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Economics of beekeeping as pollination management practices adopted by farmers in Chitwan district of Nepal

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Abstract

Background: When the natural pollinator's declines, beekeeping can contribute to the pollination services, assuring crop yields, and can also be used to strengthen the livelihoods through commercialization to increase economic revenue.

Methods: A farmers' survey and field experiment were conducted on 2011 to assess the economics of beekeeping as pollination management practices adopted by the farmers of Chitwan district, Nepal. Samples of 75 respondents from the list of beekeeper farmers of Chitwan district were selected randomly. Information was obtained from individual respondents through a pretested questionnaire and group discussion. Furthermore, to assess the benefit of bee pollination 15 experimental plots were selected to see the effect of bee pollination on mustard crop yield.

Results: From the study, the gross income (rupees/hives), productivity (rupees/man-day), average cost (rupees/hives), and gross benefit (rupees/hives) as a result of keeping bees were found to be 4475.23, 1506.30, 2526.66, and 1948.57, respectively. The benefit–cost ratio of beekeeping was found to be significantly higher, at 1.8. The contribution of the bee pollination on the mustard crop production was found significantly higher than that on the mustard production without the insect pollination.

Conclusions: This research finding will provide the new ways of thinking on the relationship between beekeeping and their importance on the crop production. The pollination shortage due to pollinator declines can be mitigated through the beekeeping which helps to uplift the sustainable livelihoods of the farmers through income generation.

Keywords: Pollination, Beekeeping, Ecosystem, Yield, Economics

Background

Pollination is considered as the most essential regulating, supporting, and cultural ecosystem services [1, 2]. It is a critical service for fruits, vegetables, nuts, cotton, and seed crop production among many other agricultural crops and supports reproduction of wild plant communities [3–6]. According to Kearns et al. [7], bees alone comprise an estimated 25,000–30,000 species worldwide, all obligate flower visitors [8]. We rely on bees to pollinate 87 of the 124 (70 %) most valuable crops used directly for human consumption [9]. The production of 84 % of crop species cultivated in Europe depends directly on insect pollinators, especially bees [10]. Worldwide, bees pollinate more than 400 crop species and in the USA more than 130 crop species [11].

The loss of insect pollinators has greater potential consequences on human food production directly through reduced crop yields. Although pollinator decline was not documented to affect crop yield on a global scale [12], there is evidence on a local scale that declines in pollinator (diversity) affect fruit set and seed production [13].

In these contexts of pollinator's declines, beekeeping contributes to the provision of pollination services, assuring crop yields and helping maintaining plant biodiversity in natural ecosystems [14, 15]. Most crops depend on a small number of managed pollinators, especially the

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honey bees which can be bought into the crops when needed [16]. Honeybees are the most efficient pollinators of cultivated crops because their body parts are especially modified to pick up pollen grains and they can work for long hours, show flower constancy, and are adapted to different climates [17, 18]. Honeybee pollination has been reported to increase seed production in oilseed, rapeseed, and sunflower seed, as well as the oil content in the seed [19], and beekeeping activity provides benefits in terms of employment, pollination of crops, and conservation of biodiversity [20].

Rapeseed (*Brassica campestris* L. Var. toria) is dominant winter season oilseed crops of Nepal. Its cultivation occupies about 80 % of the total oilseed area in the country [21]. Oilseed rape is generally considered self-fertile [18]. However, cross-pollination is probably required to maximize yield and economic return in oilseed rape. Among the numerous species that provide pollination services, the eusocial, generalist Western honeybee (*Apis mellifera* L.) is reported to visit the greatest variety of crop species [9].

Nepal is rich in honeybees and honeybee pasture diversity. There exist four native honeybees species: three open nesting wild types (*Apis florea* Fab., *A. dorsata* Fab., and *A. laboriosa* Smith) and one close nesting, half way domesticated type (*A. cerana* Fab.) with different geographical races. *A. mellifera* is exotic species which is imported and promoted in Terai of Nepal from 1996 [22, 23]. The total estimated *A. mellifera* honeybee colony in Chitwan is 10,000 [24].

Crop pollination services are being hampered by a decline in the number and diversity of pollinator populations throughout the Hindu Kush Himalayan (HKH) region [25–28]. In a recent study, it was recorded the evidence of pollinator decline at eight sites in Kaski district in Nepal [29]. They reported a decline in the number of *Apis laboriosa* S. nests from 182 nests in 1986 to 48 in 2002.

In recognition of looming pollination crisis all over the world, there has been a mobilization of effort on several levels to address pollination management and conservation. Within this context, the importance of beekeeping in potentially to mitigate it, here, we evaluated economic benefit of these practices to the farmers. Furthermore, we tested whether the mustard crops (*B. campestris*) could present better yield when visited or not by honeybees. As we shall see, the increasing beekeeping practice in the Chitwan district that helps to obtain the sustainable livelihoods of Nepalese beekeepers enlarges their income by providing pollination services into mustard crops (*B. campestris*) more than only by honey production.

Methods

Study area and sampling procedure

The study was conducted on Chitwan district from August to December 2011. Samples of 75 respondents were selected randomly from the list of beekeeping farmers in the district [24].

Data collection

The pretested interview schedule was administered to the sampled farmers for the collection of primary data. The secondary information was obtained through a literature review of publications from the Ministry of Agriculture and Co-operatives (MoAC), Department of Agriculture (DoA), Food and Agriculture Organization (FAO), International Pollinators Initiatives (IPI), Central Bureau of Statistics (CBS), Global Environment Fund (GEF), District Agricultural Development Office (DADO), Chitwan district, Village Development Committee (VDC), and Global Pollination Project (GPP).

The collected data on local units of measurements were standardized into the scientific one. The obtained data were analyzed in Stata 12 software [30]. The occupational pattern, purpose of beekeeping, etc., were analyzed by using descriptive tools, and graphs were prepared wherever applicable. Cobb–Douglas production function was used to find the productivity and resource-use efficiency.

The form of production function used was:

$$Y = aX_1^{b1}X_2^{b2}e^{\mu}$$

The function was transformed into the log-linear form:

$$\text{In}Y = \log a + b_1 \log X_1 + b_2 \log X_2 + \mu_i$$

where Y = gross cash income beekeeping (Rs), a = constant, X_1 = human labor used (Rs/man-day), X_2 = expenses on materials (Rs), μ_i = error term, b_1 and b_2 are coefficient to be estimated.

Pollination assessment

We assess the contribution of the bee pollination on the mustard crop yield. For this, 15 field trials were set up in the different commercially mustard growing places of the Chitwan district. Each trail consisted of two treatment; i.e., one treatment covered with the nylon net cage of size 6 m × 3 m × 2.5 m to restrict the access of insect pollination, and other treatment covered with nylon net of same size allowing pollination by keeping two frames of *Apis mellifera* inside the net. When the mustard plants reached about 5 percent flowering, the mustard crops were covered with the nylon cage. Later the yield comparison was done between the two treatments to see the effect of bee pollination on the mustard yield.

Statistical analyses were carried out using the R program [31] and plotted using *ggplot2* package for R [32], as applicable. Shapiro–Wilk test ($W = 0.899$, P value $= 0.008$) was applied to test the normality of observed mustard data, and later we performed a Mann–Whitney test by testing whether mustard crops with beehives could have higher yields than opposite (without beehives) at 95 % of confidence interval.

Results

Occupation pattern of the family members

The main occupation of respondent family at different location was agriculture (54 %), followed by students (25 %) as shown in Fig. 1. A very few of family members are engaged on business (2.55 %) and services (6 %). About 13 % sampled populations are engaged on aboard services and other occupation. This shows that a large proportion of the family members were deployed in agriculture, so we can improve their livelihoods through beekeeping practices.

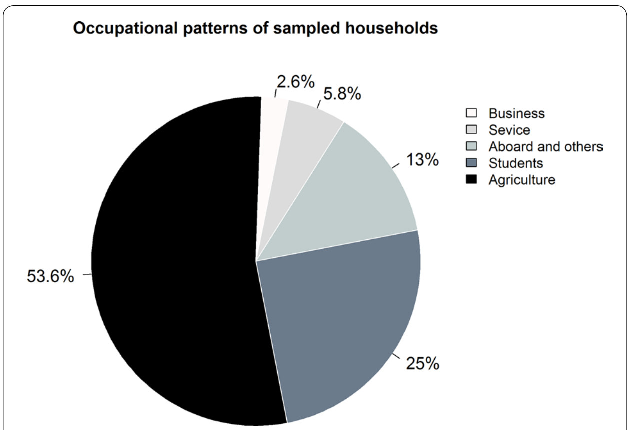

Fig. 1 Occupational pattern of sampled household in study area (2011)

Purpose of beekeeping

The purpose of the beekeeping was found mainly for the honey production. Almost 100 % farmers aimed to produce honey, and least farmers around 20 % of them produce other product than honey. About 50 % beekeeping farmers were aware about the pollination services provided by the bees, and they think about the pollination too as shown in Fig. 2.

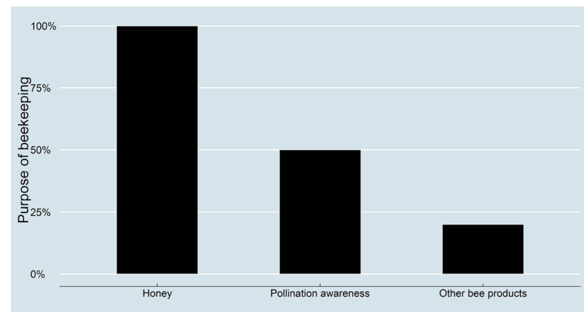

Fig. 2 Purpose of beekeeping

Productivity analysis of beekeeping

It was found that the transformation coefficient of beekeeping was positive and highly significant. In the beekeeping, the transformation coefficient of the labor expenses and material expenses was found positive and significant as shown in Table 1. It reveals that one percent increase in labor expenses and materials expenses, other factors keeping constant, would increase the yield of beekeeping by 0.49 and 0.47 %, respectively. The coefficient of multiple determinations (R^2) was 0.96 for the beekeeping which indicates that 96 % was variation for yield in beekeeping production explained by the independent variable incorporated in the model.

Table 1 Productivity analysis of beekeeping in the study area (2011)

Variable	Coefficients	*t* value	*P*
Labor expenses (man-day)	0.49 ± 0.05	8.69	<0.01
Material expenses (Rs)	0.47 ± 0.05	7.98	<0.01
Constant	4.45 ± 0.40	10.98	<0.01
Return to scale	0.96		
	$R^2 = 0.96$ Adjusted $R^2 = 0.96$		

"±" means the SE

It was observed that the summation of elasticity of different inputs for beekeeping production was 0.96. This means that with one percent increase in inputs the beekeeper farmers can increase the return by 0.96 %.

Economics of the beekeeping as pollinator-friendly practice

The result shows that the average number of beehives that was 19.62 as shown in Table 2 was found statistically

Table 2 Economics of beekeeping farmers in the study area (2011)

Particulars	Mean	*t* value	*P*
No. of beehives	19.62 ± 1.97	9.92	<0.01
Gross income (Rs/hives)	4475.23 ± 73.51	60.87	<0.01
Average cost (Rs/hives)	2526.66 ± 58.23	43.38	<0.01
Productivity (Rs/man-day)	1506.30 ± 45.87	4.74	<0.05
Gross profit (Rs/m^2)	1948.57 ± 65.02	29.96	<0.01
Benefit–cost ratio	1.81 ± 0.04	44.35	

"±" means the SE

significant for being positive value other than zero. The gross income (Rs/hives) and average cost (Rs/hives) from the beekeeping were found as 4475.23 and 2526.66, respectively. The productivity (Rs/man-day) and gross benefit (Rs/hives) were 1506.30 and 1948.57, respectively. The benefit–cost ratio from the beekeeping was 1.81 which indicates higher yield and less cost of production of beekeeping contributed to higher gross return and benefit–cost ratio. This shows the higher opportunity of the beekeeping for the higher economic revenue of the farmers.

Contribution of honeybee on mustard yield

Our results indicate that the presence of beehives into mustard crops throughout blooming rises its yields evaluated as quintals per hectare ($U = 10$, CI 95 %: −2.91, −2.08, $P < 0.0001$), as shown in Fig. 3. The study shows that the seed yield of the mustard with the beehives (data range and average) was found higher than on the non-insect pollinated condition (data range and average). The highest mean mustard yield (7.79 qt/ha) was obtained at treatment where the beehives was kept, while the yield of the mustard without the insect pollination was found 5.35 qt/ha. From this we can conclude the honey bees can be a major pollinator of the mustard crop, if the wild pollinators declined.

Discussion

As cultivated area of pollinator-dependent crops is increasing more rapidly than the practices of managed bee colonies [12] and population of wild pollinators are also in increasing threats [33, 34], pollinator's deficits may be more relevant than the previously thought. In this scenario, to obtain a sustainable agriculture development and enhance the economic livelihood of the farmers we found the relationship between beekeeping and their role in pollination for crop yield with the field experimental data. The low cost of practices and having higher benefit–cost ratio of beekeeping show the higher opportunities for the farmer to adopt this pollination management practices to earn a better living.

Keeping bees can help low-income communities to earn additional revenues from selling bee product to achieve sustainable development [35]. Moreover, beekeeping contributes the provision of pollination services, assuring crop yields and helping maintaining plant biodiversity in natural ecosystem [14]. Despite improved agricultural technologies, such as the use of quality seed, high-yielding varieties, good agronomic practices like timely irrigation and fertilizers, but without pollination, neither fruit nor seed will be properly set.

Pollinator scarcity is the main factor responsible for inadequate pollination; this can be overcome by conserving manageable species of honey bees' populations. Promoting use of beekeeping for pollination of agricultural crops will be of benefit to both the beekeeper and the farmer. A large number of pollinators visit *Brassica* flowers [36–38] and these visits play a central role in the resulting quality and yield of seed [39].

Honeybees the most abundant pollinators might partially compensate the loss of wild pollinator which enhanced the yield quality and quantity in most crops [39]. Honeybees are included in this context whose foraging behavior is favorable to increase the crop productivity [40]. Our study clearly shows the importance of the bees as good pollinator to obtain the higher agricultural yields through an example of mustard crops. The beekeeping as pollination management practices indicates more opportunity for the adoption to increase the return and increase the crop productivity for sustainable livelihood. Studies have shown most of the fruit or seed set of many crops relies on wild pollinators [41] and management for improved pollination services like rearing honeybees is uncommon to boost agricultural productivity [42] likely contributing to yield gaps globally.

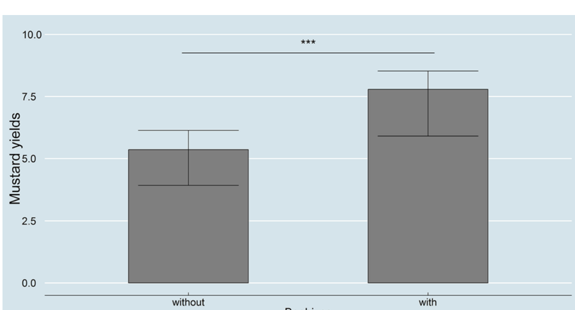

Fig. 3 Effect of the honeybee pollination on the yield of mustard crops (2011). *Note*: *bars* mean; *error bars* median plus an upper and lower quantiles at 95 % confidence intervals; *asterisks* significance <0.0001 (after Mann–Whitney test)

Conclusion

To reduce the ecological damage and loss, an understanding of the commercial and pollination needs of each country is needed to promote pollination services which help to maintain a sustainable level and reduce the risk to crop loss. We identified beekeeping as the best practices which could help many beekeepers to earn more profit due to honeybee pollination which is much more economically important than honey production [27]. Our study provides a new perspective on relationship between beekeeping and crop pollination, emphasizing that pollinator deficit can be mitigated through beekeeping which enhances the livelihoods of farmers through greater crop yields and economic benefit received by selling bee products.

Our work underlines the need for more and more research devoted to optimize powerful management practices to achieve sustainable development, helping low-income communities improve their living conditions and also contributing to the conservation of wild habitat and assuring crop pollination services. The information obtained from these research findings shows the benefit delivered by bees as good pollinators to yield quantity and quality of mustard crops, and socioeconomic condition of beekeepers' context provides an important baseline for this work.

Abbreviations

MoAC: Ministry of Agriculture and Co-operatives Department of Agriculture; FAO: Food and Agriculture Organization; IPI: International Pollinators Initiatives; CBS: Central Bureau of Statistics; DADO: District Agricultural Development Office; VDC: Village Development Committee; GPP: Global Pollination Project; Rs: rupees.

Authors' contributions

This article is part of the Master of Agricultural Economics Thesis of Kedar Devkota. KD involved in the design of the study, performed statistical analysis and interpretations of results, and wrote the manuscript. SCD and RBT also contributed to the design of the study, gave intellectual input for data interpretation, and helped to draft the manuscript. All authors read and approved the final manuscript.

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Competing interests

This was a small initiation on the pollination research in the developing countries like Nepal where we are trying to join the sustainable agriculture and livelihoods with the pollinator's importance. The authors declare that they have no competing interest.

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