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POLLINATOR-INTEGRATED AGRICULTURE: A POLICY AND EXTENSION FRAMEWORK

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ABSTRACT

Pollinators are vital ecosystem-service providers that support biodiversity, crop productivity, nutrition, and food security. In Nepal, the cultivation of pollinator-dependent crops increased by 91% over the past two decades, creating greater reliance on pollination services even as pollinator populations decline. Field studies from Chitwan and Makwanpur districts demonstrate significant yield gains through managed pollination, increasing rapeseed yields by 27–54% and buckwheat yields by 25–40%. However, climate change, habitat loss, and pesticide misuse threaten these benefits. Despite supportive national policies, a critical implementation gap persists at the local government level due to a honey-centric policy bias, limited technical capacity, and the lack of actionable metrics. Drawing on comparative household surveys (n = 240), field studies, and policy analysis, this paper addresses this "pollination paradox" through two complementary frameworks: the PEAR–IEDM–CEAL Integrated Action Framework and the Pollinator-Integrated Local Extension Framework (PILEF). Designed for municipal governance under Nepal's federal system, these frameworks integrate practical indicators, including the Pollination Dependence Index (PDI), a yield-gap metric derived from caged versus open-pollination trials, and the Pollinator-Friendly Habitat Score (P-FHS), the percentage of farm area under floral strips or hedgerows. By incorporating gender-responsive and indigenous-focused strategies, PILEF offers a scalable pathway to strengthen productivity, food security, and ecological resilience in Nepal's smallholder farming systems.

Keywords: Agricultural extension, beekeeping, ecosystem services, Nepal, policy integration, pollination

INTRODUCTION

Nepal's agrarian economy supports two-thirds of the population and contributes one-fourth to GDP, dominated by smallholder farms critically dependent on ecosystem services, particularly animal-mediated pollination. A diverse bee-pollinators community including native species (*Apis cerana* Fabricius, *Apis dorsata* Fabricius, *Apis laboriosa* Smith, *Bombus* spp.) and introduced species (*Apis mellifera* Linnaeus) sustains the production of fruits, vegetables, oilseeds, and seed crops essential for food security, nutrition, and the rural economy (Neupane et al., 2025). This reliance is accelerating; between 2001 and 2018, the cultivated area of pollinator-dependent crops expanded by 91%, a rate 3.7 times faster than for non-dependent

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crops, creating a dangerous and widening pollination deficit (Devkota et al., 2024). This vital resource is under unprecedented threat from synergistic pressures: agricultural intensification, habitat loss, pesticide misuse, and climate change.

Pollination is a keystone ecosystem service, underpinning approximately 75% of the world's leading food crops and contributing substantially to global agricultural production (Klein et al., 2007; PBES, 2016). 'Beyond yield improvement, pollination enhances crop quality attributes such as fruit size, seed viability, oil content, and nutrient density in key pollinator-dependent crops including rapeseed/mustard, buckwheat, apple, cucurbits (bitter gourd, cucumber), and citrus (Aizen et al., 2019; Poudel & Tiwari, 2025; Reilly et al., 2022). In Nepal, pollination services are foundational to the productivity of key crops, including apples, citrus, cucurbits, mustard, and buckwheat (Sharma et al., 2023). A recent national-scale assessment conservatively values insect pollination at USD 477 million annually; equivalent to 9% of total agricultural revenue (Shrestha et al., 2024). These crops are also pillars of human nutrition, with pollinator-dependent plants providing 40% of plant-derived vitamin A and 14% of vitamin C in the national diet (Chapagain et al., 2021). However, this immense economic and nutritional value is jeopardized by severe pollinator decline. Mirroring global trends driven by habitat loss, pesticide misuse, climate change, and pests (Potts et al., 2010; Sánchez-Bayo & Wyckhuys, 2019), Nepal is experiencing alarming losses. A longitudinal study in Jumla District documented a 44% decline in occupied beehives and a 50% decline in honey yield per hive over a decade (Gurung et al., 2024), signaling a critical degradation of pollinator capacity, which necessitates a robust policy and extension framework for sustainable management.

Despite clear evidence, a profound governance-implementation gap persists. 'While national policies like the Agriculture Development Strategy (2015–2035), the Bee Promotion Policy (2017), and the National Biodiversity Strategy and Action Plan (NBSAP 2014–2020) exist, they lack operational metrics, budgetary mechanisms, and localized technical guidance for Nepal's 753 local governments post-federalization. This disconnect is compounded by a foundational knowledge deficit; a survey in Jumla found only 14% of farmers were aware of the benefits bees provide to their crops (Darwin Initiative, 2024). Extension systems emphasize pest control while largely neglecting pollination services, leaving frontline workers ill-equipped to advice on pollinator ecology. This problem echoes a global pattern where agricultural innovation systems can suffer from a "flatland bias," focusing on technologies and policies suited to large, flat areas while neglecting the unique needs of complex, small-scale hillside farming systems where most pollination services are rendered.

This research directly addresses the critical gap between national policy intention and local implementation in Nepal's agricultural governance. By synthesizing field-level evidence from Chitwan and Makwanpur, conducting a policy review, and introducing the Pollinator-Integrated Local Extension Framework (PILEF), this study aims to bridge the science-policy-practice divide to suggest the science-based bee conservation and promotion strategy. The subtropical hill regions of Chitwan and Makwanpur represent a critical microcosm of these intersecting ecological and institutional challenges, providing an ideal context for developing and testing integrated solutions. Therefore, this paper addresses four primary objectives:

1. To synthesize empirical evidence on pollination benefits and threats from Nepal, with a focused analysis from Chitwan and Makwanpur districts.
2. To review and critique the existing policy and institutional landscape governing agriculture and apiculture, with specific attention to their connectivity with pollinator conservation and pollination management.
3. To propose comprehensive, evidence-based frameworks for integrating pollinator metrics into local extension and development planning, with explicit consideration for gender and social inclusion.

METHODOLOGY

This study employs a mixed-methods, multi-evidence approach to develop actionable frameworks for integrating pollinator conservation into local governance in Nepal. The methodology was structured in five integrated phases:

STUDY AREA

The study focuses on the subtropical regions of Chitwan District (inner-Terai lowland, 300–500 masl) and Makwanpur District (mid-hills, 500–1,200 masl) in central Nepal. Chitwan represents commercialized, diversified cropping systems with strong market connectivity. Makwanpur represents subsistence-oriented, mixed crop-livestock-forest systems with higher topographic complexity and reliance on forest resources. This contrast allows for a comparative analysis of pollinator dynamics across different agro-ecological and socio-institutional contexts.

DATA COLLECTION AND SYNTHESIS

Household Survey and KII: A total of 240 households (120 HH/district) engaged in farming and/or beekeeping were selected using stratified random sampling. Data were collected through structured questionnaires, field observations of pollinator activity and floral resources, and key informant interviews (KIIs) with extension officers, cooperative leaders, and municipal planners during August-December 2024.

Desk Review, Synthesis and Analysis of Secondary Data: Empirical data on pollinator diversity, crop yield dependencies, and population trends were extracted from peer-reviewed literature, university thesis (notably from Agriculture and Forestry University and Institute of Agriculture and Animal Sciences), and project reports. A core dataset was derived from the Ph.D. dissertation "Pollinators' Deficit on Rapeseed, Buckwheat and Bittergourd Production in Chitwan, Nepal" (Poudel & Tiwari, 2025; Rijal, 2019) and related studies (Pokhrel & Thapa, 2012; Rijal et al., 2018).

Policy and Institutional Analysis: National and sub-national policy documents (e.g., Bee Promotion Policy 2017, Local Government Operation Act 2017, municipal agricultural plans) were critically analyzed using content analysis to identify objectives, implementation mechanisms, and gaps.

Stakeholder Consultations: Participatory sessions were held with farmers, cooperatives, and local government officials in both districts to ground-truth findings and co-develop framework components.

STATISTICAL AND ANALYTICAL FRAMEWORK

Descriptive statistics were computed for all variables. Independent-sample t-tests were used to compare district means for continuous variables (e.g., yield, income). Chi-square tests assessed associations for categorical variables (e.g., access to training). One-way ANOVA tested for differences across multiple agro-ecosystems. Significance was evaluated at $\alpha = 0.05$. Qualitative data from policy reviews and KIIs were analyzed thematically. The Promoting Action on Research Implementation in Health Services (PARiHS) framework was adapted to structure the development of implementation frameworks, emphasizing the interplay of evidence, context, and facilitation.

RESULTS AND DISCUSSION

THE POLLINATION PARADOX: EMPIRICAL EVIDENCE FROM CHITWAN AND MAKWANPUR

The subtropical system of Chitwan and Makwanpur (300–1,200 masl) hosts a diverse farming system highly reliant on pollination services. Field studies provide robust evidence of a critical "pollination paradox" where agricultural dependence on pollinators is skyrocketing while pollinator security is plummeting.

Quantifiable yield and economic benefits: Empirical evidence demonstrates that managed pollination is a fundamental driver of crop production. Research in Chitwan quantifies substantial yield gaps and dramatic gains achievable through managed pollination (Table 1a, 1b).

Table 1a: Yield gain from open pollination for major crops in Saktikhor (Chitwan) and Silinge (Makwanpur), 2023/24

Crop	Pollination treatment	Grain yield (Saktikhor, Chitwan)	Yield gain over Control (%)	Yield (Silinge, Makawanpur)	Yield gain over Control (%)
Rapeseed	Open pollination	1044 kg/ha	27	1020 kg/ha	54
Buckwheat	Open pollination	950 kg/ha	25	860 kg/ha	40

Source: Primary field experiment data collected by the authors in Chitwan and Makwanpur districts, Nepal in 2023–2024.

Table 1b: Comparative crop yield and percentage gain under different pollination treatments in Chitwan, Nepal, 2012-2014.

Crop	Pollination treatment	Yield (kg/ha)	Yield gain vs. Control (%)	Source
Rapeseed/Mustard	Managed *Apis mellifera*	1071.0 kg/ha	57.8	Rijal (2020)
	Open pollination	1078.8 kg/ha	58.1	
Buckwheat	Managed *Apis mellifera*	99.2 g/m²	98.9	Rijal et al. (2018)
	Open pollination	88.9 g/m²	88.5	
Bitter Gourd	Managed *Apis mellifera*	1.9 kg/plant	59.6	Rijal (2020)
	Open pollination	2.0 kg/plant	61.7	

Source: Rijal, 2020.

Data in Table 1a show that the grain yield of local rapeseed increased by 27% in Saktikhor, Chitwan, and by 54% in Silinge, Makwanpur, under open pollination compared to control. Similarly, buckwheat yield gain from pollination was 25% in Saktikhor and 40% in Silinge.

Table 1b presents a compelling economic case. 'The yield gain of 57.8–58.1% in rapeseed falls within the 30–60% range reported globally for oilseeds (Klein et al., 2007; Garibaldi et al., 2016). The 88.5–98.9% increase for buckwheat reflects its extreme pollinator dependency as an obligate cross-pollinated crop (Jacquemart et al., 2007), while the high dependency for bitter gourd (59.6–61.7%) aligns with global findings for cucurbits (Martin et al., 2023). These figures translate the abstract value of ecosystem services into tangible, farm-level productivity metrics, which are essential for convincing farmers and policymakers of their importance.

On-farm agrobiodiversity as a foundation for pollinators: Farm-level crop diversification is a key structural attribute that influences habitat heterogeneity and floral resource continuity. Household surveys in both districts assessed the number of distinct crop species cultivated per holding, providing comparative insight into the farming systems (Table 2).

Table 2: Crop species richness* per farm holding in Chitwan and Makwanpur districts

District	Sample Size (n)	Mean Crop Species per Holding	Standard Deviation (SD)	Minimum	Maximum
Chitwan	120	8.6	2.1	4	14
Makwanpur	120	8.8	2.3	3	15
Overall	240	8.7	2.2	3	15

Source: Household surveys in 2023–2024.

* Crop species richness refers to the total number of distinct cultivated crop species maintained by a household within one agricultural year.

The surveys reveal a relatively high and comparable level of on-farm crop diversity in both districts, with an overall mean of 8.7 species per holding. This reflects the persistence of diversified smallholder systems typical of Nepal's subtropical hills (Altieri, 1999). The marginally higher mean in Makwanpur may be associated with greater reliance on subsistence-oriented, mixed farming compared to the more commercialized systems in parts of Chitwan. This existing agrobiodiversity is a critical asset, as diverse cropping systems provide extended flowering periods and heterogeneous resources that support pollinator abundance and yield stability (Garibaldi et al., 2016; FAO, 2019). Extension programs can build upon this strong foundation by encouraging the strategic inclusion of gap-filling forage species.

Comparative analysis of farming systems and forage context: The agro-ecological and socio-economic contexts of Chitwan and Makwanpur create distinct landscapes for pollinators and beekeeping, particularly regarding forage sources and vulnerabilities (Table 3).

Table 3: Comparative farming system and bee forage context

Parameter	Chitwan	Makwanpur	Implications for pollinators
Dominant System	Commercial mixed cropping (market-oriented).	Subsistence mixed farming with forest linkage.	Chitwan offers abundant but ephemeral floral resources; Makwanpur provides stable, native forest forage.
Key Forage Source	Mustard, maize, rice, buckwheat, litchi; Community Forests (Sal-dominated), Riparian zones.	Community Forests; Chiuri tree (*Diploknema butyracea*), buckwheat, mustard.	Makwanpur's reliance on Chiuri, a keystone forest species, makes apiculture highly vulnerable to its erratic, climate-affected flowering (Bhusal, 2022).
Forage Gap/ Risk	Severe monsoon gap (May-August); maize provides only pollen.	Moderate gap; Chiuri bridges late-season but is unreliable.	Both districts face seasonal dearth, requiring strategic planting of gap-filling forage species.

Source: Household surveys in 2023–2024.

The contrasting contexts are crucial for tailoring interventions. Makwanpur's dependence on the Chiuri tree (*Diploknema butyracea*), a keystone species now flowering unpredictably due to climate change (Bhusal, 2022), underscores a unique vulnerability and the need for forest conservation and climate-resilient forage planning. The severe monsoon forage gap common to both districts highlights a universal challenge, pointing to the necessity of targeted extension on planting summer-flowering legumes (FAO, 2018).

Analysis of beekeeping production and adoption: The distinct agro-ecological contexts also create significant differences in beekeeping production and adoption (Table 4).

Table 4: Comparative analysis of beekeeping production and adoption

Indicator	Chitwan (Mean ± SD)	Makwanpur (Mean ± SD)	t-value / χ^2	p-value
Colony density (colonies/HH)	18.4 ± 6.2	11.7 ± 4.9	5.21	< .001
Honey yield (kg/colony/year)	50.6 ± 5.4	41.3 ± 4.8	6.03	< .001
Annual beekeeping income (Rs.)	164000 ± 180	141000 ± 150	4.87	< .001
% HH receiving training	72%	46%	χ^2=12.6	< .001
% HH using modern hives	81%	54%	χ^2=14.3	< .001

Source: Household survey of beekeeping farmers in 2024–2025.

Table 4 having significantly higher colony density in Chitwan reflects stronger commercialization, better access to inputs, and larger landholdings suitable for apiary placement. This commercial gradient is common in developing countries where beekeeping transitions from a forest-based subsistence activity to a farm-based enterprise (Bradbear & Fisher, 2014). Higher yields in Chitwan are attributed to intensive cultivation of high-nectar crops like mustard and litchi, and better colony management practices. While, lower yield in Makwanpur is linked to dependence on erratic Chiuri (*Diploknema butyracea*) flowering (Bhusal, 2022) and longer seasonal forage gaps. This yield gap presents a clear target for intervention through forage cultivation and improved management. The income disparity stems from both yield and market differences. Chitwan's proximity to major markets (Bharatpur, Kathmandu) ensures better prices. Enhancing market linkages and value-added products (e.g. Chiuri, honey, butter) in Makwanpur is crucial for equity, as seen in other remote honey-producing regions (Gemeda et al., 2018). The stark difference in extension access is a critical institutional gap. Chitwan benefits from the presence of agricultural universities and NGOs. Makwanpur has lower access and limits adoption of improved practices. This echoes global findings that effective extension is a primary driver of beekeeping success (Anderson & Feder, 2007). In Nepal, NGOs such as LI-BIRD and beekeeping cooperatives play a critical role in this ecosystem by providing technical training (colony management, queen rearing, disease control), facilitating access to inputs (hives, protective gear, sugar), and linking producers to formal honey markets — functions that government extension services often cannot fulfil at adequate scale or frequency (Neupane et al., 2025). Higher adoption of modern hives (e.g. Langstroth) in Chitwan correlates with training access and commercialization goals. Makwanpur's persistence of modern hive with traditional log hives, while culturally important, limits honey extraction efficiency and colony health monitoring. A balanced approach promoting improved traditional hives may be more adoptable in hill contexts.

Habitat dependence and growing threats: Pollination services are strongly mediated by landscape structure, particularly the type and proximity of natural habitats. A study on bitter gourd in Chitwan reported a significant negative correlation between yield and distance from natural habitat, with yields declining by 20.9% at 400 meters from the habitat edge (Rijal, 2019). In this case, the natural habitat consisted primarily of Sal-dominated community forests

(*Shorea robusta*) and associated riparian vegetation corridors, which are the dominant semi-natural landscape features of the inner-Terai region. These habitats function as key pollinator reservoirs by providing nesting sites, refuge, and supplementary forage for wild bee species such as *Apis cerana*, *Apis dorsata*, and *Bombus* spp. The yield decline with increasing distance highlights the importance of maintaining forest patches close to agricultural fields, supporting the landscape moderation hypothesis (Garibaldi et al., 2020)

Table 5: Effect of distance from natural habitat on grain yield of buckwheat in Chitwan, 2013/14

Distance from natural habitat (m)	Grain yield (kg/ha)	Yield reduction over 500m (Baseline)
500	812.4	Baseline
1000	758.2	-6.7%
2000	706.9	-12.9%
3000	605.6	-25.5%
F-test (ANOVA)	P < .01	

Source. Rijal *et al* (2018).

Table 5 quantifies the landscape moderation of pollination services in buckwheat. The significant yield decline with distance (25.5% at 3000m) provides robust, local evidence for land-use planning. Similar distance-decay effects are reported globally, emphasizing that conserving natural habitat within 200-300m of farms is crucial for maintaining pollination (Ricketts et al., 2008; Garibaldi et al., 2020). However, these services are under severe threat from pesticide misuse, habitat loss, and climate change. Beekeeper surveys report 40% colony loss during extreme heat events (ICIMOD, 2022; MoALD, 2023).

Policy and implementation gaps in the local context: Despite clear evidence, a profound policy-implementation disconnect persists in governing agriculture and apiculture. An analysis of key national policies and their translation into local planning reveals systemic gaps (Table 6).

Table 6: Gaps in the national policy framework and local planning

Policy/Planning component	Status in national documents	Status in local plans	Critical gap identified
Pollination as Ecosystem Service	Mentioned (low priority)	Not explicitly mentioned	Emphasis remains solely on honey production.
Pollinator Conservation Strategies	Largely absent	Largely Absent	No targets for habitat or species protection.
Measurable Ecological Metrics	Absent (focus on hive numbers)	Absent (focus on crop output)	No mechanism to monitor pollinator health.
Dedicated Budgetary Allocation	Minor, bundled under apiculture	Minor, bundled under crop support	Insufficient resources for integrated management.

Source: Compiled from Government of Nepal agricultural, biodiversity, and climate policies (2004–2019), LAPA framework, and Kafle, 2025.

An analysis of key policies and institutions reveals a fragmented landscape with weak coordination and a production-centric focus, failing to operationalize pollination as an ecosystem service. The Nepal Bee Promotion Policy (2017) exemplifies a "Honey-only bias", treating apiculture as a commodity-based livelihood rather than a service-based agricultural input (Dicks et al., 2016; Kafle, 2025). This bias is mirrored institutionally. Post-federalization, while municipalities (Palikas) have the mandate over agriculture, they lack the technical expertise in pollination ecology, leading to poor coordination and critical "Policy voids" in areas like pesticide regulation and habitat conservation (Gautam & Basnet, 2024). Furthermore, planning is often gender-blind, overlooking the distinct roles and indigenous knowledge of women and marginalized communities like the Chepang in Makwanpur, who are primary managers of key forage species.

Table 7: Key national policies relevant to agriculture and apiculture in Nepal

Policies and Year	Main focus	Reference to apiculture / Pollinators	Relevance to Chitwan & Makwanpur
ADS (2015–2035)	Commercialization, competitiveness. indirect support for apiculture through broader strategy	Mentions beekeeping as high-value enterprise	Guides provincial & local agriculture plans
National Agriculture Policy (2004)	Promotion of beekeeping sector	Strong focus on honey production, weak on ecosystem services	Poorly operationalized at local level
National Biodiversity Strategy and Action Plan (NBSAP) 2014–2020	Biodiversity conservation	Recognizes biodiversity including pollinators, Recognizes pollinators	Limited translation into farm programs
Bee promotion policy 2017	Bee promotion and no restriction in migration and forage	Explicit policy supporting beekeeping and pollination-related activities.	Gaps between national policy intent and local-level
Climate Change Policy 2019 & LAPA Framework	Broad climate adaptation strategies in agriculture and focus on climate-resilient agriculture	No specific pollinator provisions	Implementation Influences LAPA formulation
National Forest Policy 2018	Sustainable forest management; community forestry	Indirectly supports pollinator habitat through community forest conservation provisions	Community forests in Chitwan (Sal) and Makwanpur (Chiuri habitat) are key pollinator reservoirs

Policies and Year	Main focus	Reference to apiculture / Pollinators	Relevance to Chitwan & Makwanpur
National Adaptation Plan (2021–2050)	Sectoral adaptation. long-term adaptation priorities for climate risks across sectors including agriculture	CSA prioritized; pollinators implicit	Opportunity for integration

*Authors' synthesis based on Ministry of Forests and Soil Conservation (2014), Ministry of Forests and Environment (2019), LAPA framework, and Kafle,2025.Top of FormBottom of Form

Strength and Gaps: A comparison between study sites: Chitwan shows stronger market orientation and beekeeping adoption, while Makwanpur emphasizes subsistence and has emerging cooperatives. Neither district has pollinator-focused programs in local plans. Stakeholder consultations revealed that while 83% recognize bees increase yields, however, only 21% are aware of the pollination deficit, and none of them are trained on habitat management.

Table 8: Institutional landscape and functional roles

Institution	Level	Mandate	Current Activities	Observed Gap
Ministry of Agriculture & Livestock Development (MoALD)	Federal	Policy, standards	ADS, NAP, subsidy programs	No pollinator indicators
Provincial MoLMAC	Provincial	Implementation	Input distribution, training	Apiculture marginal
District Agriculture Office previously named as Agriculture Knowledge Centers (AKC)	District	Extension	Crop & livestock advisory	No pollination advisory
Municipal Agriculture Sections	Local	Planning & service delivery	Farmer groups, subsidies	Lack technical capacity
NGOs / Cooperatives	Local	Livelihoods	Beekeeping training	Fragmented

Source: Authors' synthesis based on (MoALD, 2020; FAO, 2016, 2017; LI-BIRD, 2025; World Bank, 2012; IPBES, 2016)

Extension Worker Awareness and Capacity Building: A critical precondition for any pollinator-integrated agricultural system is the awareness and technical competency of frontline extension workers. Key informant interviews of extension officers conducted in both districts revealed that none had received formal training on pollination ecology or pollinator monitoring. While all officers were familiar with standard crop advisory services (fertilizer management, pest control, varietal recommendations), knowledge of pollination dependence, bee forage management, or bee-safe pesticide protocols was largely absent. The PILEF's Tier 2 (Extension Delivery) directly addresses this gap through the designation of "Pollinator-Smart Advisors" - trained extension officers equipped with a standardized pollinator literacy curriculum and practical field skills. The PLR (Extension Officer Pollination Literacy Rate) metric, proposed in Table 9, provides a mechanism to monitor and ensure sustained capacity building over time

PROPOSED INTEGRATED FRAMEWORKS FOR ACTION

To systematically bridge the evidence-policy-practice gap, we propose two complementary, evidence-based frameworks tailored for municipal-level action within Nepal's federal structure: i) Foundational Metrics and the PEAR–IEDM–CEAL Integrated Action Framework

The first one is simple, actionable metrics for local governments to integrate into planning and monitoring (Table 9). The PEAR–IEDM–CEAL integrated action framework adapts principles from implementation science, particularly the i-PARIHS framework, by integrating context assessment, evidence-informed intervention design, facilitation, implementation, and iterative evaluation to support the scaling of evidence-based practices (Harvey & Kitson, 2015).

1. Diagnose & define (Context): Engage stakeholders to map local "Pollination deficits."
2. Evidence & design (Evidence): Synthesize and present local research to co-design interventions.
3. Implement & adapt (Facilitation): Pilot tailored interventions "Buckwheat pollination package".
4. Review & scale (Evidence + Context): Monitor outcomes using simple metrics to refine and scale policy.

Table 9: Proposed core pollinator metrics for local agricultural extension

Metric domain	Proposed indicator*	Measurement method (Local extension)	Policy/Planning use
Outcome (Impact)	Pollination Dependence Index (PDI)	Simple field trials (caging vs. open pollination).	Measure yield gap; allocate resources to high-risk crops.
Output (Activity)	Pollinator-Friendly Habitat Score (P-FHS)	Percent farm area with floral strips/hedgerows.	Guide land-use planning; incentivize habitat conservation.
Process (Risk)	Pesticide Risk Index (PRI)	Survey on use of bee-toxic pesticides & timing.	Trigger IPM training; regulate spraying near bloom.
Knowledge/ Capacity	Extension Officer Pollination Literacy Rate (PLR)	Annual test/assessment of extension staff knowledge.	Ensure adequate training and capacity building.

* Authors' synthesis based on Giovanetti, (2021), Mirrare et al. (2021) , Klein, et al., (2006), Allebone-Webb (2024), Christmann (2021) and Pardee, et al. (2023)

(ii) The second one is Pollinator-Integrated Local Extension Framework (PILEF). The PILEF provides the concrete operational structure for extension services, guided by a five-step evidence-based practice cycle (Ask, Acquire & Appraise, Apply, Adapt, Assess) and implemented through a three-tier model (Table 10). Here, Gender and Social Inclusion (GESI) is a core design principle. The framework mandates proactive strategies such as >65% women's participation in FFS, employs female extension facilitators, and tailors programs for indigenous communities (e.g. Chepang in Makwanpur) to ensure interventions are equitable and leverage unique local knowledge.

Table 10: The pollinator-integrated local extension framework (PILEF)

Tier	Focus	Key Actions & Tools*	Proposed Metrics for Integration
Tier 1: Municipal Planning	Policy & Budget	Integrate pollinator metrics into annual agricultural plans and budgets.	Pollinator Habitat Index (PHI); Pesticide Risk Score (PRS).
Tier 2: Extension Delivery	Capacity & Advisory	Train extension workers as "Pollinator-Smart Advisors"; deploy bee-safe IPM protocols.	Extension Officer Pollination Literacy Rate (PLR).
Tier 3: Farmer Action	Awareness & Practice	Conduct Farmer Field Schools (FFS) with demonstration plots; promote forage planting.	% farmers adopting ≥2 Pollinator-Friendly Practices.

*Authors' synthesis based on LI-BIRD's Farmers Field School Manual on Pollination Management (2025) and project documentation on embedding sustainable pollination management into Nepalese agriculture (LI-BIRD).

Roadmap for pilot implementation and national scaling: A phased, learning-oriented approach is proposed, beginning in the evidence-rich districts of Chitwan and Makwanpur. These pilot sites will be designed to function as a National Learning Hub (see Table 11). Key recommendations include:

1. Shift to service subsidies: Provide forage planting subsidies for bee-friendly plants instead of only hive/sugar subsidies.
2. Establish pollination desks: Create specialized cells within Agriculture Knowledge Centers (AKCs) /ADO to track bloom times and issue bee-safe spray advisories via mobile apps.
3. Designate a national learning hub: Leverage the altitudinal gradient of Chitwan-Makwanpur as a pilot region for testing and scaling the PILEF nationally.

Table 11: Roadmap for pilot implementation and scaling for five years (2026-2030)

Phase	Timeline	Key activities*	Success indicators
Phase 1: Strategic Piloting	Years 0–2	Establish pilot "Pollinator-Smart" municipalities; train advisors; launch FFS; integrate metrics.	Municipal budget line created; 40+ staff trained; 30% farmer adoption.
Phase 2: Consolidation & Vertical Scaling	Years 2–4	Evaluate pilots; develop policy briefs; advocate for provincial integration.	15–25% yield increase documented; metrics adopted in Provincial Agricultural Plan.
Phase 3: National Mainstreaming	Years 4–6	Synthesize evidence for national dialogue; support a National Pollinator Strategy.	National Pollinator Strategy endorsed; metrics in National Agricultural Census.

*Authors' synthesis based on FAO (2018), IPBES (2016), Rogers (2003), World Bank (2012), and Nepal national agricultural policy frameworks (2061).

CONCLUSION

The widening "Pollination deficit" in Nepal represents a critical but addressable vulnerability in its agricultural system. Consolidated evidence from Chitwan and Makwanpur districts proves that integrating pollinator management is a viable and high-impact strategy for enhancing productivity (25–70%+ yield gains), nutrition, and climate resilience on smallholder farms.

The proposed Pollinator-Integrated Local Extension Framework (PILEF), supported by the PEAR–IEDM–CEAL action cycle, offers a comprehensive, scalable, and socially inclusive model to bridge the current policy-implementation gap. It moves beyond a "Honey-only" focus to position pollination as a measurable agricultural input. By equipping municipalities with actionable metrics, empowering extension workers as pollinator-smart advisors, and ensuring gender-responsive and inclusive interventions, Nepal can systematically transform pollination from an invisible "hidden input" into a managed and protected pillar of its agricultural economy. It is recommended as immediate designation of Chitwan and Makwanpur a National Learning Hub to pilot, refine, and demonstrate the PILEF. This pragmatic first step can generate the necessary evidence and political will for national scaling, positioning Nepal as a regional leader in harmonizing agricultural development with essential ecosystem stewardship.

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