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Beekeeping Livelihood Development in Nepal: Value-Added Opportunities and Professional Support Needs

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Abstract

Beekeeping contributes to poverty reduction in many developing countries, and in addition, provides pollination services for sustainable crop production. In Nepal, management practices associated with beekeeping are poorly characterized, and so the potential for this sector to further contribute to livelihood development remains unclear. This study sought to examine and identify factors associated with production efficiency and financial profitability of beekeeping with the aim of enhancing economic gains for Nepali beekeepers. Our study included a sample of 150 respondents from more than twenty commercial beekeeping districts across the Terai and mountainous regions of Nepal. Profitability of beekeeping with the European honeybee (*Apis mellifera*) Linnaeus, 1758 (Hymenoptera: Apidae) and the Asian honeybee *Apis cerana* Fabricius, 1793 (Hymenoptera: Apidae) was quantified and disaggregated according to several variables, including hive-derived products produced, marketing strategy employed, number of beehives managed, and postharvest management practices. Our results showed that the different types of management practices adopted (such as number of beehives kept, colony multiplication, supplementary feeding, month of honey harvesting, and marketing approach) significantly influenced the productivity and economic profitability of beekeeping. Our results also revealed that professional supports, such as the availability of subsidies and training, were key factors to enhance productivity. As a whole, this study provides insight into the biological factors and management practices associated with higher economic returns from beekeeping. This work can help guide policymakers and professional support agencies to expand commercial beekeeping for sustainable livelihood development in Nepal and beyond.

Key words: beekeeping, beekeeper, livelihood, income, management practice

Beekeeping is an important source of income in rural and urban areas across the globe (Formato and Smulders 2011, Mizrahi and Lensky 2013, Rollin et al. 2016, Devkota 2020). Furthermore, it is fundamental for the maintenance of pollination services within crop fields (Potts et al. 2010, Bommarco et al. 2012), and global food security (Tscharntke et al. 2012, Rollin et al. 2016). It is well recognized that beekeeping can assist in the sustainable development and resilient farmer livelihoods (Devkota et al. 2016, Devkota 2020), providing a source of commercialized bee products such as honey, pollen grains, propolis, royal jelly, and beeswax (Ismail 2016). In particular, beekeeping has been shown to promote self-reliance and novel employment generation prospects for rural and marginalized farmers in developing countries, where often beekeeping livelihoods require relatively little capital investment (Bradbear 2009, Carroll and Kinsella 2013, Deloitte 2013).

In many regions, environmental stressors associated with global change (e.g., agrochemical poisoning, land use change, climate change, disease, and parasites) and suboptimal management conditions pose important challenges to the development and long-term sustainability of beekeeping (Vanbergen et al. 2013, Henry et al. 2014, Odoux et al. 2014, Böhme et al. 2017, Jacques et al. 2017). The combined effects of these variables are considered to be responsible for observed declines in the number of beehives and total honey yield in many places in the world, e.g., 2005–2009 (FAO

2016). These declines in particular can have serious consequences for the income of beekeepers in developing countries. Furthermore, fluctuations in honey yield and price associated with the effects of global change and suboptimal management generally increase the risk and uncertainty of beekeeping as a livelihood strategy. These fluctuations and risks ultimately affect the economic inputs and outputs associated with beekeeping, which can greatly affect the profit margins of already vulnerable commercial beekeeping farmers (Shiferaw and Gebremedhin 2015).

Currently, Nepal possesses ca. 1 million beehives, which have an estimated total annual honey production of 10,000 tons (Pokhrel et al. 2014). This considerable quantity of highly productive beehives appears to be favored by the wide topographical and environmental variety of the country, as well as by the large floral diversity available to bees (Adhikari and Ranabhat 2011, Aryal et al. 2015), (Fig. 1). Moreover, even though the beekeeping sector has a small contribution (< 1%) to Agricultural Gross Domestic Product (AGDP), it has recently received relevant political encouragement. For example, it has been considered in the Agricultural Perspective Plan (APP) as a valuable agriculture activity with high potential for income generation (Pokhrel et al. 2014). Likewise, the National Planning Commission has also mentioned it in the Tenth Plan (Pokhrel et al. 2014).

Five of the world's ten species of honeybees (*Apis laboriosa* S., *Apis dorsata* F., *Apis florae* F., and *Apis cerana* F., and one exotic, but well-established and managed honeybee *Apis mellifera* L.) are distributed in Nepal from the Himalayan region in the north to the subtropical Terai region in the south. These bee species play a crucial role in the conservation of Himalayan ecosystems by pollinating wild flowers, and in some cases, are important species for ecotourism since tourists are invited to traditional local ceremonies that precede the honey harvesting (Thapa 2001). However, to be successful and profitable, local beekeeping is dependent on several key factors and considerations, including: (i) the type of the beehives used, in conjunction with the total number of hives, (ii) year-round provision of bee forage, (iii) a reduced incidence of absconding, (iv) membership to local beekeeping cooperatives, (v) training provided to beekeepers, (vi) proximity and access to market, and (vii) household wealth (Al-Ghamdi et al. 2017, Amulen et al. 2019).

In this context, there exists an urgent need to better understand the financial benefits associated with different management practices, as well as the professional support and management options available to enhance profitability, which can contribute to beekeeping livelihood development in Nepal. Our main goals were to investigate four relevant questions concerning to value-added opportunities and professional support needs of beekeepers: (1) which management practices increase the profit margin of beekeeping; (2) which socioeconomic factors (e.g., main occupation, number of hives, beekeeping experience) are associated with a high financial reliance on beekeeping—i.e., where beekeeping provides a high percentage of total income; (3) do more reliant individuals receive appropriate professional and financial support; and (4) which biological factors can be managed in order to increase the yield of honey production?

Materials and Methods

Study Area and Data Collection

The study was carried out in the primary honey-producing districts of Nepal. This includes commercial beekeeping districts identified and recognized by the Federation of Nepal Beekeepers Associations (FNBK, http://www.fnbk.org.np/), Nepal.

Sampling Procedure

A multistage sampling technique was used to select participant beekeepers. From the list of the districts identified by the FNBK, 22 districts were selected using a random stratified technique that incorporated districts from almost all agroecological zones in Nepal. This

Fig. 1. Pictures depicting some beekeeping's activities in Nepal, Asia. (A) Beehives for the distribution to the farmers through the Global Pollination Project, Nepal (GPP) (B) Beehives in the mustard crops field (*Brassica* sp.). (C) Traditional methods of keeping beehive in the home garden.

step was important to account for variability in the bee species kept across these zones, and differences in the extent of beekeeping commercialization. Altogether 150 beekeeping households were selected as respondents from the sampling frame (list of beekeepers) obtained from FNBK representing all selected districts. The respondents were met face to face to explain the purpose of the study and to conduct the survey.

Mixed methods, including questionnaire surveys, key informant interviews, and observations, were used for data collection to capture relevant information. The structured questionnaire in local language (Nepali) was prepared to gather the information aligned with the specific objectives raised in the study. The questionnaire comprised of: (a) the basic socioeconomic background: age, sex, income level, land-holding, household size, level of education, year of experience (b) beekeeping practices, (c) bee species kept: *Apis mellifera*, *Apis cerana*, or both, (d) number of beehives kept, (e) transportation costs associated with beehive migration, (f) total income derived from beekeeping: honey yield per year, beeswax sales, propolis sales, hives sales, and (g) access to extension services, markets, and any practical problems related to beekeeping. Before full implementation, the questionnaire was pretested on 25 (approx. 15% of the total respondents) beekeepers other than the sampled respondents. Feedback obtained from the pretesting was used to refine the questionnaire to obtain more relevant and accurate information. The survey was carried out over six months between August 2016 and January 2017.

Data Analysis

Variables Measured

Gross profit margin from beekeeping was defined as the percentage of revenue that exceeds the cost of goods sold, and was calculated according to the formula (Rötter and Van Keulen 1997):

$$\text{Gross margin} = (\text{Total incomeTotal variable cost}) / (\text{Total variable cost} \, * \, 100).$$

As such, the gross profit margin provides a general indicator of profitability. The level of financial dependence on beekeeping was estimated as the percentage of total income derived from the sale of all hive-derived products (e.g., honey, beeswax, and propolis, and the sale of divided hives) relative to other nonbeekeeping income.

Socio-Demographic Index

To account for the diverse socio-demographic backgrounds of survey respondents, a categorical socio-demographic index was derived and used as a random effect in models below. For this, nonmetric multidimensional scaling (NMDS) was used to ordinate a mix of continuous and categorical socio-demographic variables. These included, in ascending order of their loading weight on the first NMDS axis: sex (0.23), family size (0.43), age (0.54), and level of educational attainment (–0.90, which is comprised of five levels: no formal education, primary, secondary, higher secondary, university).

Statistical Analysis

Which Management Practices Increase the Profit Margin of Beekeeping?

To analyze which management practices increase the profit margin of beekeeping, a linear mixed model (LMM) was fitted using R packages *lme4* (Bates et al. 2015) and *lmerTest* (Kuznetsova et al. 2017). The beekeeping profit margin was specified as a response variable, while the socio-demographic index and district were ascribed as crossed random effects. Nine explanatory variables representing three different types of management practices were considered as fixed effects in the model. These included: 1—marketing strategies employed (whom honey is sold to, whether nonhoney products and beehives are additionally sold); 2—how hives are managed (number kept, whether hives are multiplied, the time of year honey is harvested), and 3—postharvest management (how long honey is stored, whether it is processed). The type of bee kept (*A. cerana*, *A. mellifera*, or both) was added in the model as a covariate, in order to generalize the results across all types of beekeeping. The variables time of honey storage, the time of honey harvesting per year, and number of hives were standardized using the function "scale" in R.

In this LMM, the F-values for the fixed effects were generated from the fitted model using the "Anova" function of package *car* (Fox and Weisberg 2011). Yet, the significance of the random effects was tested by means of a likelihood ratio chi-square test. The goodness-of-fit (GOF) of the LMM was assessed through calculation of marginal and conditional *Pseudo*-R^2 values using the package *MuMIn* (Barton 2016). Thus, both parameters try to explain how much of the variance is explained by fixed or fixed plus random effects. Therefore, while the marginal *Pseudo*-R^2 describes the proportion of variance explained by the fixed factor alone, the conditional *Pseudo*-R^2 describes the proportion of variance explained by both the fixed and random factors. Finally, LMM validation was performed first by visual and statistical evaluation of residuals for normality, and secondly by calculating variation inflation factors (VIFs) for the explanatory variables. All VIFs were ≤2.5, ensuring that multicollinearity was not of issue.

Socioeconomic Factors Associated With a High Financial Reliance and Subsidy on Beekeeping

Our second and third questions were, respectively: what socioeconomic factors are associated with a high financial reliance on beekeeping (i.e., beekeeping provides a high percentage of total income), and do highly reliant individuals receive greater professional and financial support than less reliant individuals? These questions were evaluated by fitting a generalized linear mixed model (GLMM). The model initially failed to converge when fitted using the package *lme4*, and so the function "pqlmer" of the package *r2glmm* (Jaeger et al. 2017) was used to overcome this issue by fitting a penalized quasi-likelihood GLMM. A binomial error distribution was used due the response variable "financial reliance on beekeeping" was bound between 0 and 100 % (i.e., the total beekeeping [success], income from agriculture [failure]). Before fitting the model, we removed three cases (ca. 2 % of data) in which the respondent's main occupation was "services", because income information was only available for agriculture and beekeeping activities. Additionally, the "access credit facility" and "provide credit" variables had to be removed from the model because of very unstable model estimates.

As a result, fourteen explanatory variables, grouped within four categories, were considered as fixed effects in the model. These included: 1—the background of the respondent (main occupation, number of hives kept, total property, and the purpose of beekeeping—i.e., to produce for sale, home consumption, or both); 2—the experience of the respondent (number of year of beekeeping experience, whether training was received); 3—marketing (the profit margin derived from beekeeping, to whom honey is sold); and 4—the type and accessibility of professional supports available to the respondent (source of technical information, access to technical support, membership of cooperative, number of years of membership, subsidy received). The variable "type (species) of bee kept" was added as a covariate to generalize the results across all types of beekeeping. The significance of the fixed and random effects were tested using methods described above. Model validation steps were also similarly performed.

Biological Factors Affecting the Yield of Honey

For the fourth model examining which biological factors should management target in order to increase honey yield, a LMM was fitted using the previously described steps. The average honey production (per hive per year) was used as the response variable. Eight explanatory variables, representing four general categories, were considered as fixed effects in the model. These included: 1—hive management (number of hives kept, position kept, whether hives are multiplied); 2—diet (if fed sugar supplement, month of supplement feeding); 3—harvesting (time of year honey is harvested); and 4—pest and pesticide impact (extent of pest damage in hives, extent of pesticide impact on hives). As above, the variable "type (species) of bee kept" was added as a covariate, the significance of the model fixed and random effects, as well as the model validation were performed as previously described. Statistical analyses were performed using R-software (Ihaka and Gentleman 1996, R Core Team 2018).

Results

Socio-Demographic Characteristics of Beekeepers

Overall, five of nine variables related to the types of management practices applied by beekeepers significantly influenced their profit margin (Table 1, Fig. 2A). On average, our model predicts that beekeepers adopting such activities would raise their profit margins by a total of ca. 20%. In order of importance, these variables included marketing strategies, such as whether beehives and other supplementary nonhoney products are sold (Fig. 2B,C), postharvest management, such as whether honey is processed (Fig. 2D), the time of year at which honey is harvested, and the length of time it is stored (for maturation) (Fig. 2E,F).

This model explained nearly a third of the variation in our dataset (pseudo-$R^2_{marginal}$ = 0.30; pseudo-$R^2_{conditional}$ = 0.35). Since the conditional variance slightly improved our model, it suggests that the crossed random effects (socio-demographic categories, beekeeper´s districts) possessed a subtle variation within them that can be a target of further analysis.

Financial reliance on beekeeping as a livelihood option was strongly associated with socioeconomic factors and access to professional support (Table 2, Fig. 3A). These positive and significant factors included: the background of the respondent, i.e., the number of hives kept (Fig. 3B), the type of professional support available, i.e., subsidy received (Fig. 3C), main occupation (Fig. 3D), beekeeping experience, i.e., whether training was received (Fig. 3E), and the marketing strategy employed, i.e., to whom honey is sold (Fig. 3F). Our model was well fitted since both marginal and conditional variances explained equally 92% of variation of profit (pseudo-$R^2_{marginal}$ = 0.922; pseudo-$R^2_{conditional}$ = 0.928). Furthermore, the model suggests a negligible influence of socio-demographic categories and beekeeper´s districts.

The average honey production (per hive per year) was associated with two biological factors (Table 3, Fig. 4A). These included which honeybee species (or if both) are managed (Fig. 4B) and capacity to keep a large number of hives (Fig. 4C). Thus, for example, the model predicts that beekeepers who manage the honeybee *Apis mellifera* make, an average, 17% more honey than beekeepers who do not, when all other biological factors are controlled for (held constant). If a beekeeper was to adopt all these behaviors, then they would on average raise honey yield by a total of ca. 28%. This model indicated that the random effects were properly included in the analysis since the marginal effects explained ca. 68% of variation (pseudo-$R^2_{marginal}$ = 0.68), while the addition of random effects increased the goodness-of-fit (pseudo-$R^2_{conditional}$ = 0.74).

Discussion

Based on an extensive and geographically-diverse questionnaire, our study suggests that beekeeping has the potential to be considerably improved in Nepal if key practices or factors are adopted or modified. To maximize return, beekeepers can focus on various management practices like the number of beehives kept, colony multiplication, supplementary feeding, marketing strategy, time of harvest, and source of finance for the beekeeping. Our findings build on a past study by Devkota et al. (2020) demonstrating that different management practices have significant potential to increase the income and profitability of beekeeping in Nepal.

In relation to our first question (which management practices increase the profit margin of beekeeping?), we observed that four management practices employed by beekeepers were associated with enhanced beekeeping profit. These included marketing strategy (i.e.,

Table 1. Outcomes of the linear mixed model evaluating which management practices increase the profit margin of beekeeping in Nepal

	Sum of squares	Mean squared	D.F. (numerator)	D.F. (denominator)	F-value	*P*-value
Type (species) of honeybee	287.8	143.9	2	70	1.46	0.24
Whom sold the honey	744.6	124.1	6	119	1.26	0.28
Whether multiply beehives	164.9	164.9	1	120	1.68	0.20
Extra practices product selling	580.6	580.6	1	121	5.91	**0.02** *
Practice beehive selling	559.1	559.1	1	121	5.69	**0.02** *
Honey process	473.1	473.1	1	111	4.81	**0.03** *
Time honey storage	406.6	406.6	1	117	4.14	**0.04** *
Time honey harvesting per year	802.4	802.4	1	115	8.17	**0.01** **
Number of hives	16.0	16.0	1	120	0.16	0.69
Variability of crossed random effects:						
	Variance	Standard deviation				
Socio-demographic category (*n* = 4)	0.00	0.00				
Districts (*n* = 22)	7.87	2.80				
Residual	98.04	9.90				

D.F. = degrees of freedom.
Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001.

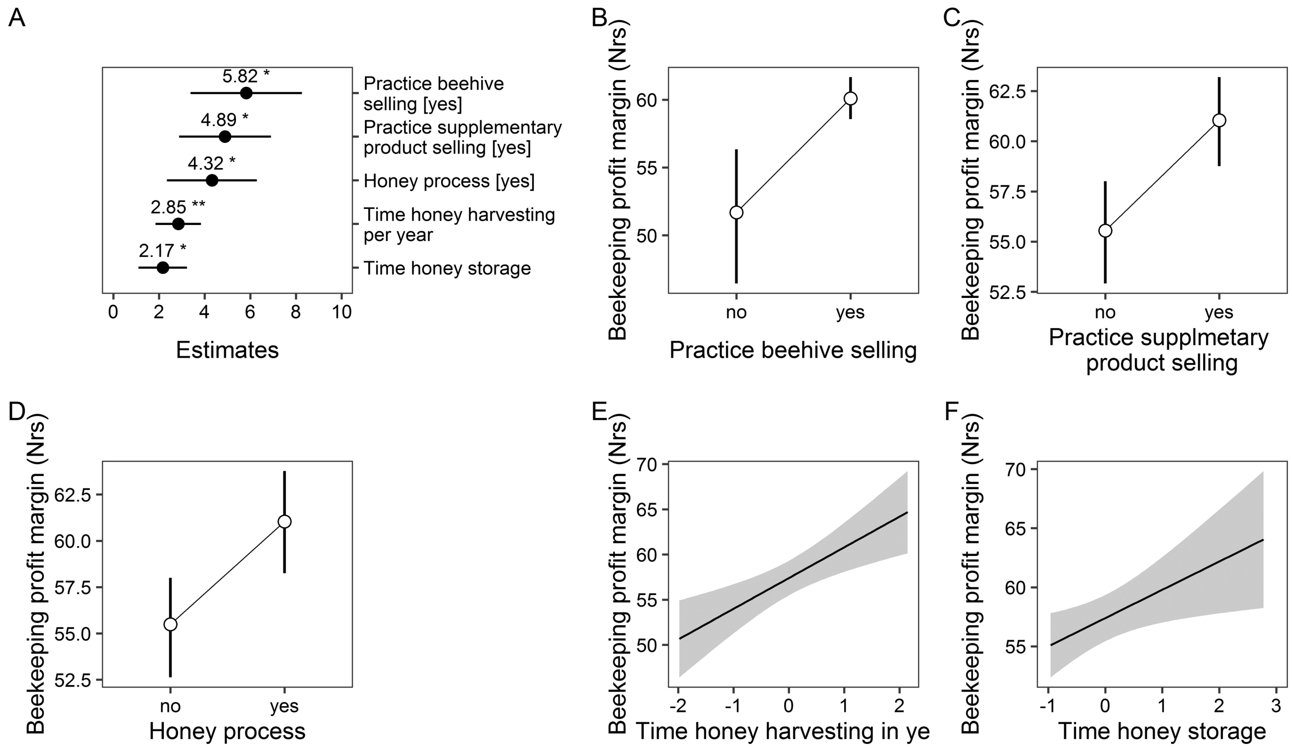

Fig. 2. (A) Estimates exhibited as forest plot showing significant fixed effects of linear mixed model evaluating which management practices increase the profit margin of beekeeping in Nepal. Estimates are sorted in descending order, from highest to lowest value. The x-axis is the percentage by which a management practice raises the profit margin. If a beekeeper was to adopt all these practices, then it would raise profit margins by a total of ca. 20% on average (altogether estimates). (B-F) Plots resulting from outcomes of the linear mixed model highlighting those variables in which the five management practices better and significantly explain the profit margin of beekeeping in Nepal, as shown in panel A. Notes: Nrs in the title of y-axis means Nepali rupees. Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001. Points indicate the average values, while the shadow and vertical and horizontal bars exhibit the confidence intervals at 95%.

Table 2. Outcomes of the generalized linear mixed model (via penalized quasi-likelihood) evaluating what socioeconomic factors are associated with a high financial reliance on beekeeping (i.e., beekeeping provides a high percentage of total income)?

	X^2	D.F.	*P*-value
Main occupation	8.09	1	**0.004** **
Total property	6.13	1	**0.013** *
Beekeeping profit margin	0.32	1	0.57
Type of bee	1.82	2	0.40
Number of hives	22.05	1	**0.000** ***
Whom sold honey	18.38	6	**0.005** **
Experience beekeeping yrs	0.51	1	0.47
Purpose beekeeping	2.42	2	0.29
Source Information beekeeping	1.03	3	0.79
Training for beekeeping	5.20	1	**0.023** *
Extension service facilities	0.02	1	0.88
Member beekeeping cooperative	0.14	1	0.71
Number of years membership cooperative	1.66	1	0.19
Subsidy beekeeping	6.96	1	**0.008** **

Variability of crossed random effects:

	Variance	Standard deviation
Socio-demographic category (*n* = 4)	0.004	0.06
Districts (*n* = 22)	0.005	0.07
Residual	0.106	0.32

D.F. = degrees of freedom.
Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001.

the sale of supplementary nonhoney products), sale of beehives, postharvest management (honey should be processed), and whether the honey was harvested during an appropriate period of the year (i.e., how hives are managed). Further, both the beekeeper district and the socio-demographic level did not have any significant conditional effect on these results. In fact, the profit from beekeeping

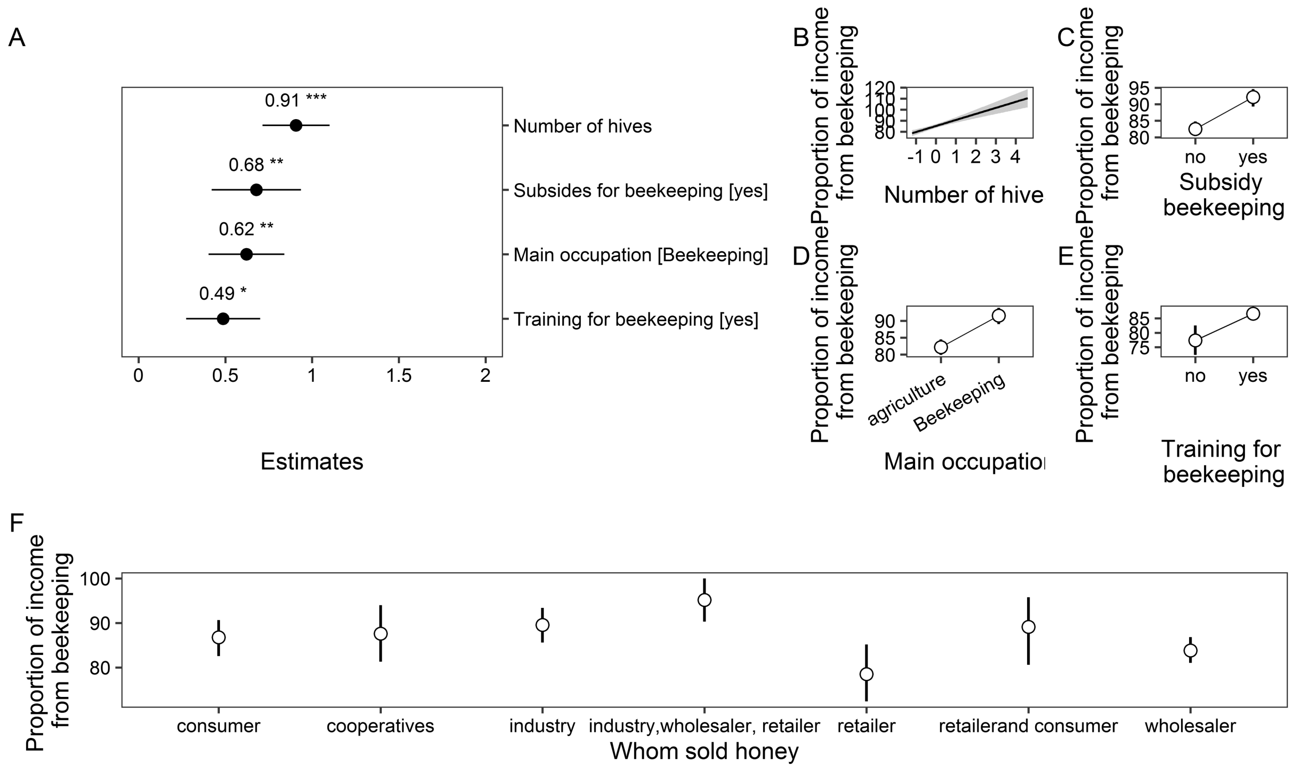

Fig. 3. (A) Estimates exhibited as forest plot showing significant fixed effects of generalized linear mixed model evaluating what socioeconomic factors are associated with a high financial reliance on beekeeping and whom are highly reliant on beekeeping receive greater professional and financial support in Nepal. Estimates are sorted in descending order, from highest to lowest value. The x-axis is the percentage by which a socioeconomic factor raises the financial reliance beekeeping. If a beekeeper was to adopt all these attitudes, then it would raise financial reliance beekeeping by a total of ca. 2.5% on average (altogether estimates). (B–F) Plots resulting from outcomes of the generalized linear mixed model highlighting those variables in which five socioeconomic factors better and significantly explain the financial reliance of beekeeping in Nepal, as shown in panel A. The estimates of the variable "Whom sold honey" are provided as follow rather than on panel A since the visualization was compromised: Whom sold honey (cooperatives) = –0.50, Whom sold honey industry) = –1.22**, Whom sold honey industry, wholesaler, retailer) = –0.56, Whom sold honey (retailer) = –0.91**, Whom sold honey (retailer, consumer) = –0.45, Whom sold honey (wholesaler) = –0.85**. Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001. Points indicate the average values, while the shadow and vertical and horizontal bars exhibit the confidence intervals at 95%.

Table 3. Outcomes of the generalized linear mixed model evaluating which socioeconomic factors and whom are highly reliant on beekeeping receive greater professional and financial support increase the financial reliance beekeeping in Nepal

	Sum of squares	Mean squared	D.F. (numerator)	D.F. (denominator)	F-value	*P*-value
Type (species) of bee	4,393.5	2,196.76	2	85.0	77.10	**0.001** ***
Number of hives	141.4	141.4	1	118.8	4.96	**0.027** *
Beehives kept	29.5	9.84	3	119.4	0.34	0.79
Fed sugar syrup	39.9	39.92	1	112.8	1.40	0.23
Months feds supplement in years	42.3	42.31	1	113.4	1.48	0.22
Time honey harvesting in year	0	0	1	116.8	0	0.99
Pest damage percent hives	0.6	0.62	1	120.3	0.02	0.88
Pesticide impact percent hives	0.8	0.75	1	112.5	0.02	0.87
Multiply beehives	74	74	1	118.0	2.59	0.10

Variability of crossed random effects:

	Variance	Standard deviation
Socio-demographic category (*n* = 4)	2.15	1.46
Districts (*n* = 22)	4.31	2.07
Residual	28.49	5.33

D.F. = degrees of freedom.
Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001.

increased with the sale of honey in different periods (offseason), the movement of honeybee hives to appropriate foraging areas, record-keeping on the various aspects of the cost and return, and market information (Karadas and Birinci 2018). To maximize income generation, beekeepers may need to adjust current management practices such as timely harvest, the number and type of hives, and postharvest

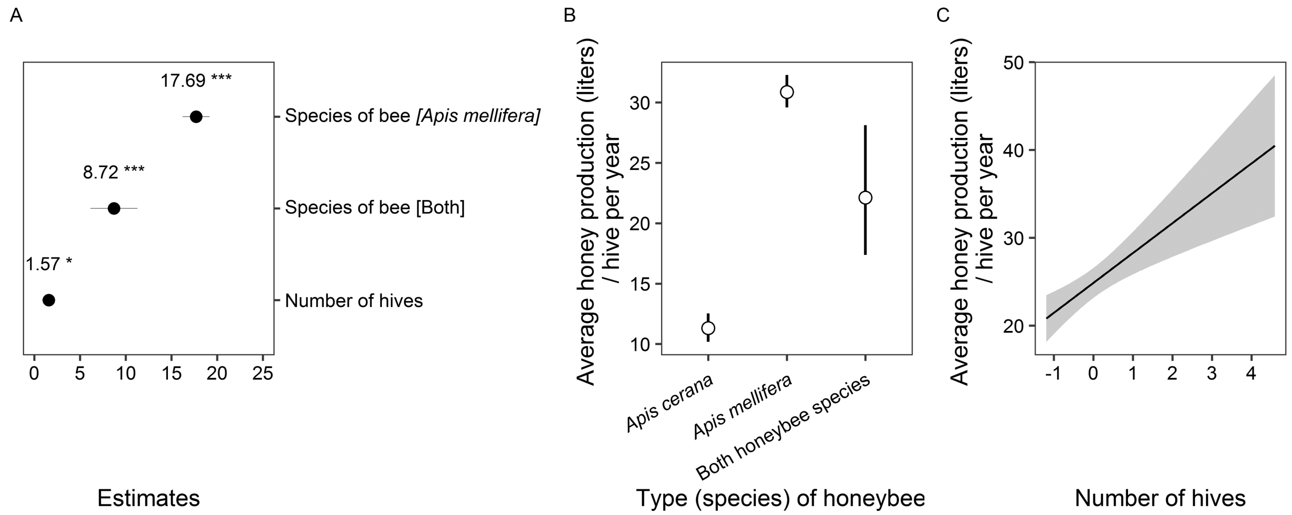

Fig. 4. (A) Estimates exhibited as forest plot showing significant fixed effects of linear mixed model evaluating what biological factors can be managed in order to increase the yield of honey in Nepal. Estimates are sorted in descending order, from highest to lowest value. The x-axis is the percentage by which a biological factor raises the yield of honey. (B–C) Plots resulting from outcomes of the linear mixed model highlighting those variables in which two biological factors better and significantly explain the yields of honey production in Nepal, as shown in panel A. Asterisks show the significance at * < 0.05, ** < 0.01, *** < 0.001. Points indicate the average values, while the shadow and vertical and horizontal bars exhibit the confidence intervals at 95%.

management (Aksoy et al. 2018, Amulen et al. 2019). The practice of colony multiplication (to generate additional sales and income) and providing supplementary feeding to bees are known to have a significant impact on colony growth and survival, and hence future multiplication potential (Jaffé et al. 2015). Our results also indicate that colony multiplication, and the sale of beehives are suitable activities to increase beekeeper income.

Analysis of the socioeconomic factors associated with a professional and larger financial reliance on beekeeping identified several important variables. For example, our findings indicate that the number of hives kept by beekeepers, their main occupation, their total property, to whom they sell honey, the type of professional support available, and beekeeping experience, all contributed to improve income derived from beekeeping in Nepal. As found here, other researchers have identified that the number of beehives kept, and the training and experience of beekeepers, significantly increases the honey production and the amount of the income generated by the beekeepers (Amulen et al. 2019, Wagner et al. 2019). Therefore, such factors can serve as key guides for beekeepers to obtain higher incomes.

As beekeeping is a dynamic activity that depends on several geographical, socioeconomic, and biological factors, its practice can differ between regions. For example, in Turkey and sub-Saharan Africa, factors such as education status of the beekeepers, price per unit of bee product, credit availability, cooperatives membership status, and the technical support facilities and services may represent significant predictors affecting the income of the local beekeepers (Amulen et al. 2017, Aksoy et al. 2018). Beekeeping is a physically demanding and time-consuming task (Bradbear 2009, Carroll and Kinsella 2013, Deloitte 2013). Since few people practice it and commonly its "culture" is transmitted between family members, it may be difficult to discourage old and inefficient practices in favor of innovative and newer technologies. As such, sufficient access to technical support, cost-saving initiatives, and the provision of adequate training in beekeeping technology have the potential to maximize beekeeper profits (Ramirez 2013). Additionally, the socio-economic conditions of beekeepers may have particular contributions to develop this sector (Amulen et al. 2017, Devkota et al. 2020). For example, experience gained via training events focused on best practices and storage of honey can greatly enhanced productivity and profit of beekeepers (Villanueva-Gutiérrez et al. 2013, Jaffe et al. 2015).

Finally, our data also demonstrate that some biological factors can also be managed to increase average honey yields per hive per year. As such, our results reveal the number of hives kept by beekeepers and which honeybee species (*A. laboriosa*, *A. dorsata*, *A. florae*, *A. cerana*, and exotic *A. mellifera*) are managed seemed to significantly contribute to average honey production within Nepali apiaries. At present, the main managed honeybee species in Nepal are *A. mellifera* and *A. cerana*. Moreover, some of the beekeepers are selling beekeeping by-products like propolis, wax, boxes, and pollen, for additional income. These practices are pertinent to Nepali beekeepers since demand for these by-products is increasing and can help to earn higher profits (Mizrahi and Lensky 2013, Jaffé et al. 2015). However, to have access to wider markets, some local limitations need to be overcome in Nepali beekeeping. For example, most of beekeepers have both limited skills and knowledge required for effectively manage their colonies against pests and pathogens, as well as a lack of protective equipment and technical skills to harvest and produce high quality by-products (Jaffé et al. 2015, Amulen et al. 2019). If Nepali farmers were sufficiently trained in such skills, it would greatly improve overall productivity, and may help beekeepers avoid the damaging impacts of pests and pathogens on colonies, as encountered in other global regions (Higes et al. 2009).

Beekeeping is increasingly recognized as an important socio-economic activity in Nepal (Pokhrel 2008) as it is a key source of income for local farmers (Formato and Smulders 2011; Mizrahi and Lensky 2013, Devkota et al. 2016, Rollin et al. 2016, Devkota 2020). Furthermore, managed bees can provide pollination services to a wide variety of agricultural crops (Hung et al. 2018). Our results can help to further enhance these prospects, and show that if specific aspects are managed, the long-term profitability and economic sustainability of beekeeping in Nepal can be secured (see also Devkota et al. 2016). Hence, although beekeeping commonly implies intensive labor (Bradbear 2009, Carroll and Kinsella 2013, Deloitte

2013), the profits may be considerably raised, which can help to offset the time and energy devoted to this activity. Increasing the profitability of beekeeping can also help secure the long-term sustainability of this sector, as enhanced profits can be expected to raise the general resilience of rural livelihoods, for example, in relation to climate change. However, additional research will be needed to inform specific policies and practices aimed towards both mitigating and adapting to the effects of climate change on the beekeeping sector in Nepal.

Our data advocate that even in face of multiple stressors and suboptimal management conditions, as previously mentioned, adequate beekeeping practices play an important role in overall productivity and economic sustainability (e.g., seasonally stable, economically profitable). Thus, widespread adoption by farmers of practices identified in our study to influence overall productivity, allied with political actions to improve access to training opportunities and equipment, have the potential to drastically improve livelihoods of Nepali beekeepers by increasing the overall weight and market value of annual honey production, and other associated bee products.

Conclusion

Our research permits insight into the biological factors and management practices adopted by beekeepers in Nepal to increase their economic returns from beekeeping. Higher economic returns were associated with specific management practices, including the maintenance of high numbers of beehives, practicing colony multiplication, supplementary feeding, novel marketing strategies, and the timing of honey harvest and storage to coincide with periods of low market availability (offseason). Similarly, the number of years of beekeeping experience, access to training, honey processing knowledge, and mode of trading had a detectible influence on profitability from beekeeping. In conclusion, this work can help guide policymakers and practitioners to expand commercial beekeeping for sustainable livelihood development in Nepal. As our data suggest, deployment of a small number of specific practices can greatly improve beekeeping across the Himalayan and Terai regions of Nepal. Our findings suggest that government subsidies for beekeepers, training, and the arrangement of the market outlets could further help sustain this sector. Thus, if beekeepers receive more technical and financial support, as well continuous access to training and secure markets, then they can find a sustainable and profitable activity to support themselves and their families.

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