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Pollination Efficiency of Indigenous Insects on Major Nigerian Crops: A Case Study of Cocoa, Cashew, and Oil Palm Farms

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ABSTRACT

The pollination activities of indigenous species are crucial for sustaining food production and enhancing the yield of cocoa (*Theobroma cacao*), cashew (*Anacardium occidentale*), and oil palm (*Elaeis guineensis*) in Nigeria. Native pollinators especially stingless bees, flies, and beetles significantly improve pollination efficiency, resulting in better fruit yield, seed quality, and crop resilience. Their role as providers of vital ecosystem services directly influences crop productivity and agricultural sustainability. However, their effectiveness is increasingly threatened by seasonal fluctuations, land-use changes, and climate variability. Unlike introduced species, indigenous pollinators are better adapted to local environments, making them more effective and resilient. Beyond pollination, native species contribute to soil health, biodiversity, and ecosystem balance, key elements of sustainable agriculture. Conservation strategies such as preserving natural habitats, protecting floral resources, practicing agroecology and agroforestry, intercropping, and reducing chemical pesticide use are vital. These efforts help maintain consistent food sources and safe habitats for pollinators. Integrating scientific knowledge with traditional practices can inform locally appropriate conservation solutions. Despite their importance, native pollinators face threats from habitat loss, pesticides, and environmental degradation. There is an urgent need for integrated policies to protect these species while improving agricultural productivity. Supporting indigenous pollinators is essential for food security and promoting sustainable farming systems in Nigeria.

KEYWORDS

Theobroma cacao, *anacardium occidentale*, pollinators, biodiversity, *Elaeis guineensis*

INTRODUCTION

The success of global food production depends heavily on pollination, with over 75% of leading food crops requiring animal pollinators for reproduction[1]. In tropical regions, effective pollination enables crops to reach maximum yields while supporting biodiversity and ecosystem stability[2]. Enhancing pollination services offers a sustainable solution to boost food production without expanding farmland, addressing

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growing food insecurity in developing nations[3]. In Nigeria, crops such as mango, citrus, cocoa, cashew, and oil palm rely heavily on pollination[4]. A decline in pollination leads to poor fruit development, reduced yields, and economic losses, especially for smallholder farmers. Practices like agroforestry, planting flowering cover crops, and reducing pesticide use can significantly improve pollination efficiency[5].

Crop sustainability in tropical systems relies largely on indigenous pollinators like stingless bees, carpenter bees, butterflies, and beetles. Indigenous pollinators outperform European honeybees in tropical habitats due to their natural adaptations and resilience to environmental stresses[6]. Smallholder farmers, native pollinators are vital, enhancing both fruit yield and quality in cashew, cocoa, and oil palm farming. However, their populations face major threats from pesticide use, deforestation, expanding monocultures, and climate change[7]. Conservation efforts such as farmer education, habitat restoration, and agri-environmental schemes are critical for improving crop yields while preserving tropical ecosystems sustainably[8].

This review underscores the vital role of insect pollinators in supporting key Nigerian crops like cocoa, cashew, and oil palm, crucial for food security and exports. Despite threats like habitat loss, pesticides, and climate change, agricultural policies often neglect pollinators. Highlighting their ecological and economic value is key to promoting sustainable farming. Figure 1 shows oil palm pollination by insects like weevils, essential for fruit production.

OVERVIEW OF MAJOR NIGERIAN CROPS AND THEIR POLLINATION BIOLOGY

Numerous districts throughout Nigeria support the cultivation of cocoa and cashew, and oil palm because these tree crops advance both economic performance and sustainable rural development[10]. The pollination processes of these crops affect their fruit production and yield potential individually. The pollination of cocoa (*Theobroma cacao*) in Southwestern States relies on *Forcipomyia* spp., midges, but ineffective natural pollination occurs because these pollinators are infrequently active[11]. Each Central and Southeastern State, together with Kogi and Oyo, maintains cashew (*Anacardium occidentale*) as its main agricultural product because bees, ants, flies, and wasps serve as the primary pollinators. Thanks to these insects, the process of cross-pollination develops nuts better and increases total agricultural[12]. Crop productivity, together with sustainable agricultural practices, depends heavily on proper pollination management in these plant systems.

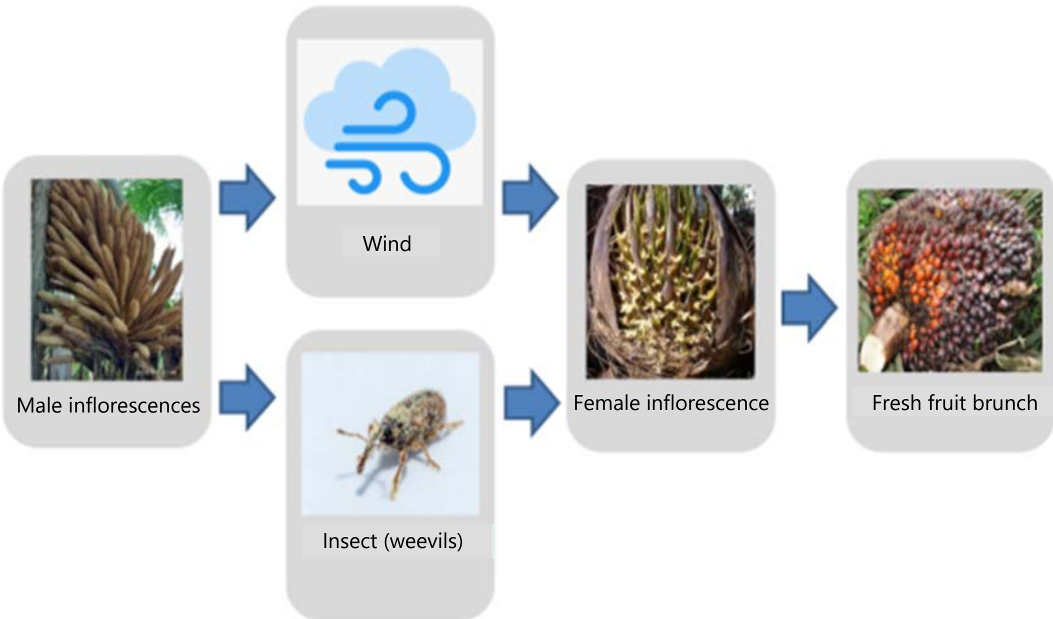

Fig. 1: Insect-mediated pollination in tropical crop (oil palm)[9]

Pollination mechanisms in cocoa (*Theobroma cacao*): The majority of cocoa (*Theobroma cacao*) pollination results from insect cross-pollination managed mostly by midges (*Ceratopogonidae*) per[13]. Flowers on the cocoa plant are both male and female, but they cannot produce healthy offspring from their pollen; therefore, they need cross-pollination from different plants. The flower fragrance draws pollinating midges because these flies seek nectar during foraging. The flying insects move from one cocoa flower to another as they gather pollen from anthers until they feed the collected material onto the female stigma of separate[11]. Too few pollinators anywhere along with unwelcoming natural conditions and inadequate flower quantity, affect the efficiency of cross-pollination[12]. The floral structure impedes extensive wind-driven pollen movement, so this wind mechanism contributes only minimally to pollination. Artificial pollination combined with habitat conservation represents two important methods to support pollinator effectiveness while improving cocoa production[13].

Floral biology and pollination of cashew (*Anacardium occidentale*): All flowers of the *Anacardium occidentale* cashew plant present as and romonoecious types with both bisexual and male flowers located together on each inflorescence. The plant displays small scented flowers that grow in groups at the tip of each branch and bloom during the dry season when pollinators reach their most active state[15]. The bisexual flowers act as a reproductive system for fruit development, but male flowers enhance pollination availability and attract pollinators. The main pollinators for cashew flowers are bees known as *Apismellifera,* together with ants, flies, and wasps. Insects are attracted to cashew flower nectar and scents so they will naturally carry male pollen between the anthers to the female stigma during their foraging activities. The cross-pollination process leads to improved cashew nuts by promoting development and better yield and quality results[14-16].

Reproductive strategy and pollination in oil palm (*Elaeis guineensis*): *Elaeis guineensis* adopts dichogamy in combination with monoecism to achieve cross-pollination by delaying the production times of male and female inflorescences on each plant[17]. Male inflorescences of the oil palm plant dominate by providing abundant pollen during their first emergence period before female inflorescences reach their receptive stage for fertilization. A single inflorescence contains hundreds to thousands of flowers combined in a compact spike form that enables mass pollination events[18]. Researchers have revealed wind-pollination was incorrectly perceived for oil palm after demonstrating that the insects, specifically *Elaeidobius kamerunicus* small weevils, function as the primary pollinators throughout various oil palm cultivation areas[19]. These sensitive insects detect the scent profiles from both male and female flowers through released volatile organic compounds that duplicate one another[20]. The feeding and breeding habits of weevils supply pollen between male flowers and female flowers to accomplish fertilization between the sexes.

Indigenous insect pollinators in Nigerian agroecosystems: The agricultural industry benefits extensively from insect involvement, since insects facilitate crop pollination in particular. Household insects play an essential role in achieving successful pollination of cocoa, cashew, and oil palm, which serve as important cash crops in Nigerian agroecosystems. The combination of pollinators that encompasses stingless bees and hoverflies, and beetles functions as a key force to increase crop production and biodiversity[21]. Determining the distinct insect species alongside their foraging actions and environmental functions enables better agricultural sustainability on oil palm and cocoa, and cashew farms. Table 1 provides details about flower characteristics along with pollination methods of cocoa, cashew, and oil palm.

Common indigenous insect pollinators: Farmers in Nigerian agricultural areas commonly encounter stingless bees of the Meliponini genus alongside hoverflies from Syrphidae as well as sweat bees from Halictidae, combined with carpenter bees from *Xylocopa* spp., and beetle species from Coleoptera. These insects serve essential functions by pollinating three important crops: Cocoa (*Theobroma cacao*), cashew (*Anacardium occidentale*), and oil palm (*Elaeisg uineensis*). The pollinators responsible for cocoa production are mainly midges (*Forcipomyia* spp.), while bees and fly species attract cashew pollination, and weevils (*Elaeidobius kamerunicus*) support oil palm reproduction[22].

Table 1: Floral traits and pollination requirements of cocoa, cashew, and oil palm

Crop	Floral traits	Pollination requirements
Cocoa (*T. cacao*)	Small, hermaphroditic flowers; pale pink/white; cauliflorous (on trunk/branches); complex hooded morphology; short-lived (24-48h); early anthesis	Requires cross-pollination by midges (Forcipomyia spp.); needs humid, shaded environments; natural fruit set is very low
Cashew (*A. occidentale*)	Andromonoecious (male+bisexual flowers); small creamy/yellowish flowers in panicles; open early in the day; short-lived	Pollination by bees, ants, flies, and both self- and cross-pollination requires adequate pollinator presence
Oil palm (*E. guineensis*)	Monoecious (separate male and female inflorescences); large, cream/yellow flowers in dense clusters; anthesis during day; female flowers long-lived	Cross-pollinated by weevils (*Elaeidobius kamerunicus*); minimal wind role; high success with insect pollinators

Habitat, behavior, and foraging patterns: The agroecosystems contain pollinators that mainly thrive in forest borders, domestic gardens, and shaded farmland areas. The Hiving behavior of stingless bees involves using tree hollows for their nests, yet carpenter bees construct their homes in woody stems. The decomposition products where flies and beetles reside are typically moist or damp areas. These pollinators display various foraging patterns by visiting cocoa together with cashew and oil palm flowers through early mornings and late afternoons[21]. These pollinators have an essential role in improving crop yields because they can successfully pollinate different flowering plants within the agroecosystems.

Ecological roles beyond pollination: Indigenous pollinators play several ecological roles beyond pollination. For example, hoverflies are effective natural pest controllers, and beetles contribute to soil aeration and decomposition, enriching soil health. These roles are essential not only for enhancing crop production in cocoa, cashew, and oil palm farms but also for maintaining ecosystem resilience and biodiversity[23]. The conservation of these insect populations ensures a sustainable agroecosystem, which is vital for long-term agricultural productivity. Figure 2 shows both popular and lesser-known pollinators. Popular pollinators like bees, butterflies, and hummingbirds are well recognized, while bats, beetles, and other beneficial insects (flies, wasps, snails, and ants) are less known but equally important. Together, they all play vital roles in pollination and maintaining healthy ecosystems.

Table 2, highlights the main insect pollinators for cocoa, cashew, and oil palm crops. Cocoa is mostly pollinated by Forcipomyia midges, with other flies and stingless bees occasionally contributing. Cashew depends largely on the African honeybee, which supports both self- and cross-pollination, while stingless bees, sweat bees, and some flies play secondary roles. For oil palm, the oil palm weevil is the principal pollinator, with other beetles and carpenter bees providing occasional support. This shows how different insect groups play varying roles in pollination, which is vital for crop production.

Pollination efficiency of indigenous insects: The service of pollination through insects plays an essential role in agriculture because it regulates food production and stability and enhances biodiversity. Native insect pollinators remain unrecognized for their crucial contribution to sustaining the major crops of cocoa, cashew, and oil palm in Nigeria's agricultural systems[3]. The local climates, as well as the vegetation and floral structures, match better with indigenous pollinators compared to managed and introduced species. Researchers need to understand pollination efficiency because it gives them fundamental knowledge to develop agricultural solutions based on nature, which work better under ecological changes and growing land use problems[25].

Measurement of pollination efficiency: The evaluation of pollination efficiency usually involves measuring fruit set percentages together with fruit dimensions and seed numbers per fruit, and total yield numbers. Studies indicate that native midges (*Forcipomyia* spp.) boost cocoa fruit set only when their species exists abundance in natural habitats[25]. Stingless bees alongside sweat bees benefit cashew flower pollination because they contribute to superior seed quality, together with increased nut sizes[7]. Under favorable conditions *Elaeidobius kamerunicus* weevils enhance the fruit bunch weight and oil yield in oil palm while providing effective pollination services.

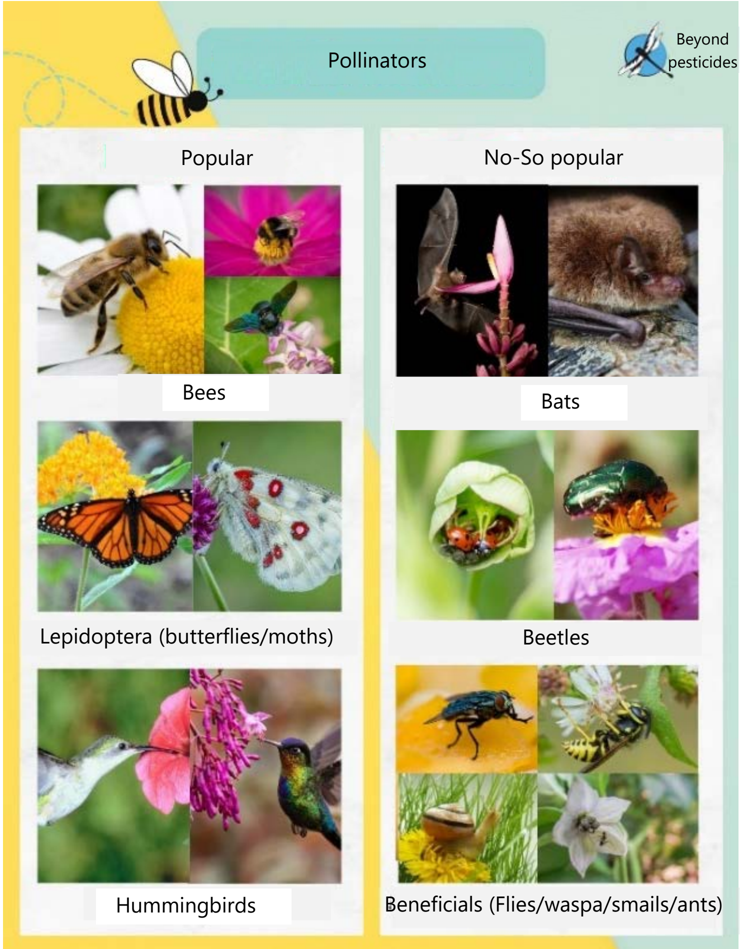

Fig. 2: Images of major indigenous pollinator species[24]

Table 2: Indigenous insect species associated with cocoa, cashew, and oil palm

Crop	Insect pollinator species	Pollinator group	Pollination role
Cocoa (*T. cacao*)	*Forcipomyia* spp. (biting midges)	Diptera (Ceratopogonidae)	Primary pollinators
	Stomoxys spp., *Clogmia albipunctata*	Diptera (Varied families)	Supplementary pollinators
	Meliponula spp., (stingless bees)	Hymenoptera (Apidae)	Occasional flower visitors
Cashew (*A. occidentale*)	*Apis mellifera adansonii* (African honeybee)	Hymenoptera (Apidae)	Main pollinator; facilitates both self and cross-pollination
	Trigona spp., (stingless bees), *Halictus* spp., (sweat bees)	Hymenoptera (Apidae/Halictidae)	Secondary pollinators
	Musca domestica, *Calliphora* spp., (house and blow flies)	Diptera	Occasional pollinators
Oil palm (*E. guineensis*)	*Elaeidobius kamerunicus* (oil palm weevil)	Coleoptera (Curculionidae)	Principal pollinator
	Microporum spp., *Prosoestus* spp.	Coleoptera (Nitidulidae)	Supplementary pollinators
	Xylocopa spp., (carpenter bees)	Hymenoptera (Apidae)	Occasional visitors (limited pollination role)

COMPARATIVE EFFICIENCY BETWEEN INDIGENOUS AND INTRODUCED POLLINATORS

Pollinators that originate from local regions demonstrate superior abilities to thrive in their native crops, together with environmental factors in relation to foreign species, according to comparative research. The African honeybee (*Apis mellifera adansonii*) shows success in cashew pollination, yet native stingless bees demonstrate superior constant floral behavior along with enhanced stress tolerance that enables better pollination quality than honeybees[26]. Research reveals that the oil palm pollination weevil *E. kamerunicus* became a dominant pollinator after naturalizing in Nigeria, even though it initially entered Nigeria from Cameroon[27].

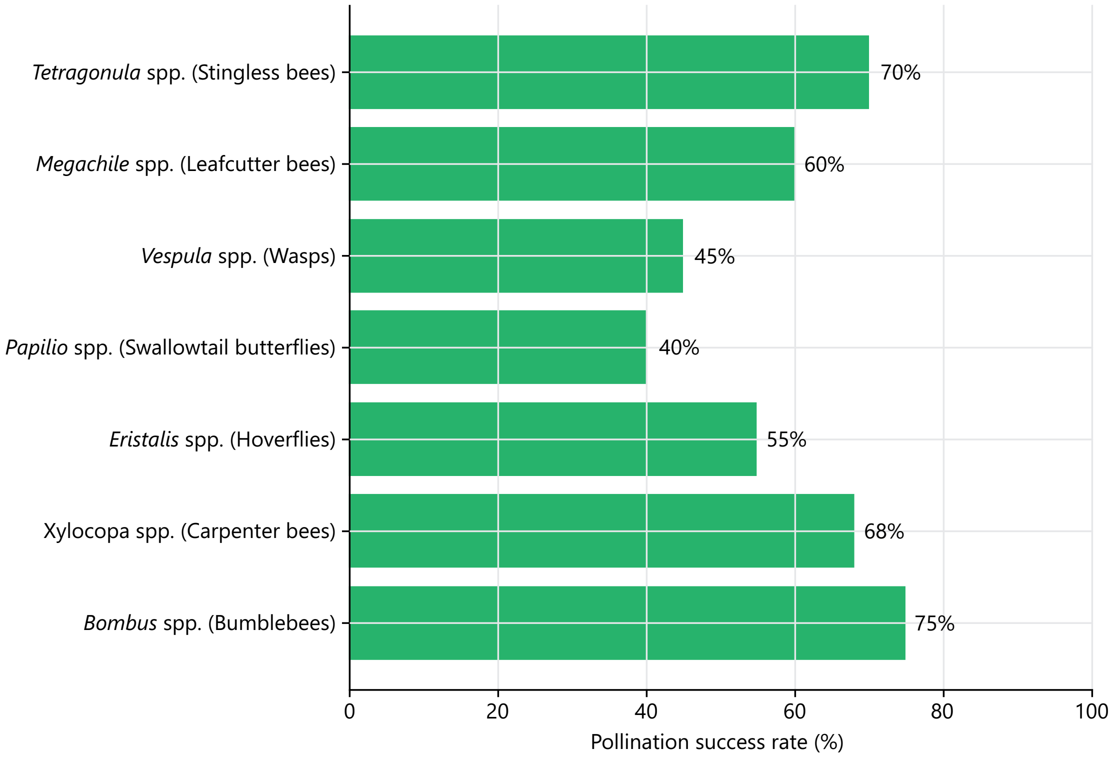

Fig. 3: Pollination success rates across different insect species[28]

Table 3: Yield comparisons in farms with high vs. low pollinator diversity

Crop	Pollinator diversity	Average yield	Observed benefits
Cocoa	High	650-800 kg/ha	Higher fruit set, better pod development
	Low	350-500 kg/ha	Misshapen pods, lower bean count
Cashew	High	900-1200 kg/ha (nuts)	Improved nut size, seed quality, and uniformity
	Low	500-750 kg/ha	Poor nut fill, increased abortion rate
Oil palm	High	18-22 tons/ha (FFB)	More uniform fruit ripening, increased bunch weight
	Low	12-15 tons/ha	Smaller bunch size, incomplete fertilization

FFB: Fresh fruit bunch

SEASONAL AND ENVIRONMENTAL FACTORS AFFECTING POLLINATION

The effectiveness of pollination depends on seasonal factors that consist of rainfall amounts together with temperature conditions, and the timing of plant flowers (Fig. 3). Overall, pollinators that originate from indigenous backgrounds, including stingless bees and midges, show fresh activity schedules throughout early morning and late afternoon hours of dry season periods, according to[20]. Excessive rainfall at the time of cocoa flower reproduction can render midges inactive, thus resulting in decreased fruit yield. Pollination services suffer because habitat destruction and pesticide usage, and nesting habitat reduction impact the indigenous insect populations in negative ways.

Table 3 shows how different kinds of pollinators play a role in the yields and quality of crops on cocoa, cashew, and oil palm farms. Having a wide range of pollinators on a farm leads to more and better-harvested crops. For example, cocoa plants on farms with many pollinators can produce around 650-800 kg/ha, but those places with little diversity do not do as well and often see deformed pods. Just like bees in watermelons, high activity by pollinators in cashews causes the cashews to grow larger and be better filled, but a lack of pollinator types causes the nuts to ripen unevenly and leads to more becoming aborted. Oil palm produces more and more even fresh fruit bunches the more pollinators are present in the field. The research evidence highlights the key role played by pollinators in increasing the value and quality of crops grown in tropical agriculture.

FACTORS AFFECTING INDIGENOUS POLLINATORS

The pollination services of native bee colonies together with beetles and midges, and the native fly populations, boost the yields of cocoa and cashew and oil palm tree crops. Multiple environmental and anthropogenic stresses endanger these native pollinators and their population levels, together with their pollination capabilities. Agroecological strategies must be developed with full knowledge of these environmental factors[29].

Land-use change and habitat fragmentation: The loss of essential natural habitat spaces for nesting and foraging activities occurs because of agricultural expansion, together with logging operations, as well as development projects that lead to ecosystem fragmentation. Fragmentation of land produces pollinator population isolation that causes reduced genetic diversity and diminished resistance within these populations[30].

Pesticide use and agricultural intensification: Industrial chemicals utilized throughout cashew and oil palm plantations create detrimental effects on insect pollinator condition as well as behavior patterns. Sub-lethal pesticide exposure creates adverse effects on foraging capacity and navigation, and reproduction abilities in Halictid bees and *Meliponula* spp. Plants become more isolated from one another when farmers plant only one crop type because it eliminates the seasonal variety of blooming flowers[7].

Climate change and seasonal variability: Formal climate variations such as temperature escalation, together with changed rainfall patterns and abnormal weather patterns, create disharmony between pollen availability and pollinator movement schedules. The activity of midges decreases when heavy rainfall occurs during cocoa flowering season, thereby causing poor fruit set according to[25], cashew farms have been shown to face challenges to both nesting and foraging activities of stingless bees and sweat bees because of dry seasonal conditions[31].

Conservation and sustainable pollination strategies: Conservation and sustainable pollination strategies are vital for maintaining healthy ecosystems and ensuring consistent yields of pollinator-dependent crops such as cocoa, cashew, and oil palm. These strategies involve protecting natural habitats[15], promoting agroecological practices[25] and integrating indigenous knowledge with scientific approaches. Together, they help sustain pollinator populations, enhance biodiversity, and support more resilient and productive farming systems.

Protecting natural habitats and floral resources: Protecting natural habitats and maintaining diverse floral resources are crucial for sustaining healthy pollinator populations, particularly in agricultural landscapes where crops like cocoa, cashew, and oil palm depend on insect pollination[32]. Natural habitats such as forests, wildflower meadows, and riparian zones serve as nesting sites and foraging grounds for bees, midges, and weevils that pollinate these crops[33]. Conservation efforts that preserve or restore these habitats can significantly improve pollination services and contribute to sustainable agricultural production. The map in Fig. 4, illustrates farming areas in Nigeria where the populations of pollinators are decreasing.

Promoting agroecological farming practices: Agroecological farming practices enhance pollinator diversity and abundance by creating more hospitable environments within agricultural landscapes[32]. Techniques such as intercropping, agroforestry, cover cropping, and reduced pesticide use support natural pollinators by providing continuous floral resources, shelter, and safe nesting areas[33]. For pollinator-dependent crops like cocoa, cashew, and oil palm, agroecological methods such as shade-grown systems and diversified planting improve microclimatic conditions and habitat structure, which in turn boost pollination efficiency and crop yields[34] control, and climate resilience, making them a key strategy in sustainable agricultural development.

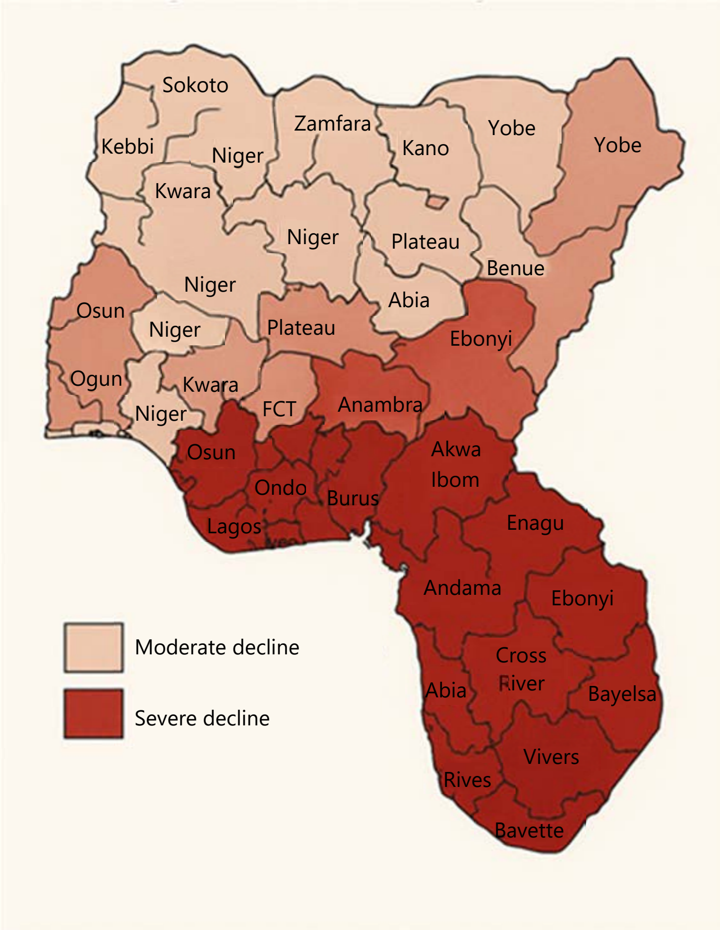

Fig. 4: Map showing areas of pollinator decline in Nigerian farm regions[33]

Table 4: Conservation strategies and their impacts on pollinator abundance[3]

Conservation strategy	Description	Impact on pollinators	Example (cocoa, cashew, oil palm)
Protection of natural habitats	Preserving forests, buffer zones, and wild vegetation near farms	Increases nesting and foraging sites; supports diverse pollinator species	Forest patches around cocoa and and cashew farms support bees and midges
Agroecological farming practices	Use of shade trees intercropping, minimal pesticide application	Enhances floral diversity, reduces chemical exposure, and promotes habitat complexity	Shade-grown cocoa and cashew agroforestry systems enhance pollinator activity
Floral resource management	Planting native flowering plants or hedgerows	Provides year-round nectar/ pollen; sustains pollinators during crop off-seasons	Wildflower strips near oil palm and cashew plantations
Reduced chemical use	Limiting pesticides and herbicides through IPM or organic practices	Protects pollinator health and boosts population resilience	Integrated pest management in in cocoa and oil palm farms
Integration of indigenous knowledge	Utilizing local knowledge of pollinators and traditional land-use practices	Improves local adaptation of pollinator-friendly practices and ecosystem management	Indigenous timing of cocoa flowering and planting supports midge activity
Scientific monitoring & education	Training farmers and using data to manage pollination and biodiversity	Helps maintain optimal conditions for pollinators through informed decision-making	Training cashew farmers in bee-friendly farming and pollination tracking

INTEGRATING INDIGENOUS KNOWLEDGE WITH SCIENTIFIC APPROACHES

Combining indigenous knowledge with scientific approaches enhances sustainable pollination strategies by aligning traditional ecological understanding with modern agricultural science[35]. Indigenous communities often have deep-rooted knowledge of local ecosystems, including the behavior of pollinators, flowering cycles, and natural pest control. In cocoa, cashew, and oil palm farming, this knowledge can guide decisions on planting patterns, habitat conservation, and seasonal management practices that support pollinator health. When integrated with scientific research, such as pollinator behavior studies or biodiversity monitoring, it results in more context-specific, culturally appropriate, and ecologically sound farming systems. This synergy not only strengthens pollination services but also empowers local communities and promotes long-term sustainability.

Table 4 highlights key conservation strategies that support pollinator abundance, demonstrating how the integration of indigenous knowledge with scientific approaches enhances their effectiveness. Traditional practices, such as preserving forest patches or timing planting with flowering cycles, complement scientific methods like integrated pest management and biodiversity monitoring. Together, they promote sustainable farming systems in cocoa, cashew, and oil palm cultivation[36].

CONCLUSION

Key findings show that diverse pollinator populations enhance fruit set, yield quality, and crop resilience. Natural habitats near farms support wild pollinators, such as bees, midges, and weevils, which are vital for cocoa and oil palm production. Agroecological practices and traditional knowledge further improve pollination services, boosting crop yields, quality, and reducing chemical input reliance. These strategies promote long-term sustainability by increasing biodiversity, improving soil health, and strengthening farm resilience to climate change. Future research should focus on quantifying pollinator contributions in various farming systems and identifying optimal habitat configurations for conservation, while policies prioritize habitat protection, promote agroecological farming, and support research that integrates indigenous knowledge. Strengthening education on pollination ecology will be key to scaling sustainable practices, ultimately ensuring pollinator protection, food security, and ecological balance in agriculture.

SIGNIFICANCE STATEMENT

This study explores how native insects contribute to pollinating key Nigerian crops, i.e. cocoa, cashew, and oil palm, which are vital for the country's economy and food security. By measuring pollination efficiency, insects that are most effective in boosting crop yields are identified. These findings highlight the important role of indigenous pollinators, emphasizing the need to protect their habitats for sustainable agriculture. Understanding their contribution can help farmers improve crop productivity naturally, reducing reliance on costly or harmful alternatives. This research also encourages further studies on conserving pollinator diversity and developing farming practices that support these beneficial insects

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