollinators provide pollination services that are crucial for sexual reproduction of many flowering plants. Beside wind and water, pollination services are provided by animals but mainly by insects. They improve the quality and the quantity of many crops. This study aimed at accessing the economic value of pollination services on selected crops in 2010 in Benin. Thus, 29 valued crops were considered and their individual pollination service values obtained from literature. At national scale, the individual gains in production due to pollination services of the selected crops were summed. In this study, all crops used for the calculation require pollination services and their economic added values were estimated to about 99,866.44 billion of local currency (FCFA) (that equal US $ 199.21 million) in 2010. This contributes substantially to the economy of Benin (3.03% of GDP). These results reveal the need to pay more attention to pollinators and their services in agricultural policies definition in Benin. We suggest a rational use of pesticides in agriculture and the preference of traditional practices in agriculture such as the preservation of few native plants in farming areas to give opportunity to conserve pollinators in these areas.
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Keywords: Added value, agriculture, conservation, pollinators.

INTRODUCTION

Plants and crops are very useful for human, animals and their environment/habitats. Their different organs are exploited for human and animals nutrition, for disease treatment, in house building and in many activities. The majority of these plants and crops need pollinators' services for their sexual reproduction. Pollinators provide an essential ecosystem service that result in the out-crossing and sexual reproduction of many plants (Eardley et al., 2006). They contribute to conserve natural ecosystem and biological diversity. Over 80% of flowering plants are pollinated by animals mainly by insects (Kevan and Imperatriz-Fonseca, 2002; FAO, 2009). These pollinators are butterflies, bats, birds, beetles, flies and bees which contribute heavily to plant pollination in the tropics and subtropical parts of the world (Crane, 1992; Williams, 1994; Tim, 1999). Approximately 73% of the world's cultivated crops are pollinated by some variety of bees (Pollinator Diversity, 2004). Among those, the honey bee (*Apis mellifera*) is the principal species used for crop pollination worldwide (Free, 1993). Pollinators provide several services to humans through increasing crop yield ensuring food

security. Their effect on crops may hence be quantitative and qualitative. 87 of the 124 single crops grown in the world increase their production with pollinating animals services (Klein et al., 2007). Similar results have been reported for many crops grown in the world (Carlos et al., 1998; Pando et al., 2011; Chang et al., 2011; Sarah et al., 2006). Quality and quantity of crops production are clearly positively affected by pollination services (Chautá-Mellizo et al., 2012) and wild and honey bees are complementary in pollination services (Ghazoul et al., 2013). Pollinators thereby enhance the economic profits (Garratt et al., 2014). Despite the importance of pollinators, their populations decrease in many regions of the world (FAO, 2008) due to human activities like agricultural and industrial chemicals, diseases, parasites, habitat loss, imported pollinators and fragmentation (Freitas, 2004). This situation will be very harmful for humanity particularly for African countries where economy largely depends on agriculture and natural resources exploitation. It might also have severe consequences for the farmers themselves (Eisikowitch, 2004).

In order to value pollinator's importance within landscape and for human, investigations have been done worldwide for many years to evaluate their economic value. It was then demonstrated that crop pollination by bees and other animals is an ecosystem service which has a great economic value (Allsop et al., 2008; Losey and Vaughan, 2006). Different methods have been proposed to evaluate the economic value of pollinators depending on the case. According to Bauer and Wing (2010), there are five methods.

The first category contains studies that value the pollination services provided by managed, commercially-available bee colonies. The second category of pollination valuation uses an approach that calculates the value of total annual crop production that can be directly attributed to animal pollination. The third category of valuation measures the economic value of pollination as the sum of the changes to producer and consumer surplus induced by the decrease in production due to a loss of pollination services (Kevan and Phillips, 2001). The fourth type of analysis estimate the costs of other market-based pollination alternatives involving labour (hand pollination) or capital (mechanized pollen dusting) that would be needed to maintain the level of crop production at that specific level provided by animal pollinators (Allsop et al., 2008). In the final category of pollination valuation, a landscape-based approach is used to value wild pollinator habitat. Its objective is to relate the characteristics of habitat fragments to crop yields (Morandin and Winston 2006; Oleschewski et al., 2006; Ricketts et al., 2004).

These different methods have been used to estimate the pollination value in some countries such as USA (Morse and Calderone, 2000), France (Borneck and Bricout, 1984), United Kingdom (Carreck and Williams, 1998), Australia (Gordon and Davis, 2003), and New Zealand (Gibbs and Muirhead, 1998). However, no study concentrated on pollination value was yet conducted in Benin. In this climate change context and manmade threats on pollinators, it becomes relevant to evaluate their economic value in order to point out their contribution on countries income. Estimating even a minimum value for a subset of the services that functioning ecosystems provide may help establish a higher priority for their conservation (Losey and Vaughan, 2006). This work accessed the economic value of pollinators in Benin and thus the economic losses that would be experienced in case of pollinators' decline. It aims at contributing to document the economic value of the pollination services provided my unmanaged pollinators in order to raise awareness in local communities but also for management decision making in agriculture.

MATERIALS AND METHODS
Study area
The study has been conducted on Benin, a tropical, sub-Saharan country situated between 6°30' and 12°30'N (Figure 1). The country covers 114763 square kilometres with a population estimated to 7 356 756 inhabitants in 2008. Four major groups of soils can be distinguished: ferrallitic soils covered by semi-deciduous forest,

ferruginous soils covered by dry forest, woodland, and savannah, vertisol in the depression of Lama covered by a particular dry type of semi-deciduous forest, and hydromorphic soils covered by swamp and riparian forests (Adomou, 2005). The annual rainfall varies between 900 to 1300 mm with four seasons in south-Benin and two in the north. The main activity of the rural population is agriculture.

Economic value calculation

This study aims at estimating the economic value of pollination services in Benin during year 2010. Thus, 29 relevant value crops were selected. These crops are distributed in three groups: field crop, vegetable crops and fruits and nut. The added value (economic value) due to pollination services was calculated following the formula used by different authors (Levin, 1984; Carreck and Williams, 1998; Morse and Calderone, 2000):

$$EVP = \sum D_i \times Q_i \times P_i$$

Where *EVP* is the economic value due to pollination, D_i = the dependency of each crop on pollinators, P_i = the price of each crop and Q_i = the quantity produced for each crop *i*

This method is used because it helps to estimate the value of the pollination service at the national scale (FAO, 2006).

Information about economic value of plants was collected from the literature mainly from FAOSTAT. These values expressed in US dollar were converted in the local currency (FCFA). The dependence of each plant on pollinators' activities was also obtained from the literature. According to Klein et al. (2007), the dependence of plant to pollinator's services and successful fruit and seed setting varies from one crop to another. This ratio was calculated base on the impact of pollinator's absence on crops yield. For this work, four categories of plant were used: *i*) plants which depend lightly on pollinator (0-10% of yield); *ii*) plants which depend modestly on pollinators (10-40%); *iii*) plants which depend greatly on pollinators and *iv*) plants for which pollinators are essential (more than 90% needed).

For pollination value estimation, the midpoints of these ranges: 5, 25, 65 and 95 were used respectively.

At the end, the value estimation of individual crops was summed to get the global economic value of pollination services on the selected crops in 2010 for Benin. The calculations were done in Excel Microsoft 2007.
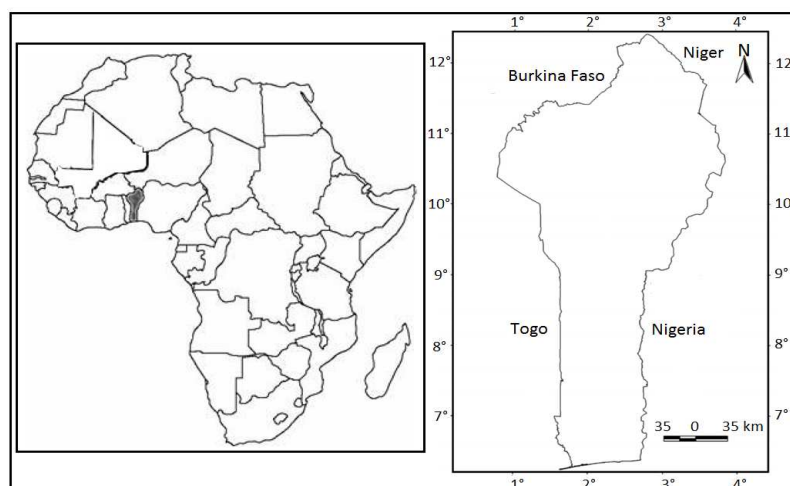

Figure 1: Map of Benin and Africa map showing Benin position.

RESULTS

Table 1 presents the crops with their cash produced for Benin in 2010. According to FAOSTAT (2011) followed by economic value of pollination services (EVP), we calculated that mean with the added value. These estimated values show the monetary losses that should be engendered by pollinator's lack.

Table 1: Economic value of pollination services in 2010 for Benin.

Crops	Scientific name	Pollination effect	Cash per crop (million of FCFA)	Pollination added value (million of FCFA) (%)*
Banana	*Musa spp.*	Breeding potential / fruit	2661,22	133,06 (5)
Bitter apple	*Citrullus colocynthis*	seeds	27,82	26,43 (95)
Black pepper	*Piper nigrum*	seeds	174,82	8,74 (5)
Cashew nut	*Anacardium occidentale*	fruit and nut	32029,72	20819,32 (65)
Cassava	*Manihot esculenta*	breeding potential	227456,25	11372,81 (5)
Castor-oil plant	*Ricinus communis*	seeds	122,85	6,14 (5)
Chillies	*Capsicum spp.*	fruit	16447,72	822,39 (5)
Cocoa	*Theobroma cacao*	fruit	54,6	51,87 (95)
Coconut	*Cocos nucifera*	nut	998,55	249,64 (25)
Cola nut	*Cola nitida*	nut	204,75	133,09 (65)
Cotton/ lint	*Gossypium spp.*	fibre	57,250.2	14,312.55 (25)
Cotton/ seed	*Gossypium spp.*	Seeds	17,968.12	4,492.03 (25)
Cowpea	*Vigna unguiculata*	seeds	51306,68	2565,33 (5)
Groundnuts	*Arachis hypogaea*	seeds	27711,6	1385,58 (5)
Irish potato	*Solanum tuberosum*	breeding potential	3,68	0,18 (5)
Karite	*Vitellaria paradoxa*	nut	916,65	229,16 (25)
Maize	*Zea mays*	seeds	91919,1	4595,96 (5)
Mango/guajava	*Mangifera indica/ Psidium guajava*	fruit	4309,72	2801,32 (65)
Okra	*Abelmoschus esculentus*	fruit	13395,9	3348,98 (5)
Onion	*Allium cepa*	seeds	3539,55	3362,57 (95)
Orange	*Citrus sinensis*	fruit	1359,75	67,99 (5)
Pineapples	*Ananas comosus*	seeds	33042,45	1652,12 (5)
Potato	*Ipomoea batatas*	breeding potential	2458,575	122,93 (5)
Sesame	*Sesamum indicum*	seed	3553,72	888,43 (25)
Soybean	*Glycine max*	seeds	2304,22	576,06 (25)
sweet pepper	*Capsicum frutescens*	fruit	6178,72	308,94 (5)
Taro	*Colocasia esculenta*	breeding potential	256,2	12,81 (5)
Tomato	*Lycopersicon esculentum*	fruit	29995,88	7498,97 (25)
Yam	*Dioscorea spp*	breeding potential	320003,25	16000,16 (5)
Total			904586,52	99866,44 (11)

* These percentages show the insect dependency of each crop

The table shows a range of 5 to 95% of added values. Crops such as onion and bitter apple (goussi) had the highest EVP (95%) followed by cola nut tree, cashew tree (65%), sesame, soya been, tomato, etc. (25%) whereas the smallest EVP was obtained for fruits and nuts like okra, orange, pineapples, etc. (5%). For added value, the highest amounts were recorded for cashew nut (20819.32 million), cotton lint and seed (18804.58 million) and yam (16000.16 million). These crops are produced in the whole country in large quantity contributing meaningfully to the country's economy. Cashew and cotton are among the major exported crops on which the whole country economy depends. Lower added values were reported for crops such as Irish potato, castor-oil plant and black pepper which depend lowly on pollinator's services.

DISCUSSION

Many plants need animal pollination services and their production successes are directly correlated with the quantity and the quality of these pollination services. The present study that reports on the contribution of the animal pollination services to different crops revealed that pollinators are needed for many crops grown in Benin. Pollinators then contributed greatly to crop production in Benin in 2010. This is due to the increase of area devoted to pollinator-dependent crops (Aizen, 2008). In fact, during this last decade, the production of some crops such as yam, cassava, pineapple and palm fruit has increased because of the yields improvement and agricultural area extension (MEF, 2011). Crops which do not depend on animal pollination are essentially Gramineae that are generally wind pollinated (McGregor, 1976; Tchuenguem, 2002).

Added values due to pollination services were substantial for the economy of a developing country like Benin in 2010. This value represents 3.03% of Beninese Gross Domesticated Product (GDP) estimated by World Bank to reach US $ 6.55 billion in 2010. Similar results were reported for USA (Morse and Calderone, 2000), Australia (Gordon and Davis, 2003), Canada (Oliveira, 2005) and Egypt (Brading et al., 2009) supporting the meaningful role played by these pollinators even though the added value vary from one country to another. The number of crops used for the calculation and their yields could affect the added values explaining the differences observed between countries. For instance, many of crops used for calculation in USA and Canada are fully dependent on animal pollination services compared with the situation in the present study where only few (7%) are fully dependent to animal pollination services.

Other parameters to be considered are the quality of habitat and environment quality that could be favourable for animal pollination services expression. As a confirmation, Ricketts et al. (2004) reported 20.8% higher yield in coffee plants situated at the edge of forest compared with those situated in the centre of the field far from forest. This situation raises the problem of the impact of habitat fragmentation which is very harmful to pollinators. It leads to the reduction of pollinators within disturbed habitats (González-Varo et al., 2009) and to pollination failure (Wilcock and Neiland, 2002). Segal et al. (2006) stressed that fragmentation may link the effects of inbreeding depression and pollinator activity to generate a "pollination crisis", expressed as significant reduction in sexual reproduction.

In another hand, agricultural practices in agro-systems could also affect pollinators and their services. In Benin, farmers who are in majority not trained at technical schools pay almost no attention to insects when comes

to apply agrochemicals in their farms, moreover, sometime the quantity to be applied per hectare is not respected. It was recognized that these chemical pollutants contribute to pollinator's decline (Freitas, 2004).

Pollination contribution on Beninese economy in 2010 was estimated to FCFA 99866,44 billion but, it should be more important because only few cultivated crops were targeted for the present study. We didn't take into account some wild neglected crops which are however heavily collected and used by rural communities such as *Borassus aethiopum*, *Parkia biglobosa*, *Adansonia digitata*, *Tamarindus indica*, etc. (Atchoua et al., 2009) that are also of high economic value in Benin. The data deficiency situation couldn't allow considering them although they also rely on animal pollination too for fruits and seeds production (Costanza et al.*,* 1997). In addition, the aesthetic value of pollination to ornamentals, wild flowers, and forest and range plants in terms of beauty of the landscape is recognized for specific plants but it cannot be measured too (FAO, 2008). The crop dependence on pollinators is somehow site or area specific that why different authors used different ration of this pollination services for the same crop from one area to another (Morse et al., 2000; Pouvreau, 2004; De Oliveira, 2005). Due to these differences, Klein et al. (2007) recommended to calculate this ratio on specific area for a given crop avoiding a generalizing use of pollination service dependence ratio. Until now, few studies were carried out in Benin to measure impact of pollinators on crops yields. So, the dependence ratio of crops on pollinators used for calculation was obtained from studies carried out in others countries which have a similar climate. This situation suggests that we take the values presented in this paper with caution although they fully showed the importance of the contribution of pollinators to the different crop productions and thereby

the added estimated economic values in Bénin for 2010.

Agriculture contributes to the third of Benin's GDP and provides work to 60% of Beninese (World Bank; BAFD/OECD, 2008). During the last 20 past years cotton production is increasing with heavy use of pesticides mainly in the northern Benin. In light of the results of this work that revealed the importance of pollination services for key crops and in turn to Benin agriculture's contribution to its economy, pollination services delivery can be seriously affected by pollinators decline due to agrochemicals' pollution and this is likely to impact negatively food security consideration mainly in poor rural communities.

Conclusion

Pollinators are needed for many crops grown in Benin on which depends its economy. The contribution of pollinators in crop production should increase in the near future because of the increase of crop production which is necessary to sustain the growth of the population of Benin. Therefore, pollinators need to be conserved to guaranty the services they provide to the cropping system. Agriculture policies must integrate pollinators as important production factor and work to their conservation and valorisation. In addition, the use of pesticides and others agrochemicals harmful to pollinators must be treated carefully. In addition, we suggest that similar to practices in farming systems in developed countries, we start considering honey bee colonies used to support in complementary to wild pollinators. The pollination services that we showed here is very important for food production in Benin.

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