Honeybee Health, Nomadism, and Pollution: A Practitioner-Driven Survey of Italian Apiculture during 2019–2024

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Abstract

Climatic variability increasingly threatens apicultural sustainability, yet practitioner-level observations remain underexploited in risk assessments. We report findings from the Honey-Volatility Questionnaire, an anonymous online survey of Italian beekeepers conducted via the 3BEE platform between 2019 and 2024. Respondents—from hobbyists and part-timers to full-time apiary entrepreneurs—provided insights on spatial–temporal apiary distribution, land tenure and use, pollutant exposures, feeding and overwintering practices, and adaptive nomadic translocations. Most participants engage in seasonal hive mobility to follow bloom phenology and recognize climatic hazards such as irregular precipitation, temperature extremes, and drought as significant challenges. Intensive agricultural landscapes and agrochemical drift emerged as primary stressors affecting colony health. By synthesizing these practitioner-sourced data, we propose the foundational components of a climatic volatility index to inform risk models and resilience frameworks. This survey underscores the value of integrating on-the-ground knowledge into strategies for safeguarding Italy's pollination services amid accelerating climate change.

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Introduction

Climatic variability and extreme weather events pose mounting threats to ecosystem services worldwide. Pollination by honeybees (*Apis mellifera*) underpins the productivity of both agricultural and wild ecosystems, supporting food security, biodiversity and rural livelihoods across the globe. In Italy—where apiculture is deeply rooted in cultural traditions and landscapes span from the Po Valley plains to Mediterranean islands, and Alps—beekeepers are increasingly confronted with climatic variability that disrupts flowering calendars, reduces forage availability and exacerbates exposure to agrochemicals and pathogens. Despite advances in climate modeling and land-use mapping, the practical experiences of those who manage hives day-to-day remain largely absent from vulnerability assessments and resilience planning. In Italy, beekeepers face an array of challenges—from irregular precipitation and temperature swings to intensified agrochemical use, habitat fragmentation and colony desease—that directly influence colony health and productivity. Despite abundant meteorological data, practitioner-level observations remain underexploited in modeling risk and designing adaptive strategies. This work presents the Honey-Volatility Questionnaire, an anonymous, online survey administered via the 3BEE platform to a broad cross-section of Italian beekeepers between 2019 and 2024. Participants ranged from hobbyists managing a handful of hives to full-time apiary entrepreneurs operating at industrial scale. The questionnaire captured spatial–temporal apiary locations, land tenure and use, perceived exposures to pollutants and climatic hazards, overwintering and feeding practices, and hive mobility ("nomadism") patterns. All data were gathered in compliance with GDPR, ensuring confidentiality and enabling candid practitioner input. Our primary objectives are to (1) translate on-the-ground beekeeping practices and perceptions into quantitative variables, (2) identify key stressors and adaptive responses across heterogeneous landscapes, and (3) lay the foundation for a Climatic Volatility Index to inform risk assessment models and resilience frameworks. By integrating detailed land-use, pollutant exposure, phenological tracking, and management-strategy data, we aim to bridge the gap between climate science and beekeepers decision-making. Survey results indicate that most respondents engage in seasonal hive translocations to follow bloom phenology, predominantly in northern regions, while recognizing erratic rainfall, late frosts and drought as major colony and forage risks. Beekeepers overwhelmingly cited intensive agriculture and pesticide drift as principal stressors, yet also reported reliance on feeding interventions and diversified land uses to buffer variability. Spatial analyses revealed a mix of stationary and migratory operations across plains, hills and mountain zones; demographic profiling highlighted a core of mid-career practitioners supported by both newcomers and veteran operators. Additional findings cover honey production trends, increasing colony mortality factors, and limited uptake of paid pollination services, underscoring multifactorial pressures on Italian apiculture. By synthesizing these practitioner-sourced insights, this survey not only enriches our understanding of beekeeping under accelerating climate change but also provides actionable data to policymakers, extension services and industry stakeholders. Emphasizing the value of stakeholder engagement, our work demonstrates how translating beekeeper knowledge into robust environmental indices can drive targeted mitigation, support sustainable management and ultimately safeguard vital pollination services in a changing world. By foregrounding practitioner knowledge, this study not only documents the lived realities of Italian beekeepers but also provides a rich empirical foundation for policymakers, extension services and industry stakeholders. Integrating these survey-derived data into resilience frameworks will be critical for developing targeted interventions, enhancing landscape diversification, reducing agrochemical risks and ultimately safeguarding pollination services in the face of accelerating environmental uncertainty. The remainder of the paper is structured as follows. In Section 1 we describe in detail the survey methodology and our study objectives. Section 2 reports the general characteristics of the beekeeper sample, while Section 3 examines the geographic and topographic distribution of apiaries and delves into nomadic management practices. In Section 4 we analyze farm ownership status, land tenure and certification schemes. Sections 5 and 6 are devoted to assessing exposure to environmental pollutants and the role of protected areas in foraging landscapes, respectively. We then turn, in Section 7, to the impacts of surrounding land-use on colony health. Section 9 investigates recent trends in colony mortality and its primary drivers, and Section 10 evaluates the deployment of hives for commercial pollination services. Finally, Section 10 summarizes our key findings, discusses policy implications and outlines directions for future research.

1 Methodology and Objectives

The survey was conducted anonymously using the 3BEE digital platform, in a sample of 129 professional and hobbyist beekeepers across all regions of Italy. Among these 129 beekeepers only 3 rejected to reply to the survey. So that, we left with a sample of 126 beekeepers. No personal identifiers were collected, and all responses were encrypted in transit and at rest, ensuring complete participant privacy. Participation is voluntary and anonymous; all data will be processed in compliance with the General Data Protection Regulation (GDPR), the European Union's legal framework for data privacy and protection. This online questionnaire, distributed via national apicultural associations and digital platforms, is structured to capture a holistic picture of beekeeping operations from 2019 to 2024. The survey begins by recording participants' consent, age, professional status, and years of experience. It then prompts detailed localization of apiaries, asking for municipalities and the corresponding annual intervals (in relation to the localizations in order to understand the periods of time during which the apiaries were located there), while also documenting land property rights—own versus rented land—and its extent within a 1.5 km foraging radius. This questionnaire is meticulously designed to capture how Italian beekeepers are adapting their management strategies in response to accelerating climate change, with the aim of transforming practitioner knowledge into actionable data for vulnerability assessment and resilience planning. By weaving these practitioner-sourced data threads into a unified dataset, the study provides the empirical foundation for constructing an environmental index of climatic volatility, which represents one of the core objectives of this research. The spatial–temporal mapping enables direct linkage between colony outcomes and local climate anomalies—such as heatwaves, late frosts, or extreme precipitation—documented by meteorological records. The questionnaire also quantifies proximity to protected areas, land-cover proportions (e.g., monocultures, agroecological practices, forests, urban interfaces), and the beekeeper's assessment of land-use effects on apiary health and honey yields, while specifying whether hives are placed on owned or rented land and characterizing prevailing agricultural practices within the 1.5 km foraging radius. Through detailed land-use inquiries, participants specify whether hives occupy owned or rented land, the prevailing crop types, and the dominant agricultural practices (e.g., conventional monoculture, organic, regenerative agroecology) within the 1.5 km foraging radius. These insights reveal how shifting agricultural landscapes under climate stress influence forage availability and ecosystem interactions. In subsequent sections, respondents describe perceived exposures to chemical pollutants and climatic risks, specifying sources and main hazards impacting both colonies and forage resources. Annual honey production figures and product types (e.g., monofloral varieties) are recorded alongside feeding and overwintering practices, including sugar supplementation rates and trends in usage from 2019 to 2024. Beekeepers then report perceived environmental stressors, quantifying exposures to agrochemicals (pesticides, fertilisers), industrial pollutants, and climatic hazards. They also describe the proximity and percentage coverage of protected or conservation zones, enabling evaluation of natural buffer mitigation against extreme events and pollutant influx. Production metrics are linked to climate dynamics by collecting average annual honey yields, breakdowns of monofloral varieties, and exhaustive records of winter feeding: type and kilograms of sugar supplementation, application methods, and year-to-year trends since 2019. These data elucidate how nutritional interventions are modulated to offset seasonal forage deficits induced by climatic variability. The nomadism module investigates adaptive mobility: participants detail the number of translocations per season, distances traveled, and rank their motivations—whether to follow shifting bloom phenology, evade adverse weather, or access premium floral resources. This reveals strategic transhumance as a frontline climate adaptation strategy within Italian apiculture. By weaving these practitioner-sourced data threads into a unified dataset, the questionnaire delivers the empirical foundation for constructing an environmental index of climatic volatility. This index will underpin robust risk assessment models and guide targeted mitigation strategies, ultimately strengthening the resilience of Italy's beekeeping sector and safeguarding vital pollination services in an era of rapid climate change.

2 General Survey Results

In our survey of 126 participants, 85.7% reported active involvement in the apiculture sector, confirming that the questionnaire successfully reached individuals with direct beekeeping experience[1]. Among these practitioners, 70.6% describe themselves as *apiary entrepreneurs*, managing hives or honey-related enterprises on a commercial basis. Finally, 61.1% classify beekeeping as their primary profession, whereas the remaining 38.9% engage in apiculture on a part-time or hobbyist level. As shown in Figure 1, most respondents report between 5 and 15 years of experience, with a peak around 10 years. A smaller group of highly veteran practitioners—some with over 80 years in the sector—raises the average above the median. This distribution highlights the coexistence of relatively new entrants and long-standing operators within Italian apiculture.

[1] We specify that the questionnaire also asked respondents to indicate the years of activity of their beekeeping enterprise, in order to understand how long they have been operating.

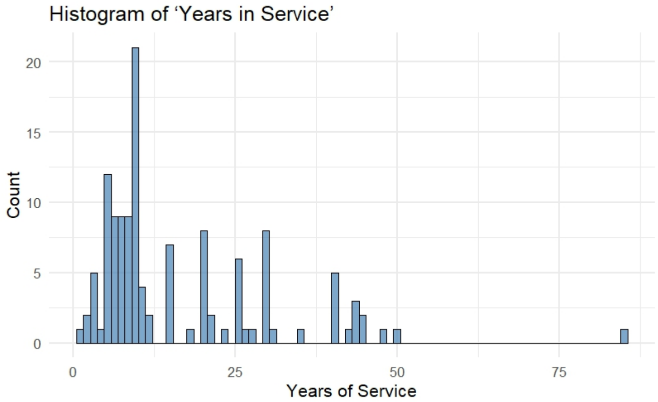

Figure 1: Distribution of years of beekeeping experience (N = 126).

With respect to operation size, most beekeepers manage only a few apiaries and a limited number of hives, while a minority operate at much larger scales. The median respondent manages fewer than five apiaries and around twenty hives, but industrial operators in the sample reach several hundred apiaries and over one thousand hives. These right-skewed distributions confirm a strong polarization between small-scale hobbyists and commercial enterprises (Figures 2 and 3).

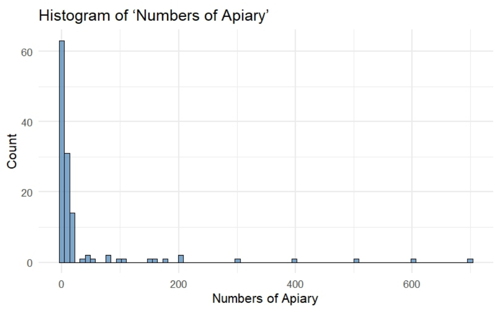

Figure 2: Number of Apiaries per Respondent

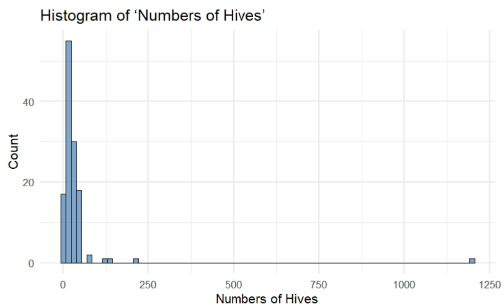

Figure 3: Number of Hives per Respondent

Spatial dispersion is also heterogeneous. While many respondents concentrate their apiaries within a few kilometers, others report distances of several dozen or even hundreds of kilometers between sites. This variability reflects different strategies for managing forage availability, climate risks, and logistical constraints. As illustrated in Figure 4, the majority of respondents keep their apiaries on agricultural land, either their own (68.3%) or that of others (69.8%). Forested environments play a secondary role (23%), while other locations—such as gardens or state-managed land—are used only marginally. These findings emphasize the predominance of rural agricultural contexts, with some diversification into natural and semi-natural areas.

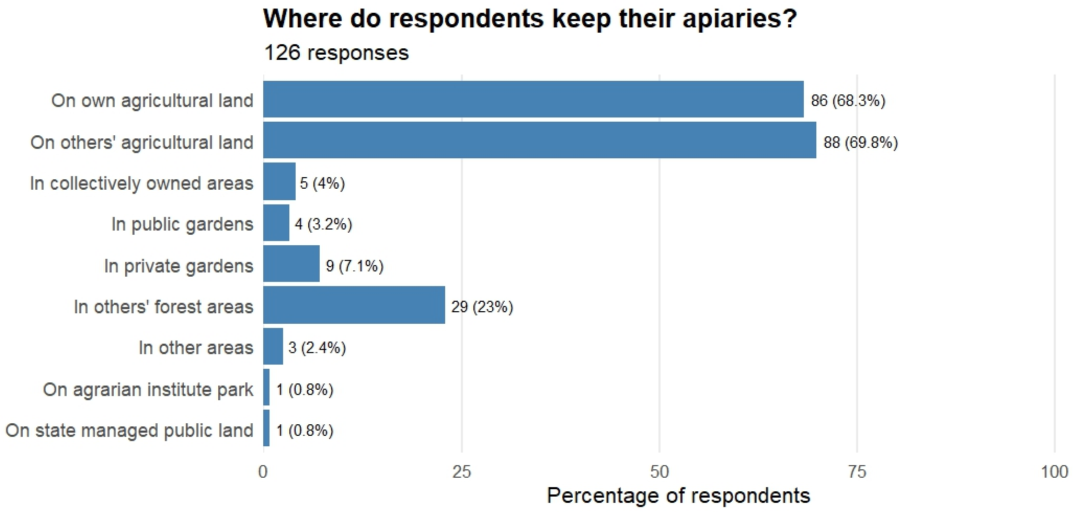

Figure 4: Distribution of locations where respondents keep their apiaries (N = 126).

3 Geographic and Topographic Distribution of Apiaries

A majority of respondents (63.5%) report that their apiaries are not all located within the same area, indicating a strategy of spatial diversification to mitigate local risks such as disease outbreaks resource scarcity or whether volatility. Conversely, 36.5% of beekeepers keep all of their sites clustered in a single area, which may reflect logistical convenience, site condition or localized forage availability. The predominance of diversification in the colonies locations suggests that many beekeepers employ translocation or transhumance as part of their management practices to increase production season or to reduce risk of losses, likely in response to temporal variations in bloom phenology, weather conditions, and resource distribution. The sample includes Apiaries widespread in all the different county's regions, specifically in Northern Italy are predominantly sited in the Po Valley plains—especially in the provinces of Pavia, Milano, Bergamo, Verona and Como—where stationary operations exploit intensive forage from oilseed rape, sunflower and corn. Many of these beekeepers practice seasonal transhumance into the Pre-Alps and Alpine foothills (e.g., Valtellina, Sondrio, Val d'Ossola) during summer months to harvest chestnut, linden and high-elevation nectar sources such as beech and rhododendron. In addition, rolling hill areas in the Langhe, Monferrato and Collio regions provide valuable acacia and chestnut flows on mixed woodland–vineyard terrain. In Central Italy, apiaries cluster on the Tuscany–Umbria valley floors around Arezzo, Siena, Grosseto and Perugia, where acacia, polyfloral and wildflower honeys are produced. From these plains, beekeepers move into the Apennine hills (Casentino, Marche uplands, Sabina hills), rotating between valley-bottom acacia blooms and mid-slope chestnut and heather sources. A smaller but notable share of beekeepers locates hives above 1000m in the Sibillini and Gran Sasso regions to tap summer peaks of rhododendron, gentian and alpine wildflowers. Southern Italy samples include stationary apiaries in the Calabria lowlands. Many of these same beekeepers undertake seasonal transfers into the Calabrian and Lucanian Apennines (Sila, Pollino) and Sicilian highlands (Etna, Nebrodi) to capture midsummer blooms of thyme, oregano and chestnut. Hill-zone sites in Campania and Basilicata balance agricultural valleys with woodland edge forage, while fully stationary mountain placements remain rare due to harsher overwintering conditions. Overall, plain-based apiaries represent the largest share of sites, hill terrain accounts for a substantial complement, and mountain placements are chiefly itinerant—reflecting a strategic alignment of colony movements with regional phenology and climatic variability. The spatial distribution depicted in Figure 5 reveals a clear concentration of apiary sites in the northern regions—particularly along the Alpine foothills and across the Po Valley—while central and southern areas exhibit a sparser yet still significant presence. The islands of Sardinia and Sicily also host numerous apiaries, often clustered near their coastal plains. This pattern suggests that beekeepers preferentially locate their hives in zones combining favorable climatic conditions and diverse floristic resources, while more arid or mountainous territories see fewer installations.

Figure 5: Geolocated apiaries in Italy over a high-resolution satellite basemap (Esri World Imagery).

The land in which respondents keep their apiaries exhibits a strong concentration on very small surfaces, with a tail extending towards higher values. The overall distribution ranges from a minimum of 0 ha to a maximum of 40 ha, with an average area of approximately 4.85 ha—an average inflated by a few very large values—and a median of 1 ha. The mode is 1 ha, reported by 26 out of 52 respondents (50%), followed by modes at 2 ha and 10 ha, each cited by 5 respondents (about 9.6%), and then 3 ha (4 respondents, about 7.7%) and 5 ha (2 respondents, about 3.8%). A small number of beekeepers report areas between 8 and 40 ha (one response each for 8, 9, 11, 16, 20, 30, and 40 ha). These higher values push the mean upward but remain rare: only 7 responses exceed 10 ha. The majority of beekeepers (over 75%) manage their apiaries on areas of at least 1 ha and at most 3 ha. Only a few operators own surfaces larger than 10 ha, highlighting that, in our survey, beekeeping is predominantly practiced on a small scale. This finding underscores the importance of tailoring any interventions or incentives to the needs of small-scale beekeepers.

3.1 Nomadism

Nomadism, defined here as the practice of moving hives between different locations, is adopted by 56.3% of respondents, while 43.7% remain stationary. This majority engagement in hive relocation suggests that more than half of the beekeepers actively follow seasonal blooms or avoid unfavorable conditions by transporting their apiaries in different sites. At the same time, the substantial proportion of stationary beekeepers indicates that both sedentary and migratory approaches coexist, likely reflecting differences in farm size, land access, and production goals across beekeepers. As shown in Figure 6, the majority of transhumance of bee colonies occur in northern Italy (85.4%). This reflects the highly staggered sequence of floral resources in the Alpine and Po Valley regions, which enables beekeepers to follow nectar flows across different altitudes and valleys. In contrast, southern Italy accounts for just 7.0% of nomadism, while central Italy contributes only 4.2% and the islands a mere 3.3%. The much lower percentages outside the North likely stem from favorable Mediterranean climate and the logistical challenges of botanical conditions.

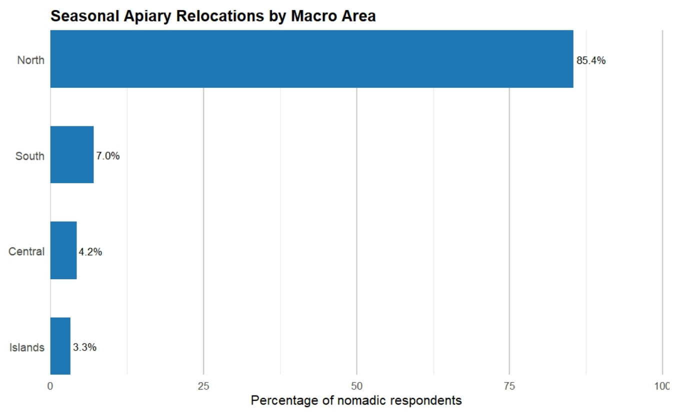

Figure 6: Percentage distribution of nomadic apiary relocations across macro-areas (North, South, Central, Islands).

The summer season sees the vast majority of respondents relocating multiple apiaries: most report moving between three and ten hives on average, over one-way distances that typically range from 40km up to 150km (and in some cases even beyond 500km for long-distance transhumance). By contrast, winter movements are extremely rare—over 80% of beekeepers do not move any hives at all during the winter season. Those who do tend to bring back only a handful of colonies (one to three hives) over very short distances (often under 20km), simply reconsolidating summer sites rather than following new forage flows. This stark contrast highlights that hive translocation is almost exclusively a summer activity tied to sequential floral availability, whereas winter management is largely stationary. As illustrated in Figure 7, the principal driver of hive transhumance is *extending the productive season by following bloom sequences*, cited by 39.1% of respondents. The second most common motivation, of respondent 21.7%, is *producing specialty honey* (e.g. rhododendron, chestnut, linden, alfalfa). Both *overwintering* and *avoiding unfavorable weather* each account for 13.0% of mentions, underscoring concerns for colony health and climatic risk management. *Pollination services* represent 8.7%, reflecting contracted agricultural work, while *preventing overgrazing* is the least frequent reason at 4.3%. Overall, these results confirm that phenological optimization is the core rationale for nomadism, with honey quality, colony welfare, and environmental risk serving as supporting factors.

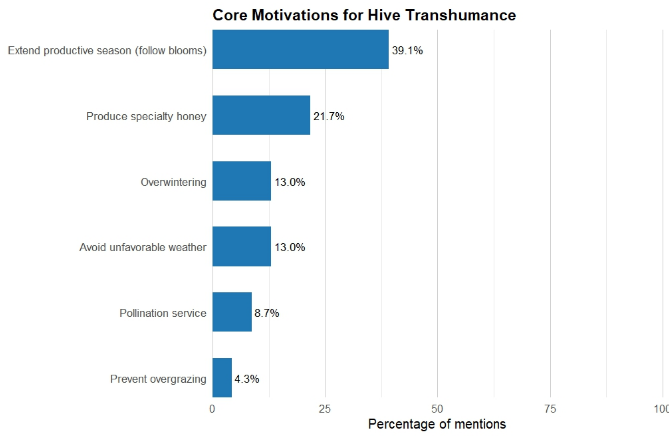

Figure 7: Percentage distribution of the primary motivations among nomadic beekeepers.

After excluding respondents who do not move their hives for winter, we see a clear preference for hill-side locations: over half of nomadic beekeepers ($\simeq$ 52%) move their colonies to hills during the colder months. Roughly one-fifth split between the plain ($\simeq$ 22%) and mountain ($\simeq$ 20%), reflecting strategies either to avoid deep frost or to anticipate brood breaks at altitude. Only a small fraction ($\simeq$ 6%) choose coastal or littoral sites. This pattern suggests that beekeepers favor moderate hill-top or lower-mountain climates for wintering, balancing milder temperatures with adequate forage reserves. The descriptive evidence presented in this study suggests that the choice of overwintering sites is primarily shaped by geographic and climatic context rather than by individual beekeeper characteristics. Hive relocations are overwhelmingly concentrated in Northern Italy (85.4%), where pronounced altitudinal gradients between plains, hills and Alpine foothills allow beekeepers to optimize microclimatic conditions. In this setting, the preference for hill areas during winter (52%) reflects a strategic search for moderate thermal regimes that reduce frost exposure while avoiding the harsher conditions typical of high mountain zones. By contrast, southern and insular regions—characterized by more homogeneous Mediterranean climates—exhibit markedly lower levels of seasonal relocation overall, suggesting that overwintering choices are less constrained by extreme cold and therefore less dependent on altitudinal shifts. The coexistence of stationary and migratory models (43.7% versus 56.3%) further indicates that overwintering strategies are embedded in broader operational logics tied to regional phenology and landscape structure. No clear evidence emerges linking winter site selection to farm size, total land surface, or number of hives managed. Given the strongly right-skewed distribution of apiary and hive numbers, with a majority of small-scale operators and a minority of very large enterprises, overwintering preferences appear relatively consistent across scale categories. Likewise, while the survey records demographic variables such as years of experience, the aggregate results do not indicate systematic differentiation in wintering choices along age or professional-status lines. Overall, the data point to geography and landscape configuration—rather than beekeeper socio-demographic profile—as the dominant determinants of overwintering site selection within the sampled Italian apicultural system.

4 Farm Ownership

Among the 126 respondents, 57.1% reported that are farmers, while 42.9% do not. This majority indicates that over half of the beekeepers manage their hives as part of a farming activity, suggesting integrated crop-pollination or honey production activities. The remaining respondents are just beekeepers with ant engagement in farm business independently of any formal farm, reflecting a significant cohort of hobbyists or specialized apiarists. We computed descriptive statistics on the responses as shown in Table 1. The distribution is heavily right-skewed: half of respondents cultivate 3 ha or less, and 75 % manage at most 8 ha, but a few very large holdings (up to 20000 ha) inflate the mean to 345 ha and produce a high standard deviation. This suggests that while most beekeepers work on small plots, a minority operate on intensive large farms. Figure 8 reveals that the overwhelming majority of apiary operators (72.9%) manage their hives under *Conventional* farming systems. *Organic* farms constitute the next largest group (22.9%), reflecting a substantial minority committed to certified organic standards. The remaining categories—*Organic&Regenerative*, *In Conversion*, and *Mixed (Organic&Conventional)*—each account for only 1.4% of respondents.

	Value
Minimum	1 ha
1st Quartile	2 ha
Median	3 ha
Mean	345.6 ha
3rd Quartile	8 ha
Maximum	20000 ha
Standard Deviation	2481.96 ha

Table 1: Descriptive statistics of agricultural land size.

Respondents cultivate a rich mosaic of land uses that can be broadly grouped into

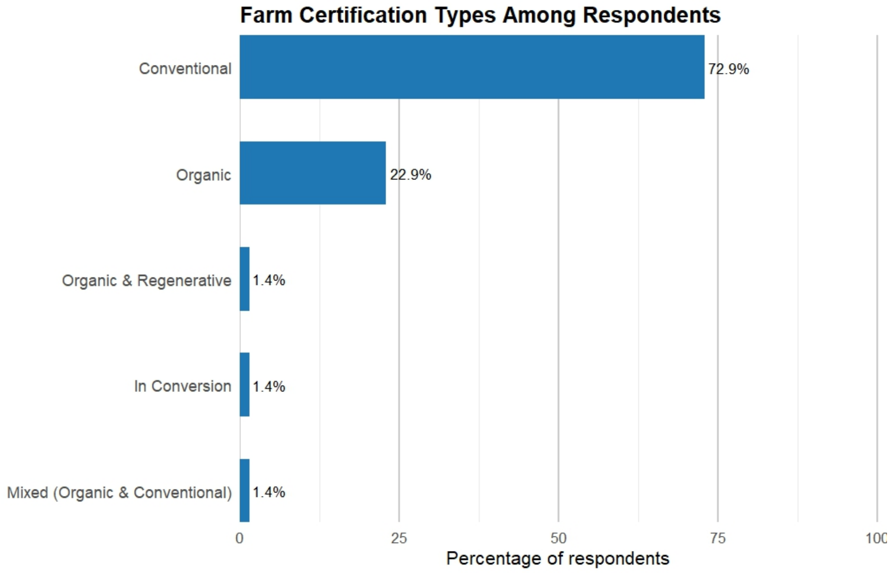

Figure 8: Distribution of farm certification categories among survey respondents (N = 126).

five interwoven categories. First, *tree crops* such as olives, vines and various fruit orchards (including cherries, pomegranates, citrus and chestnuts) form the backbone of many properties, often interplanted with medicago or grass understoreys. Second, *arab crops*—notably cereals (wheat, barley, maize, rice), legumes and dedicated forage mixtures—provide large-scale nectar and pollen sources. Third, specialized *horticultural areas* appear on horticulture and floriculture parcels for vegetables, berries (strawberries, blueberries) and ornamental or aromatic herbs. Fourth, *permanent grasslands and pastures* (flower-rich meadows, grazing pastures) supply seasonal flowering plants and overwinter forage. Finally, many beekeepers maintain adjacent or scattered *woodland and semi-natural zones*—managed forest stands, wildflower margins or fallow scrub—that supplement floral diversity. In practice, most apiaries integrate several of these crop types—such as olive groves with wildflower strips, vineyards next to chestnut stands, or meadow strips bordering vegetable plots—thereby ensuring a continuous and varied forage calendar for honey bees. Figure 9 shows that *Livestock* (including beekeeping) is the most common specialization at 23.4% of valid responses, reflecting the strong role of animal husbandry and apiary management in this cohort. *Cereals* (arable lands) follow at 18.8%, indicating substantial arable cropping activity. *Pasture* operations account for 17.2%, underscoring the importance of forage and grazing systems. *Orchards* (fruit production) represent 15.6% of specializations, while *Vineyards* and *Monoculture* farms each comprise 12.5%. Together, these results highlight the predominance of mixed livestock–crop systems in the sample, with significant engagement in both arable crops and perennial fruit or vine enterprises. The evidence presented in this study indicates that land-use patterns display a clear stratification across geographic areas and operational profiles. In Northern Italy, where nomadic practices are markedly concentrated (85.4% of relocations), apiaries are predominantly embedded in intensive agricultural plains (oilseed rape, sunflower, maize), combined with seasonal movements toward hill and pre-Alpine woodland systems. This configuration reflects a dual land-use structure: intensive monocultures in lowland areas and mixed forest–farm mosaics in upland environments. In Central and Southern regions, where nomadism is far less prevalent, apiaries tend to remain more stationary within Mediterranean agro-ecosystems characterized by tree crops (olive groves, citrus, vineyards), semi-natural pastures, and mixed woodland edges. The more homogeneous climatic regime in these areas appears to reduce the need for altitudinal redistribution, resulting in a comparatively stable land-use embedding. Across the full sample, conventional and monocultural systems dominate (88.9% and 77.8%, respectively), but these coexist with an almost ubiquitous presence of mixed forest–farm mosaics (93.7%). This suggests that even within intensive agricultural matrices, semi-natural buffers remain structurally integrated into apiary landscapes. Importantly, this mosaic structure does not appear to be confined to specific farm-size categories. Given the strongly right-skewed distribution of land surface and hive numbers—where the majority of respondents manage small areas (median 1–3 ha) and relatively limited hive counts—land-use composition appears broadly consistent across dimensional classes. Similarly, no marked differentiation emerges between "pure beekeepers" and farmer–beekeepers in terms of dominant surrounding land-use types. While 57.1% of respondents operate agricultural enterprises and 42.9% do not, both groups report high exposure to conventional and monocultural systems as well as proximity to forested or semi-natural zones. This suggests that landscape context is largely determined by regional agricultural structure rather than by individual production status. Finally, nomadic operators—who represent 56.3% of the sample—are structurally more exposed to multiple land-use categories due to seasonal mobility, effectively integrating plains, hills and mountain ecotones within a single production cycle. Stationary operators, by contrast, exhibit a more localized land-use embedding but still operate predominantly within diversified rural mosaics rather than exclusively within single-use landscapes. Overall, the results indicate that land-use stratification in Italian apiculture is primarily shaped by geographic macro-area and climatic gradients, while farm size, production status (farmer versus specialized beekeeper), and dimensional class of occupied area do not generate strong structural segmentation in reported land-use contexts.

5 Exposure to Potentially Hazardous Pollutants

A substantial minority of beekeepers (39.7%) report that they believe their colonies are exposed to potentially harmful environmental pollutants, whereas 60.3% do not perceive such risk. This split highlights that while many apiaries are situated in relatively clean or well-managed environments, a significant portion operates under threat from pesticide drift, industrial emissions or other pollutant sources. Understanding and mitigating these exposures remains a priority for nearly two-fifths of practitioners. Figure 10 shows that *Pesticides* are by far the most commonly cited threat, accounting for 61.1% of all

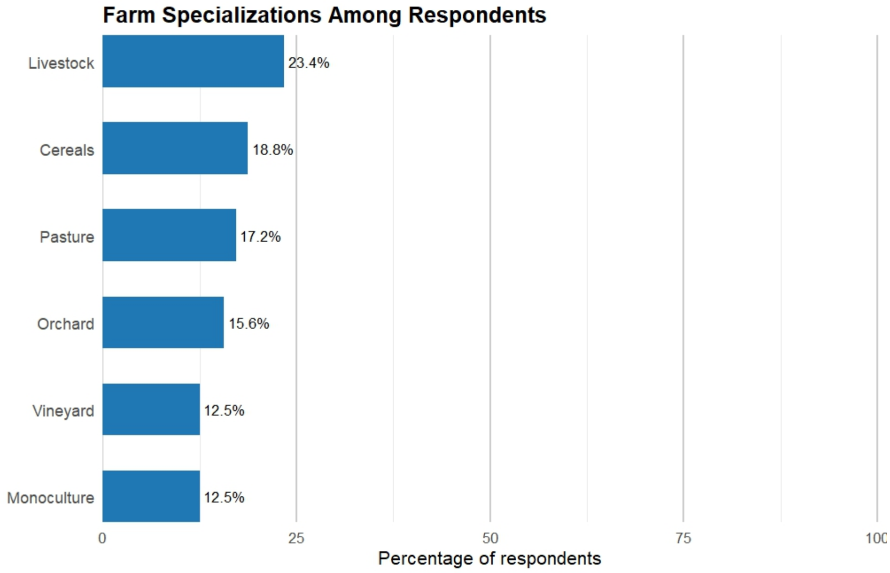

Figure 9: Distribution of primary farm specializations among respondents mentions).

mentions. *General environmental pollution* follows at 25.0%, reflecting concerns over industrial and urban contaminants. *Electromagnetic interference* is noted by 11.1% of respondents, while *light pollution* is comparatively rare (2.8%). These results highlight the dominant role of agrochemical exposure in perceived colony risk, with secondary attention to broader pollution and technological emissions.

According to the data, a clear majority of respondents—77%—believe their colonies face climate-related risks, while 23% do not. This indicates widespread concern over factors such as unseasonal temperature swings, drought, heavy rainfall or late frosts. Given the central role of weather in nectar flow, brood development and overwinter survival, most beekeepers recognize climatic variability as a critical challenge for apiary management. The current analysis does not provide cross-tabulated evidence linking pollution concern (39.7% of respondents) to specific beekeeper profiles such as age, years of experience, number of hives, farm size, or production status (farmer vs. pure beekeeper). The results are reported only in aggregate form. Similarly, while conventional agricultural contexts (88.9%) and monoculture exposure (77.8%) are highly prevalent in the overall sample, the data do not allow us to determine whether those expressing greater concern about pollution are disproportionately located in conventional landscapes, belong to particular size classes, or differ systematically by demographic characteristics. Therefore, based strictly on the reported results, no statistically supported stratification of pollution concern by structural, geographic, or socio-demographic variables can be inferred.

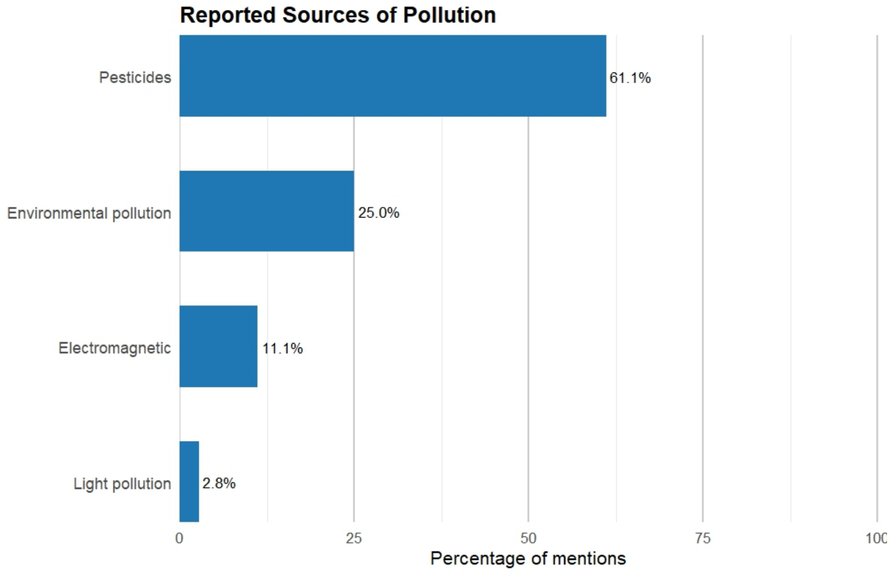

Figure 10: Distribution of reported pollution sources affecting apiaries.

5.1 Comparison of Primary Climatic Risk Factors

Figure 11 illustrates that *heavy rain* and *late frost* are the most frequently cited threats to both colonies and forage resources, appearing in roughly 18–24% of mentions across contexts. *Seasonal shifts* (e.g. unpredictable bloom timing) are emphasized equally for direct colony health (20.8%) and resource availability (19.1%), underscoring concerns over mismatches between bee activity and floral phenology. *Drought* poses a slightly greater direct risk (22.2%) than resource risk (17.6%), reflecting colony stress under water scarcity. *Heat* and *wind* feature less prominently but remain relevant: heat is noted by 11.1% (direct) versus 8.8% (resource), and wind by 8.3% versus 10.3%. Overall, while all risk factors affect both colonies and their forage sources, the relative weighting shifts subtly—heavy rain and late frost loom largest for resources, whereas drought and seasonal timing shifts carry marginally greater direct colony impact.

6 Presence of Protected Areas

One-third of respondents (33.3%) report that their foraging areas include recognized protected areas, while two-thirds (66.7%) do not. This suggests that most apiaries are located far away from natural protected areas. Maintaining hive placements within such areas could enhance floral diversity and reduce exposure to intensive land use, but may also entail additional permitting or management constraints. Among those beekeepers whose pasture overlaps protected areas, the data reveal a complex mosaic of park and reserve designations with widely varying coverage levels. National Parks feature most prominently in the upper coverage brackets: approximately one-third of respondents

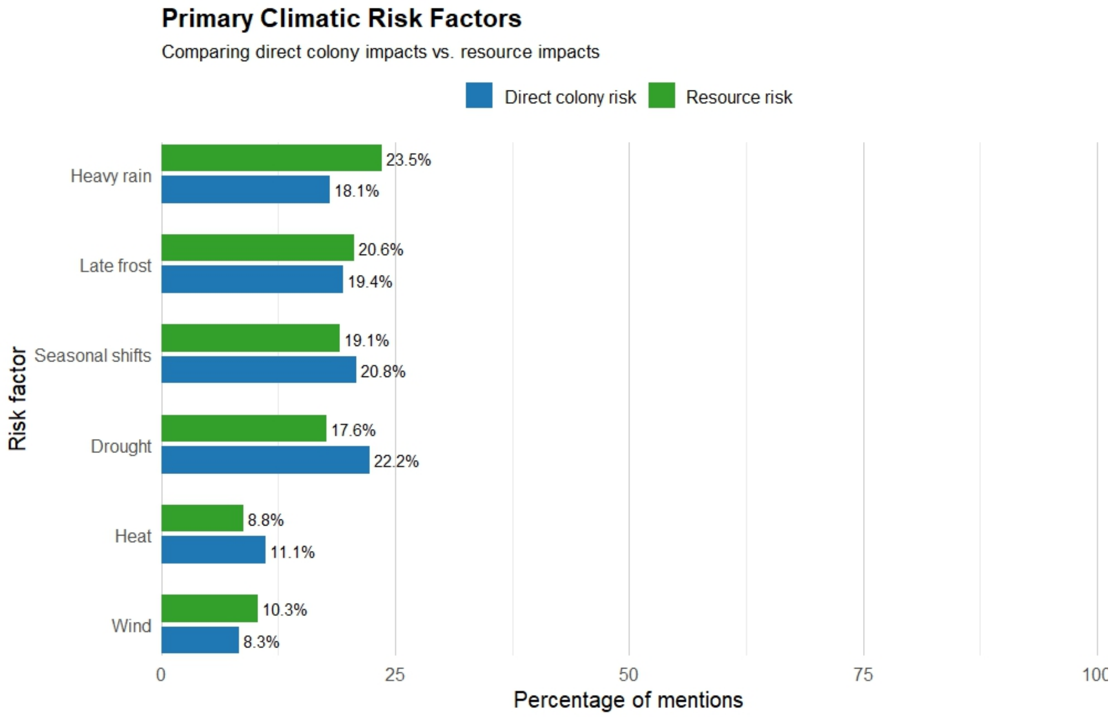

Figure 11: Direct colony impacts versus resource impacts for key climate hazards.

report that over 80% of their foraging area lies within a National Park, and another quarter fall into the 40–60% range. Regional Parks exhibit the broadest distribution, spanning from minimal overlap (under 5%) to substantial inclusion (61–80%), but clustering largely between 20% and 60% coverage. Nature Reserves tend to occupy smaller portions, with the majority of mentions in the 5–20% bracket and fewer operations reporting 21–40% or 41–60% of their land under reserve protection. Sites designated under Natura 2000 (SIC/ZPS/ZSC) most often cover 5–20% of foraging grounds, though roughly one-third of those mentions indicate overlap of 21–40%. Generic "protected area" designations—statutory zones not otherwise categorized—also primarily affect modest shares (5–20%), with occasional plots extending to 40%. Many apiaries fall within intersecting layers of protection (for example, Regional Park plus Natura 2000 or Reserve status), resulting in cumulative coverage that may range from a fifth to four-fifths of their total pasture. This heterogeneity underscores both the regulatory complexity and the conservation potential of apicultural landscapes embedded in multiple protected-area frameworks. The majority of beekeepers in protected-area surveys (approximately 70%) report that their hives lie directly within the boundaries of the referenced zone (0 km). Among those located outside, the modal distance is 5 km, cited by nearly 20% of respondents, indicating that most apiaries are sited just beyond park or reserve perimeters. Smaller shares report mean offsets of 1–3 km (about 5%), while only a handful place their colonies more than 5 km away, with very occasional distances up to 10 km.

These findings suggest that, even when not strictly inside, apiaries tend to remain in close proximity to protected habitats, maximizing access to conserved forage and minimizing exposure to intensive land use. Of the total sample, 33.3% of respondents report that their foraging areas include recognized protected zones, while 66.7% do not. The analysis does not provide cross-tabulations linking the presence of protected areas to beekeeper type (farmer vs. pure beekeeper), nomadic versus stationary practice, geographic macro-area, farm size, or hive number. Among those declaring overlap with protected areas, approximately 70% report that their hives are located directly within the protected boundary (0 km distance). The remaining respondents are typically situated at short distances, most frequently around 5 km, with only rare cases exceeding this range. No further stratification by structural or demographic characteristics is reported in the dataset.

6.1 Characterization of Apiary Landscape

Respondents were asked to indicate the type of landscape in which their hives are situated. The vast majority of apiaries lie in rural agricultural settings—cropland, pastures or orchards—where access to diverse nectar and pollen sources is maximized. A smaller share are positioned in semi-natural or wooded environments (hedgerows, forest edges and meadows), providing late-season forage and shelter. A minority of operations are found in peri-urban zones, where gardens, parks and remnant green spaces offer supplemental floral resources but may also expose colonies to urban stressors (pollution, human disturbance). Overall, most beekeepers locate their hives within productive countryside, with fewer opting for purely wild or suburban contexts. The predominance of conventional and monoculture fields—reported by 88.9% and 77.8% of respondents respectively—underscores that most Italian apiaries operate within highly managed, homogeneous agricultural systems. This intensification often reduces biodiversity and may increase exposure to agrochemical, potentially harmfull for honeybee colonies. Simultaneously, the near–ubiquity of mixed forest–farm mosaics (93.7%) and substantial forest–pasture or forest–natural cover (77.0% and 77.8%) highlights the critical role of remaining semi-natural habitats in bolstering forage availability and ecological resilience. The fact that 60.3% of respondents report proximity to agroecological practices suggests growing adoption of integrated or organic management, which can mitigate some risks associated with intensive cropping. Moreover, high rates of urban adjacency—73.8% within 1 km of built-up centers and 71.4% experiencing diffuse settlement—indicate that even rural apiaries face pressures from expanding human infrastructure. These dual pressures of agricultural intensification and urban sprawl emphasize the urgent need for targeted conservation of landscape heterogeneity. Protecting and restoring semi-natural corridors, promoting diverse cropping systems, and buffering apiaries from urban edge effects will be essential strategies for sustaining healthy pollinator populations and resilient beekeeping enterprises across Italy. The accompanying bar chart (Figure 12) illustrates these percentages.

The current analysis reports aggregate landscape frequencies but does not provide disaggregated evidence by geographic macro-area, nomadic versus stationary status,

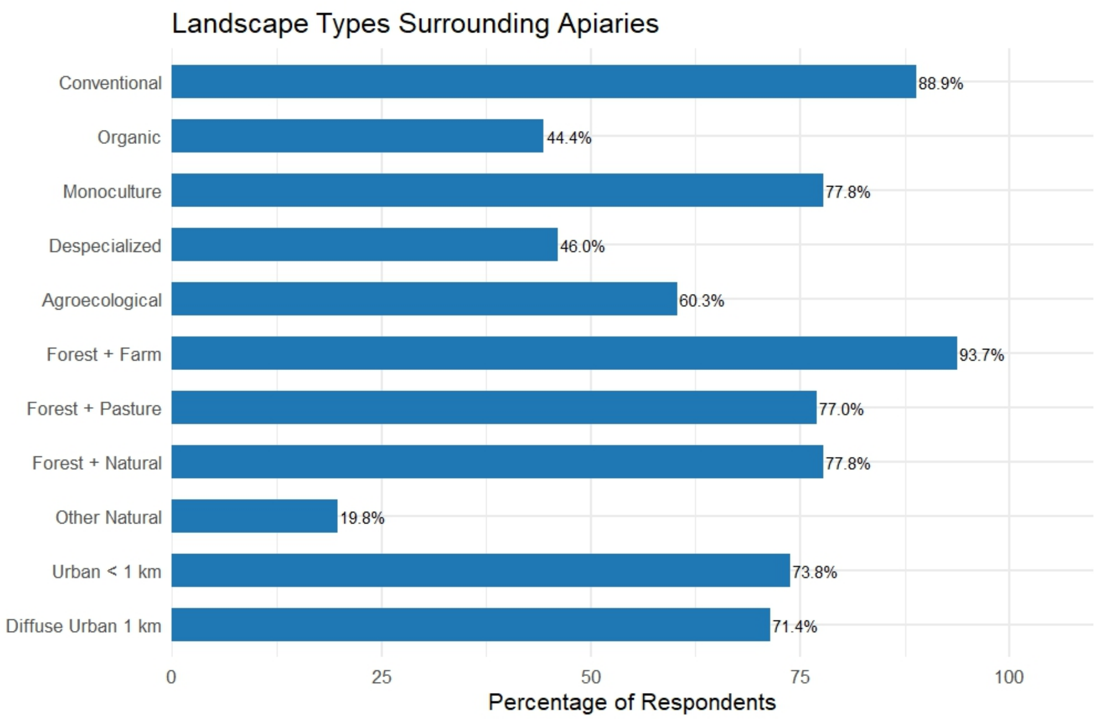

Figure 12: Percentage of respondents reporting each dominant landscape type within the foraging area of their apiaries.

farm size, or beekeeper profile. While conventional (88.9%) and monoculture (77.8%) contexts are highly prevalent across the full sample, the dataset does not include cross-tabulations allowing verification of whether different territorial clusters exhibit statistically distinct landscape compositions, nor whether subgroups defined by operational or demographic characteristics are internally homogeneous. Therefore, based strictly on the reported results, no differential landscape distribution across geographic or structural sub-samples can be inferred.

7 Land-Use Impacts on Colony Health

In our survey of 126 beekeepers, a clear majority (60.3%) reported that specific land-use categories in the proximity of their apiaries have a noticeable effect on colony health, while 39.7% did not observe such impacts. Respondents most frequently identified intensive monocultures and intensive high input agriculture as detrimental factors, citing increased disease incidence and reduced brood viability. Conversely, proximity to diversified or organic farms—and especially semi-natural habitats—was commonly associated with stronger, more resilient colonies. These results underscore that beekeepers perceive a direct link between surrounding land management and colony well-being, highlighting the value of incorporating producer experiences into agricultural planning and policy to safeguard pollinator health. In the survey, participants overwhelmingly pinpointed intensive agriculture as the main environmental stressor impacting honeybee colonies, with over 80% of mentions. This finding underscores the pervasive influence of pesticide use and intensive cropping system on colony health. In contrast, fewer than 10% of respondents cited degraded or under-managed farmland, urban/peri-urban pollution, industrial emissions, or transport-related disturbances. The pronounced gap between the dominant role of intensive agriculture and all other factors highlights the critical need for policies that reduce agrochemical inputs and diversify forage landscapes to safeguard pollinator welfare. The reported results do not provide a stratified comparison of land-use impact perceptions across rural, peri-urban, or urban apiary locations. Although a large majority of respondents operate in rural agricultural contexts and intensive agriculture is cited as the dominant stressor (over 80% of mentions), the analysis does not include cross-tabulations that would allow verification of whether beekeepers located in peri-urban or semi-urban settings express systematically different patterns of concern. Therefore, based strictly on the available evidence, it cannot be determined whether the perceived impact of land-use practices differs across territorial settlement categories.

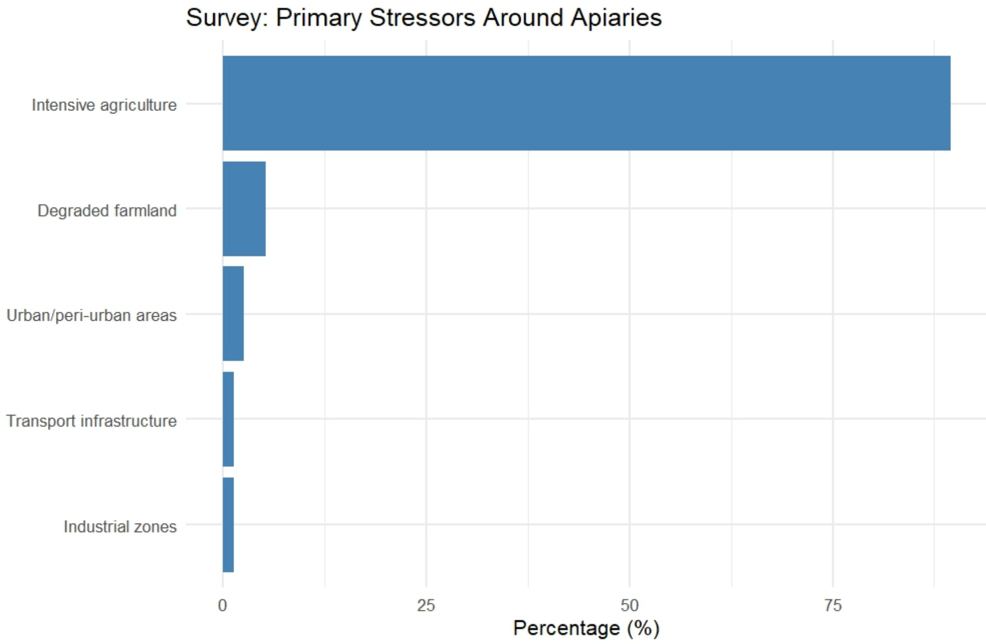

Figure 13: Primary stressors reported by beekeepers around their apiaries (N=126). Almost all respondents identified *Intensive agriculture*—exposure to pesticides and monoculture practices—as the dominant risk factor, while far fewer mentioned degraded farmland, urban/peri-urban areas, industrial zones, or transport infrastructure.

In response to the question “Do you believe that specific land-use practices endanger your honey production?”, an overwhelming 90.8% of respondents answered “Yes,” indicating broad concern among beekeepers about the adverse impacts of surrounding land management on hive productivity. Only 9.2% stated “No.” This near-unanimous perception underscores the critical role that soil use and landscape practices play in apiculture, highlighting the need for targeted interventions—such as reducing agrochemical inputs, preserving semi-natural forage habitats, and mitigating urban and industrial pollutants—to safeguard and sustain honey yields. As shown in Figure 14, the most frequently cited driver of honeybee health issues is the use of harmful agricultural inputs, mentioned by approximately 35% of respondents. Air pollution follows at 18%, with water pollution and the presence of predators each accounting for about 16%. Competition from other apiaries and electromagnetic pollution were noted by 8.5% and 2.8% of beekeepers respectively, while competition from wild pollinators and light pollution were seldom reported (2.8% and 0.7%). These results underscore that intensive agricultural practices remain the dominant concern among practitioners, far outpacing secondary stressors such as environmental pollutants or biotic competition. The reported results indicate a clear concentration of perceived stressors around intensive agriculture, which accounts for over 80% of mentions in the surrounding-area stressor question and approximately 35% when respondents identify primary causes of honeybee health problems. Urban/peri-urban areas, industrial zones, transport infrastructure, and degraded farmland are mentioned by fewer than 10% of respondents. However, the analysis is presented in aggregate form and does not provide cross-tabulations by geographic location (rural vs. peri-urban/urban), nomadic versus stationary status, farm size, or beekeeper profile. Consequently, while intensive agriculture clearly dominates as a perceived stressor in the full sample, it is not possible—based on the available results—to determine whether this perception varies systematically across territorial or structural subgroups.

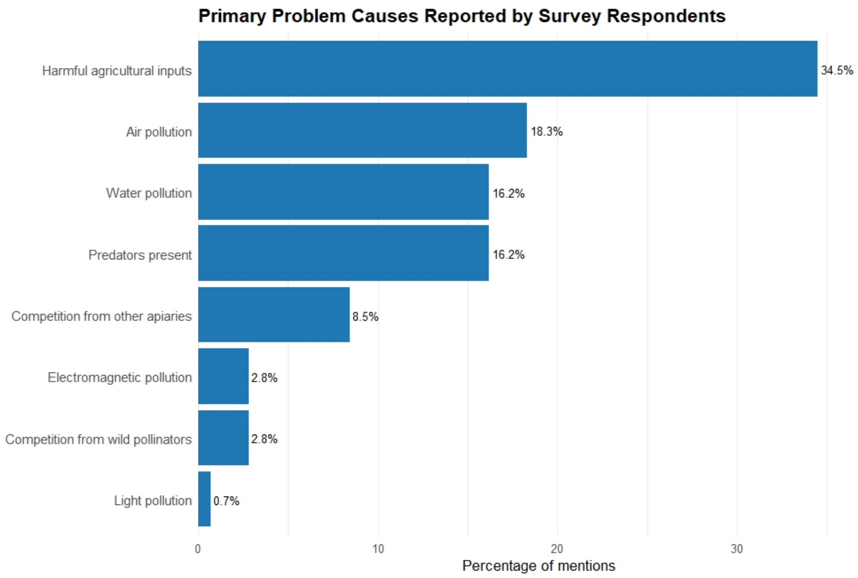

Figure 14: Primary problem causes reported by survey respondents (n=126).

In interpreting the results in Table 2, note that while half of the apiaries produce 500 kg or less per year, a small number of very high-yield operations (up to 40000 kg) drive the mean well above the median, indicating a positively skewed distribution of honey production across respondents. Of the 126 survey respondents, 74.6% indicated that they produce monofloral honey, while 25.4% do not. This predominance of monofloral production suggests that most beekeepers in our sample are able to place their hives in locations where a single floral source dominates the forage landscape, allowing for high-purity honey varieties. Such specialization may reflect both market demand for distinctive monofloral honeys and the availability of sufficiently large, homogeneous floral stands. Conversely, the quarter of respondents who do not report monofloral production likely manage hives in more heterogeneous environments or adopt practices aimed at producing

	Value (kg)
Minimum	5 kg
1st Quartile	20 kg
Median	500 kg
Mean	2800 kg
3rd Quartile	5000 kg
Maximum	40000 kg
Standard Deviation	5200 kg

Table 2: Descriptive statistics of annual honey production among survey respondents.

polyfloral blends. These findings underscore the importance of landscape composition and hive placement in determining the type of honey yield. Figure 15 presents the breakdown of self-reported percentage ranges of different honey types produced by each respondent. The most striking pattern is the overwhelming dominance of the "Less than 5%" category for both *Citrus* and *Sunflower* honeys, indicating that nearly all beekeepers treat these varietals as niche or occasional products. In contrast, *Chestnut* and *Acacia* honeys exhibit a more balanced profile: roughly one-third of respondents produce them at intermediate levels (5–20% and 20–40%), with smaller but non-negligible shares in the upper bands (40–60%). *Millefiori* honey shows the greatest diversity of production scales, with significant proportions in every bracket from 5–20% up to 80–100%, reflecting its role as a flagship, multi-floral blend. The "Other" category, capturing specialty or rare varietals, clusters largely in the lower to mid ranges (5–20% and 20–40%), confirming that these types remain secondary outputs for most apiaries. The Table shows a strongly right-skewed distribution of annual honey production: the median is 500 kg, while the mean rises to 2800 kg due to a small number of very high-yield operations (maximum 40 000 kg). Half of respondents produce 500 kg or less, and 75% produce at most 5000 kg. However, the analysis does not provide disaggregated evidence linking production levels to geographic area, nomadic versus stationary status, farm type, land size, or beekeeper demographic characteristics. The predominance of monofloral production (74.6%) is likewise reported in aggregate form, without subgroup differentiation. Therefore, based strictly on the available results, no structural or territorial stratification of honey production levels or monofloral specialization can be inferred.

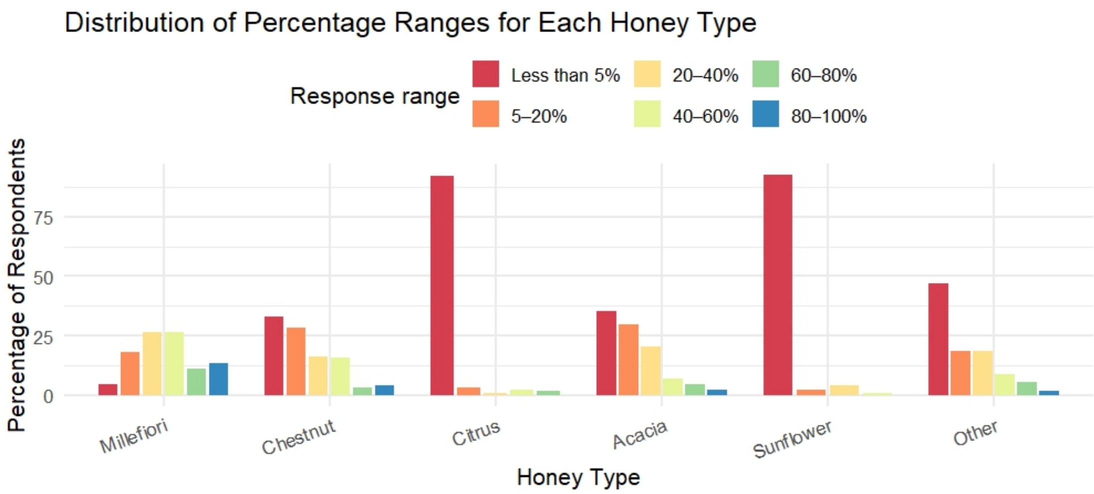

Figure 15: Percentage of respondents by stated production range for each honey type.

A clear majority of respondents (73.8%) report increasing difficulty in producing monofloral honeys, while 26.2% do not perceive such an increase. The analysis is presented in aggregate form and does not provide cross-tabulations linking reported difficulty to geographic area, nomadic versus stationary status, production scale, farm type, or demographic characteristics. Therefore, based on the available results, it is not possible to identify which structural or territorial subgroups are disproportionately represented among those experiencing greater difficulty, nor to compare their profiles with those who report no change.

8 Use of Supplemental Sugar Feeding

Among the 126 beekeepers surveyed, a slight majority (54%) report that they routinely resort to sugar feeding in their hives, while 46% do not. This near-even split suggests that supplemental carbohydrate provisioning remains a common, yet not universal, management practice—likely employed to mitigate nectar shortages or to stimulate colony growth during lean forage periods. Below results regarding this part. Table 3 summarizes the annual supplementary feeding quantities reported by beekeepers who actually provide feed. As shown, while the smallest observed feeding is only 1 kg, most active feeders administer substantially more: the first quartile is 5 kg and the median reaches 30 kg.

The mean of approximately 245 kg reflects a right-skewed distribution driven by a few very large feedings (up to 10000 kg), as evidenced by the relatively high standard deviation of 1190 kg. These results indicate that, among beekeepers who supplement, moderate feeding levels prevail but large-scale operations can raise the overall average. As shown in Figure16, the vast majority of respondents rely on feeding strictly in emergency situations, with over 60% indicating "Emergency only." A sizable minority (approximately 30%) combine scheduled feeding with emergency supplementation. Fewer than 5% feed strictly on a calendar schedule, while reported use due to climatic issues or purely "as needed" occasions is rare. These results highlight that most beekeepers intervene reactively rather than following a fixed schedule.

	Value (kg)
Minimum	1 kg
1st Quartile	5 kg
Median	30 kg
Mean	245.3 kg
3rd Quartile	300 kg
Maximum	10000 kg
Standard Deviation	1190.4 kg

Table 3: Descriptive statistics of annual supplementary feeding per apiary (excluding zero-feeding cases).

Survey respondents who reported any increase in glucose feeding (i.e., excluding those indicating no change) showed a highly skewed distribution of additional glucose per hive. The observed increases ranged from a minimum of 1 kg to a maximum of 5000 kg, with a median increase of 5 kg and a mean of approximately 200 kg. The interquartile range extended from 3 kg (25th percentile) to 80 kg (75th percentile), reflecting that most beekeepers made only modest adjustments, while a few reported very large increases. The standard deviation ($\simeq$ 800 kg) further underscores the presence of substantial outliers in the dataset.

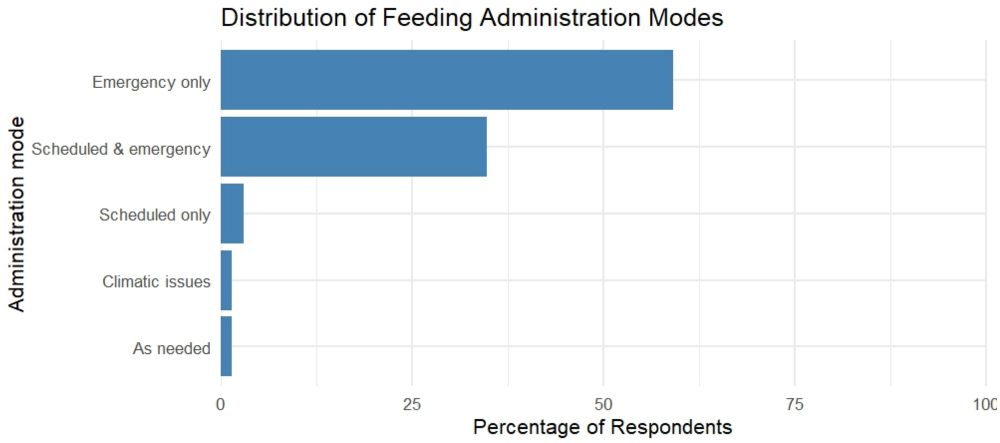

Figure 16: Distribution of feeding administration modes among survey respondents (n = 126).

9 Reported Increase in Colony Mortality

Over the course of the survey, a substantial majority of beekeepers (64.3%) reported having observed an increase in honey bee mortality in recent years, while 35.7% did not notice any rise in losses. This finding underscores the widespread concern about colony health and suggests that most producers are experiencing pressures—whether from environmental stressors, pest and disease outbreaks, or other factors—that are contributing to elevated winter and summer die-offs. The fact that nearly two-thirds of respondents perceive rising mortality rates highlights the urgency of ongoing research and management efforts to identify and mitigate the drivers behind these negative trends. Figure 17 illustrates the distribution of factors that beekeepers identified as the main drivers of colony losses. Varroa mite infestation emerges as the leading concern, cited by approximately 30% of respondents. Pesticide exposure follows at around 17%, while starvation and queen bee death each account for roughly 12%. Abnormal swarming and Nosema infection were also notable, at about 11% and 7%, respectively. Lesser-mentioned causes include the use of acaricidal treatments against Varroa (5%), invasion by the Asian hornet (*Vespa velutina*, 4%), and other factors such as *Varroa orientalis*, small hive beetle (*Aethina tumida*), European foulbrood, drought, climate change with associated viruses, and chronic paralysis virus (each under 2%). These results highlight the multifactorial nature of colony decline, with Varroa control and chemical stressors representing key areas for intervention.

10 Use of Apiaries for Pollination Services

In our survey of 126 beekeepers, only 16.7% reported having deployed hives for pollination of agricultural crops managed by others, while a clear majority of 83.3% have

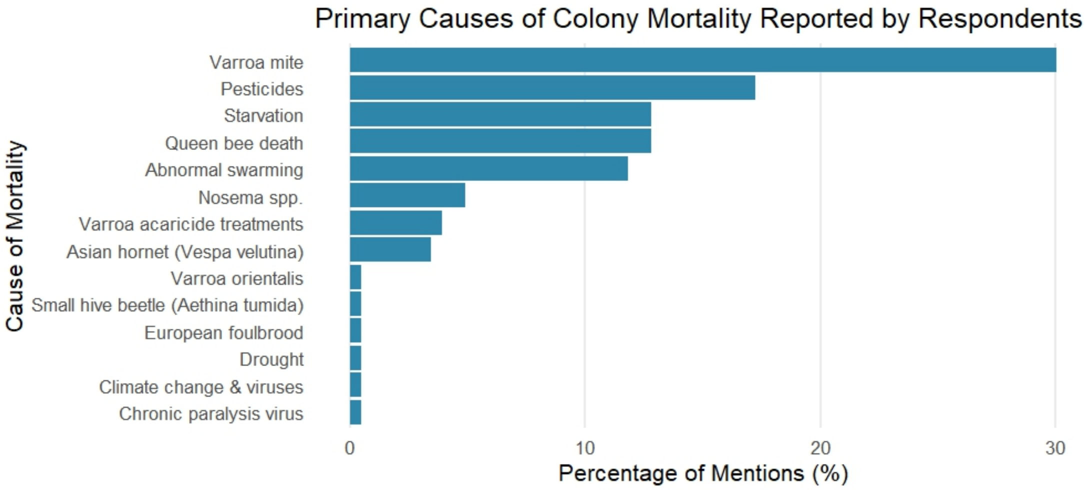

Figure 17: Primary causes of colony mortality as reported by survey respondents (n=126).

not used their colonies for such pollination services. This suggests that, within our respondent pool, renting or loaning hives for commercial pollination remains a relatively infrequent practice. Factors such as the logistical challenges of hive transport, disease risk management, and the premium value of honey production may help explain why most beekeepers do not engage in external pollination contracts. Nevertheless, the minority who do offer pollination highlight its growing importance as an ancillary income stream in regions where crop-dependent pollination is in high demand. Among the beekeepers who reported offering pollination services (16.7% of respondents), a remarkably diverse array of crops was mentioned. The most frequently cited target was sunflower, followed by a wide variety of fruit and vegetable species. The list of crops includes a variety of vegetables such as onions, coriander, tomatoes, cabbages, chicory, and assorted organic market vegetables. Orchard fruits include apples, cherries, melons (cantaloupe), and other tree fruits. The berries grown are blackberries, raspberries, and blueberries. Forage and oilseed crops consist of alfalfa and rapeseed (colza). Other crops include garden flowers, clover, and citrus. This breadth of crop types underscores the essential role that honey bees play not only in sunflower or fruit orchards but also in ensuring pollination for small berries, vegetables, and even ornamental plantings. It also reflects beekeepers' flexibility in meeting diverse agricultural needs, from field crops to high-value specialty fruits.

Acknowledgments

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Italy.

Conclusions

This study has harnessed the practical experience of Italian beekeepers to deliver a comprehensive overview of contemporary apicultural challenges and adaptive responses. Through an anonymous online survey conducted via the 3BEE platform from 2019 to 2024, we collected practitioner-level data on apiary placement, land tenure and use, exposure to chemical and climatic hazards, feeding and overwintering practices, and the prevalence and motivations for seasonal hive translocations. The respondent pool—ranging from hobbyist keepers to full-time apiary entrepreneurs—provided a rich tapestry of insights across diverse agro-climatic zones. Key findings include widespread recognition of weather-related risks (irregular rainfall, frost events, drought) and intensive agricultural pressures (pesticide drift, monocultures) as primary stressors on colony health. A majority of practitioners employ nomadic movements to follow flowering sequences, especially in northern and upland regions, and most report supplemental feeding or targeted overwintering protocols to mitigate forage shortages. Beekeepers also noted growing difficulty in securing monofloral harvests and an uptick in seasonal losses linked to parasites, nutritional stress and extreme weather. In contrast, only a small fraction engage in commercial pollination services, highlighting an area of untapped potential.By translating these observations into a structured dataset, this work underscores the value of integrating on-the-ground knowledge into apicultural research, extension and policy. The survey results reveal not only the multifaceted nature of threats facing honeybees but also the ingenuity of beekeepers in developing resilient management strategies. Such practitioner-driven evidence is essential for designing targeted interventions—ranging from landscape diversification and agrochemical stewardship to tailored feeding regimes and mobility planning—that can enhance colony resilience and sustain pollination services. Looking forward, future efforts should expand this participatory approach by repeating the survey at regular intervals to track trends over time, incorporating longitudinal hive health monitoring and remote-sensing of floral resources. Extending similar questionnaires to other regions and pollinator groups will further refine our understanding of global pollination dynamics. Ultimately, embedding beekeeper insights at the heart of apicultural research and policy will be crucial for fostering adaptive, sustainable practices in the face of mounting environmental pressures.