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REVIEW ARTICLE

The Contribution of Managed Honey Bees to Crop Pollination, Food Security, and Economic Stability: Case of Ethiopia

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Abstract: This paper reviews the role and economic importance of the pollination service by honey bees (*Apis mellifera*) to agricultural crops and food security in the Ethiopian context. Honey bees provide pollination services that are crucial for sexual reproduction and improving the quality and quantity of many agricultural crops. From the significant 53 crops cultivated in Ethiopia, 33 (62.2%) of them are dependent on biological pollinators. Besides this, honey bees play a vital economic role, and their contribution to pollination service in agriculture crops is around 0.815 billion dollars in Ethiopia. Nevertheless, this contribution is unnoticed by Ethiopian farmers. Pollination by honey bee plays an essential role in human nutrition and supplies food security, income in households, and ecosystem services. Declines in insect pollinators, including honey bees across the world, have raised concerns about the supply of pollination services to agriculture, and it is because one-third of agriculture productions depend upon pollination, mainly by honey bees. Among the several factors responsible for the decline of honey bee colonies, improper pesticide application, and climate change are the elements and make them at risk. The potential adverse effects of pollinator declines include direct economic losses incurred by reduced crop yields as well as broader impacts on the agricultural activity because of lower productivity in the ecosystems. Through promoting and the use of honey bee pollination service as agricultural development packages, it is possible to improve honey bee production and crop yield in Ethiopia.

Keywords: Crop yield, Economic benefit, Ethiopia, Honey bee, Pollination service, Public perception.

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1. INTRODUCTION

Pollination is an essential process in the production of seed plants, and it results in a genetically diverse production of offspring [1]. Globally, one-third of the total human food supply depends on insect pollination [2 - 5]. Production of agriculture crops is increasing by 50% through bees pollination [2]. Honey bees (*Apis mellifera*) are economically essential insect pollinators all over the world [6 - 11]. They provide ecologically for pollination of natural, wild vegetation plants and agricultural crops; as a result, they play a significant role in the landscape and natural resource preservation [6, 10, 12, 13].

The apiculture sector is one of the essential livestock subsectors, which contributes significant importance to the livelihoods of the people in Ethiopia [14]. Beekeeping in Ethiopia plays a vital role in the agricultural, environmental activity, and it serves as a source of additional cash income for beekeepers [15, 16]. This sector plays a great role directly by providing valuable output such as honey, beeswax, queen, bee colonies and indirectly other products such as pollen, royal jelly

jelly, bee venom and propolis in which it has high demand globally for different functions including medicinal and nutritional value [17 - 19].

Animal pollinators include many insect species (managed and wild), species of birds are crops pollinators, and the honey bee are considered one of the primary pollinators [20]. Honey bee plays a central role in agriculture as pollinators, and their contribution to the global economy for food production is estimated between \$ 235 and \$ 285 billion annually [21] and \$0.815 billion in Ethiopia, which is 6.24% of the agricultural GDP [22]. According to Shrestha [23], the impact of honey bee pollination to crop production and quality has been estimated to be more than the value of honey and wax production. The economic benefit of the honey bees pollination service is 4.58 times higher than the honey production in Ethiopia [22].

Other sources revealed that income generation, food consumption, pollination of crops, and natural resource conservation are among the list of importance of the beekeeping sector [24]. Therefore, the objective of this paper will focus on reviewing the role, economic importance of honey bees (*Apis mellifera*) pollination service to agricultural crops, and food security in Ethiopia.

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1.1. Role of Honey Bee Pollination Service on the Productivity of Different Agriculture Crops in Ethiopia

As Central Statistical Agency informs every year, fifty-three significant crops are cultivated in Ethiopia [22]. Out of the 53 major agricultural crops cultivated in Ethiopia, 33 of them (62.2%) are dependent on biological pollinators, and from the total biological pollinator, honey bees contribute 80% of pollination service [22]. This indicated that honey bees are the most efficient insect pollinators in cultivated crops. Workers of honey bees visit multi-flowering plant species at a time to collect nectar and pollen at a time they serve as cross-pollinator. Both survival and conservation of genetic diversity of many crops and wild plant populations largely depend on insect pollination service [25]. Concerning specific insects, it is expected that almost one-third of all plants or plant produced food eaten by humans is dependent directly or indirectly on bees for their pollination [26]. This shows that the life of humans somewhat depends on the existence of honey bee. Without any extra cost for inputs, only the use of crops pollinated by honey bees, has been proven to produce higher yields and better quality [27 - 29].

Even though improved agricultural technologies include the use of the quality seed, applying techniques, high-yielding varieties, good agronomic practices (timely irrigation and fertilizers) increased agricultural crop production. However, without pollination, neither the fruit nor the seed will be set appropriately. The pollination process is an essential activity for the production of fruit plants, a variety of flowering plants deal with fundamental ecosystems facilities to human welfare [2, 12]. Beekeeping plays a parallel role in the cross-pollination of industrial farming crops and medicinal plants with the manufacturing of honey. The honey bee is a strong pollinator for many crops. It is the pollinator species that can be most easily managed by humans in enormous numbers for the pollination of highly diverse crops [30, 31]. Reports indicate that honey bee boosts the production of different fruit crops up to 30-40% [32] and increases the production of most agriculture crops by 5-50% [2].

Honey bee pollination is as essential for crop production as water and fertilizer but, its role is not well understood and appreciated in the local farming system [33]. Exposing sesame (*Sesamum indicum L.*) to honey bee during flowering time increases the pod and seed productions [34]. In a study conducted previously, both open pollination and *Apis mellifera* pollination treatments were sufficient to increase the seed yield of sesame by 22% and 33% [35], and 43.92% and 35.23% [36] respectively, which is more than that of pollination excluding insects. Other scientific documents describe that it is possible to increase the production of sarsoon (*Brassica Rapa rilocularis*) and toria (*Brassica napus*) by 47% [37] and yield and physicochemical properties of tomatoes (*Solanum*

Lycopersicum) [38] through honey bees pollination and insect pollinators respectively.

In Ethiopia, research evidence documented that honey bee pollination increased the seed yield of Niger seed by about 43% [39], onion (*Allium cepa L.*) yield by double [40] and by 94% [7]. According to Bezabih & Gebretsadikan [41], the seed yield of onion increased by 41.2%, the mass of 1000 seeds by 25%, and the germination percentage by 68% through open pollination especially by honey bees. Crane [42], also reported that honey bees pollination increases the yield of *Citrus sinensis* by 30%, watermelon by 100%, and tomato by 25%. Besides the yield maximization of honey bee pollination service, they also contribute to improving the quality of different crops such as onion [41], apple fruit [43], and sesame seeds [34].

According to Tura *et al.* [43] from Table 1 through honey bees pollination, it is possible to increase the marketable apple fruit yield by about 50%, and the average marketable apple fruit yield per individual tree is 3.2 kg (caged with honey bees), and 2.2 kg (open to all insect pollinators). Another study by Gebremedhn and Tadesse [44], revealed that pollination of crops caged with a honey bee was significantly affecting the seed yield Niger seed (16.7 quintals/ ha) than crops yield caged without insects (9.6 quintals/ha). Sufficient pollination service results in higher marketable fruit yields and quality, per tree of apple crops, compared with those unexposed to insect pollinators [30, 43, 45]. Generally, the fruit yield of *Malus sylvestris* increased by 77.8% if we were using honey bee as pollinators and by 22.2% using insect pollinators with free access to the apple trees compared to trees caged without pollinators [43]. The productivity and quality of strawberry were increased by the use of honey bee as a pollinator [46]. Stimulating the use of beekeeping for pollination of crops will be of benefit to both the beekeeper and the farmer. Therefore, farmers should use pollination service to maximize their income without paying an extra cost through only placing the honey bees on the cropland during the flowering session.

1.2. Economic Value of Honey Bee Pollination Service

Cross-pollination through honey bee is essential to increase quality through a more unified ripening period and earlier harvesting time. Honey bees pollination service not only maximizes agricultural crop production but also increases the honey yield harvested from the hive because honey bees collect more nectar and pollen while they pollinate the flowering. The economic value of pollinators for some agricultural crops was estimated to be \$ 0.815 billion dollars in Ethiopia, and in addition to this, the regional distribution is shown as Oromia and Amhara regional being ranked the first and second regional states to benefit from biological pollinators in the country [22]. In the absence of the pollinators, the economic value may drop by 16% [47].

Table 1. The mean and standard error (SE) of marketable fruit yield per tree, per hectare of apple trees, and seed yield of Niger seed /hectare under different treatment.

Treatment	Mean Marketable Apple Fruit Yield kg/tree + SE (kg)	Average Apple Fruit Yield kg/ha	Seed Yield of Niger Seed /ha(kg)
T1 = Caged with honey bees	3.2 + 0.4 ^a	3,560	1669 ^a
T2 = Open pollination	2.2 + 0.37 ^{ab}	2,440	1324 ^{ac}
T3= Caged without insect pollinators	1.8 + 0.22 ^b	2,000	960 ^c

Source [43, 44];

Table 2. Economic Value of Pollination (EVP) service for biotically pollinated crops (agricultural and horticultural) in Ethiopia.

Crops	EVP in US\$	Rank	Crops	EVP in US\$	Rank
Coffee	2,500,905.0	1	Groundnut	50,262.1	18
Faba beans	1,431,599.4	2	Linseed	45,561.6	19
Niger seed	1,430,488.6	3	White haricot bean	27,764.2	20
Sesame	549,087.7	4	Ethiopian cabbage	27,082.1	21
Cotton	485,714.2	5	Fenugreek	23,506.0	22
Red pepper	383,424.3	6	Green pepper	14,050.8	23
Mangoes	175,806.2	7	Mung bean	12,932.8	24
Chick peas	166,539.2	8	Safflower	10,192.7	25
Field peas	118,422.3	9	Tomatoes	8,139.8	26
Rape seed	101,567.4	10	Papayas	6,174.8	27
Lentils	99,589.2	11	Oranges	4,473.4	28
Potatoes	90,280.9	12	Head cabbage	4,091.3	29
Grass peas	85,822.8	13	Lupine	3,565.0	30
Avocados	85,132.5	14	Beetroot	3,378.3	31
Soya beans	81,145.1	15	Guavas	1,622.5	32
Red haricot bean	66,134.4	16	Lemons	1,010.7	33
Onion	57,005.6	17			

Source [22]:

In Ethiopia, during the 2015/16 production season (Table 2), the economic value of pollination service for the specific crops ranges from \$ 2,500,905.0 to \$ 1,010.7 in which coffee is higher pollination economic value (\$ 2.5 million), followed by Faba bean (\$ 1.431 million) and Niger seed (\$ 1.430 million) respectively [22]. Honey bee pollination service improves both the quantity and quality of apples and its impact is increasing the market value and growers' profits [48 - 50]. According to Tura *et al.* [43], application honey bees pollination service has boosted the income by 136.6 US\$ per 100 apple trees. It is important to use honey bees pollination service as a yield-enhancing tool and/or technology and as a development extension package to improve productivity and food security in individual producers' level and boosting the national economy in Ethiopia (Table 3).

1.3. Perception of Farmers' on Pollinators and Pollination

Nowadays, there is a global loss of pollination services that resulted in a \$302 billion reduction in the value of production across all sectors [57]. Reduction in output through pollination service is due to human-induced impacts such as habitat destruction, land-use change, use of chemicals (pesticides and

herbicides), climate change, and invasive species [58, 59]. Abundances and distributions of pollinator species are affecting agricultural yields, and other agroecosystem functions in many ways. About 77% of farmers in the gozamin district of the Amhara region in Ethiopia did not know pollination and the importance of insect pollinator, and they consider crop pests to insect pollinators [60]. The majority of cocoa producing farmers in Ghana (87.6%) did not have the general scientific concept of pollination [61]. However, 50% of beekeeping farmers in the Chitwan district of Nepal were aware of the pollination services provided by the bees [29].

Only a few farmers (23%) know the role honey bees play in pollination service [60], and similar to this the majority of farmers in western Kenya [62] and Uganda [63] were not aware of the importance of pollination for crop production. This indicates the need for training and awareness creation to the farmers on the significance of pollinators to enhance productivity. In most parts of Ethiopia, golden pollination service of honey bees is not recognized well. Therefore, it is still a need and essential to create awareness on the relevance of honey bees pollination service to farmers.

Table 3. Economic values of honey bee pollination in different parts of the world.

Country	Economic Values (US\$)	References
United States of America	14.6 billion	[51]
Australia	4-6 billion	[52]
East Africa	1.2 billion	[53]
Ethiopia	0.815 billion	[22]
China	0.7 billion	[54]
Uganda	0.46 billion	[55]
Benin	0.199 billion	[56]

1.4. Pollination and Human Nutrition

The most significant benefit of beekeeping lies in the fact that honey bees pollinate agricultural and horticultural plants. Pollinators play an essential role in human nutrition in the developing world [64]. Besides, the economic impacts and the possible consequences for the socio-economics of human societies, loss of pollination may also affect human nutrition [65]. Insect-pollinated crops are crucial for proper human diet [66], and they provide nutritional variety and nutrients, including lipids, vitamins, folic acid, and minerals, which are essential for human health [2, 66]. In addition to the quality and quantity improvement, insect-pollinated crops also provide about 70% vitamin the deficiency of which is a primary human health concern worldwide, and pollinators are responsible for up to 40 percent of the world's supply of nutrients [66]. Hence, generally, it is possible to deduce that loss of pollinators and the service they provide could produce a potential problem on human nutrition, although the magnitude of the problem will often depend on geographical location and degree of societal development.

1.5. Contribution of Apiculture to Food Security

Ethiopia designed a competitive advantage in honey and beeswax production improvement to develop a substantial export trade is an essential goal of the Growth and Transformation Plan (GTP) to eradicate poverty [67]. Apiculture is one of the livelihood sources in most developing countries, and its success has been noted in countries like Ethiopia [68]. Beekeeping plays a critical role in agriculture and having many comparative advantages that help farmers to improve their livelihoods and ensure food security [69, 70]. In addition, it is an excellent source of income for landless farmers [71]. Beekeeping has a significant contribution in alleviating poverty and improving the standard and wellbeing of the rural beekeeping community through the income from the sector as secures of financial power [72]. Practically, beekeeping does not compete with crop production and animal husbandry practice, but it is advantageous for agricultural and horticultural plants.

Ethiopian government focuses on the rehabilitated Ex-closure areas given to landless youths through organizing them as trained cooperatives and providing initial capital to run modern beekeeping activities as alternative employment opportunities and food security [73]. The honey bee produces honey, and brood is an essential source of food [74, 75]. In agriculture production, pollination plays a crucial role in enhancing food security and yield stability through the linking of an ecosystem with agricultural production [76 - 78].

In the country, about 1.55 million households are engaged and getting incomes from beekeeping [79]. Due to bimodal rains, beekeepers harvested honey twice a year [73, 80, 81]. The country produces about 47,352 tons of crude honey and 5.4 thousand tons per year [82 - 84]. Out of the total honey produced, almost 80% is used for local consumption and for local brewing called *Tej*, and the remaining is sold either as table honey in the domestic market or to the export market [74]. Keeping a resilient honey bee colony and managing them in a wall manner help to ensure the future viability of crops. It provides vital stability in the agricultural sector and millions of

people as employment opportunities. Maximizing the yield of honey bee-pollinated plants can improve the performance of the agriculture sector, increase national wealth, and help to ensure the long-term food security and economic resilience of the rural populations.

1.6. Challenges of Honey Bee Pollination Services

Farmers use different inputs, including pesticides, to grow subsistence and commercial crops of different varieties for agricultural crop maximization. Even if honey bees pollination has proved to be essential for food production, directly and indirectly, the supply of human food and animal feed resources are considered to be at risk today [85 - 87]. Beekeepers are experiencing high colony losses due to the unwise application of pesticides [88, 89] and climate change [90]. Insecticides and herbicides have been reported as significant causes of death and absconding of the honey bee colonies [91, 92] and their food source [88]. Due to the misapplication of these chemicals, honey bee mortality and reduction of honey bee colonies, which eventually results in a reduction of bee products and crop yield are faced [88, 93]. Reports indicate that there was a decline of honey bee colonies in Ethiopia [47, 60, 91, 94] due to pesticide application and deforestation. The impacts of pesticides on honey bee production are likely to be aggravated by the limited knowledge among users on the toxicological and chemical properties of these substances and the fact that labels on pesticide containers were in a language that cannot be understood.

Even variation in the production system, the average honey bee colony holding capacity of beekeepers is 5 [24, 95, 96]. Agrochemical poisoning is the primary challenge for the beekeeping sector, and three-quarters of beekeepers lose two honey bee colonies per year [89] and some beekeepers lost all their colonies [88] due to unwise application. Through the application of pesticides, the subsequent financial loss to the beekeepers is estimated to be about 819291.4 US\$ at selected districts of the Amhara Region, Ethiopia [91]. Scientific study indicates that all of the farmers apply agrochemicals on barley, wheat, millet, and onion before blooming [89] and majority of farmers apply chemicals on mango (92.9%), orange (97.2%), potato (81%) and maize (81%) at blooming and liquid spray at the morning and the middle of the day [89, 91, 92]. The majority of farmers use pesticides at the time when the honey bees most visited the flowering plants to collect nectar and pollen; as a result, they poison themselves or contaminate the resources found in the hive. Pesticide application is increasing its impact, including honey yield, killing flowering plants, pollination service, and efficiency and honey bees population. Limiting the use of pesticides [94] and wise application of pesticides during the flowering period of crops is important to minimize honey bee losses in Ethiopia.

1.7. Knowledge Gaps and Priorities for Future Research on Honey bee Pollination Service

- The contribution honey bees to pollination service to the yield and/or quality of multiple crops from individual pollinator species and pollinator communities should be identified and documented appropriately.
- It needs a further assessment of why farmers do not

use pollination services as yield and quality improvement tools and technology.

- The socioeconomic and environmental relevance of honey bees pollination service should be assessed and documented.
- Skill and knowledge gap on the farmers how and when to use pesticides [89, 91, 92].
- Farmer's awareness of honey bees pollination service to agricultural crop production is low [60].
- Developing conservation policy for pollinators; especially, honey bees, and legislation and monitoring for pesticide application [47, 89, 92].
- Awareness creation on protecting the honey bees from pesticide poisoning and the importance of honey bees on agricultural crop pollination [47, 60].

CONCLUSION

Globally, one-third of the total human food supply depends on insect pollination and animal pollination. The honey bee is responsible to pollinate 62.2% of crops cultivated in Ethiopia. In this respect, mainly, the honey bee has brought about a significant economic contribution to improve agricultural crop production quantity and quality, essential for ecological maintenance and improvement, human food, and nutrition security in Ethiopia. Nevertheless, the double benefit approach of honey bees pollination service has been overlooked in agricultural development strategies and has not been included as a technological input in agricultural development packages. High-value agriculture is being promoted in several areas and extension institutions offer packages of practices for each type of crop. However, the importance of managing pollination to achieve higher yields still has been overlooked in Ethiopia.

In Ethiopia, farmers have no way of knowing how essential honey bees pollination services to their crops. This gap in the agricultural extension system needs to be addressed by designing policies and strategies to use honey bees pollination service as a tool and technology for the improvement in production and sustainability.

Recently, a decline in honey bee keeping has been reported in Ethiopia, owing to several factors including the unwise use of pesticide climate change. The use of pesticides has been affecting the honey bees through poisoning, death, destroying the honey bees forage, pollination service, and efficiency. This, in turn, results in a reduction of bee products and crop yield.

To reduce the ecological damage and losses, what is required is understanding the commercial and pollination service needs of the country. Furthermore, utilizing honey bees pollination services will help to maintain and sustain the ecology and agricultural crop production. In conclusion, promoting the honey bees pollination service as the tool for improving honey production and crop yield in Ethiopia is essential.

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CONFLICT OF INTEREST

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