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Diversity of bees during flowering of onion crops in a xeric environment

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Diversidad de abejas durante la floración de cultivos de cebolla en un ambiente xérico

RESUMEN. El estudio de las especies de abejas presentes en paisajes agrícolas es necesario para identificar potenciales polinizadores de cultivos y promover el servicio ecosistémico que brindan. Los estudios de comunidades de abejas son el primer paso para conocer las especies de un área determinada como así también su abundancia y períodos de actividad. El objetivo de esta investigación fue identificar las especies de abejas como potenciales polinizadores de cultivos de cebolla en un área xérica de Argentina (provincia de San Juan). Los individuos fueron capturados utilizando trampas de atracción elevadas durante la floración de cultivos de cebolla, y la comunidad de abejas fue caracterizada a través de rasgos funcionales tales como tamaño, biología de nidificación y comportamiento social. Adicionalmente, se estudió el período de actividad de cada especie de abeja en relación al pico de floración del cultivo. Las trampas recolectaron un total de 1.765 individuos y 55 especies/morfoespecies fueron identificadas, reportando 21 nuevos registros para la provincia de San Juan. Las especies más abundantes fueron *Apis mellifera* L. y dos especies de *Lasioglossum* (*Dialictus*) Robertson. La comunidad de abejas se caracterizó por una gran riqueza de especies de tamaño pequeño y muy pequeño, con preferencia por nidificar en el suelo y de comportamiento solitario. Entre las abejas silvestres, el género *Lasioglossum* Curtis mostró una alta diversidad (riqueza y abundancia) durante la floración de la cebolla. Futuras investigaciones son necesarias para determinar su contribución a la polinización de este cultivo. En este estudio, destacamos la diversidad de abejas silvestres presentes durante la floración del cultivo de cebolla en un ambiente xérico y su importancia para futuros estudios ecológicos, de conservación y polinización.

PALABRAS CLAVE. Abejas silvestres. Cultivo de cebolla. Diversidad de abejas. Polinizadores. Trampas de atracción.

ABSTRACT. The study of bee species present in agricultural landscapes is necessary to identify potential crop pollinators and promote the ecosystem services they provide. Bee community studies are the first step to know the bee species in a given area, as well as their abundance and activity periods. The aim of this research was to identify bee species as potential pollinators of onion crops in a xeric area of Argentina (San Juan province). Specimens were captured with elevated pan traps during flowering of onion crops, and the bee community was characterized by functional traits such as body size, nesting biology, and sociality. Additionally, we studied the period of activity for each species in relation to the peak of onion blossom. Traps collected a total of 1,765 individuals and 55 species/morphospecies of bees were identified, reporting 21 new records for San Juan province. The most abundant species were *Apis mellifera* L. and two species of

Lasioglossum (*Dialictus*) Robertson. The bee community was characterized by a great richness of species of small and very small size, with a preference for nesting below ground and solitary behavior. Among wild bees, genus *Lasioglossum* Curtis showed a high diversity (richness and abundance) during onion flowering. Future studies are needed to determine their contribution to the pollination of this crop. In this study, we highlight the diversity of wild bees present during onion flowering in a xeric environment and its importance for future ecological, conservation, and pollination studies.

KEYWORDS. Bee diversity. Onion crop. Pan trap. Pollinators. Wild bees.

Over the last decades, many pollination studies have focused on the contribution of pollinators to seed and fruit production of several commercial crops (Kremen et al., 2007; Garibaldi et al., 2011, 2013; Klein et al., 2018; Ramello et al., 2024). Among pollinators, wild and managed bees (Hymenoptera: Apoidea: Anthophila) are regarded as the main pollinators of many flowering plants, including several crops, playing an important role for human well-being through the ecosystem services they provide (Cardinal & Danforth, 2013; Klein et al., 2018). Bees represent a remarkably diverse group, including over 20,400 described species around the world (Engel et al., 2020). Managed bees, like *Apis mellifera* L., as well as wild bees such as bumblebees (*Bombus* spp.), carpenter bees (*Xylocopa* spp.), and leafcutter bees (*Megachile* spp.) are among the groups considered as important for agricultural production (Freitas & Oliveira Filho, 2001; Velthuis & van Doorn, 2006; Keasar 2010; Pitts-Singer & Cane, 2011; Khalifa et al., 2021).

The dominant role of bees as pollinators is supported by their great taxonomic diversity and broad range of functional traits such as sociality (solitary or social), nesting biology, voltinism (univoltine, partially bivoltine, bivoltine or multivoltine), body size, foraging behavior, and diet breadth (oligolectic or polylectic) (Michener, 2007; Danforth et al., 2019; Ostwald et al., 2024). Since different crops have been shown to respond positively to increased taxonomic and functional traits (Greenleaf & Kremen, 2006; Garibaldi et al., 2013), it is relevant to provide suitable foraging and nesting sites for the different wild bee species (Torretta & Poggio, 2013; Monasterolo et al., 2020). In addition, studies focused on bee diversity highlight the relevance of functional traits of key species for the pollination of a wide variety of crops (Greenleaf & Kremen, 2006; Hoehn et al., 2008; Garibaldi et al., 2013; Klein et al., 2018; Dalmazzo et al., 2024; Ostwald et al., 2024). Among functional traits, body size is considered as a relevant trait for pollen transport among flowers of crops, being large bees more efficient species at depositing pollen on the stigmas due to their large pollen-carrying surfaces and hairiness compared to smaller bees (Hoehn et al., 2008; Devi et al., 2015; Ramello et al., 2024).

Onion (*Allium cepa* L., Amaryllidaceae) is an important commercial crop grown across the world, ranking second after tomato in the global area production of vegetables (Kuete, 2017; FAO (Food and Agriculture Organization), 2022). The onion umbel is a roughly spherical inflorescence containing between 50 and 2,000 flowers per inflorescence, depending on genotype and other factors related to the mother bulb (Devi et al., 2015). The anthesis in each umbel is highly irregular and lasts about two weeks, requiring at least 30 days or more for all field stalks to flower (Pushpalatha et al., 2023). Although onion has protandrous and self-compatible flowers, insect-mediated cross-pollination improves seed production, increasing the quality and quantity of seed set per plant (Chacoff et al., 2010; Korichi et al., 2021). Dish-shaped flowers with easily accessible nectar and pollen are highly attractive to different orders of insects (Devi et al., 2014), such as Coleoptera, Diptera, Hymenoptera (including several species of bees) and Lepidoptera (Pushpalatha et al., 2023). Although the honey bee (*A. mellifera*) is considered an important pollinator of onion crops (Devi et al., 2014, 2015; Caselles et al., 2019), wild bee species also improve the pollination and increase the yield of seeds (Parker, 1982; Korichi et al., 2021).

In Argentina, previous reports have documented *A. mellifera* visiting onion flowers (Caselles et al., 2019; Allasino et al., 2023), but the potential role of wild bee fauna in onion crop pollination is poorly understood. Therefore, as a first step to increase knowledge about this important group of pollinators, the aim of this study was to characterize the bee community associated to onion crops in a xeric environment of western central Argentina. We studied bee diversity in terms of species richness, abundance, and functional traits (body size, nesting biology, and sociality).

The study was conducted in a xeric area of Argentina (Tulum Valley, Department of Rawson, San Juan province: -31.618, -68.523; 614 m.a.s.l.; 'Monte de llanuras y mesetas' ecoregion, Burkart et al., 1999), which is an important seed production region for varietal and hybrid onions (*Allium cepa*) (Fig. 1a). The climate of Tulum Valley is arid to desertic, daily and seasonal temperatures vary greatly, the annual mean temperature ranges from 14 °C to 19 °C, and the annual rainfall values range between 100 mm and 124 mm (Rodríguez et al., 2018).

Bees were trapped in a 40 m x 40 m onion plot (*A. cepa*) during the crop flowering period (from October to November with peak flowering in mid-November). We carried out a total of nine samplings per year for two consecutive years (23 days of samplings in 2014, and 25 days in 2015). The bees were trapped using elevated pan traps (passive sampling), which consisted of circular yellow plastic bowls (15 cm in diameter and 9 cm deep), mounted on PVC poles elevated 80 cm from the ground and half-filled with 250 ml of soapy water (Fig. 1b).

Twenty-one traps were installed inside the crop plot (Fig. 1c) when 15 % of the flowers in each umbel were open. The traps remained in place after reaching peak flowering (80-100 %) until 15-20 % of the flowers were still open and available for pollinators. We collected bees and refilled the traps every three days, repeating this process nine times, following the percentage of open flowers in the crop. This passive trapping method was selected to collect the wider diversity of bees in the environment during the onion flowering (Wilson et al., 2008). Finally, trapped individuals were transported to the laboratory and identified to the lowest possible taxonomic level (i.e. genus or species). The specimens studied were deposited in the Colección de Entomología, Museo de La Plata, Argentina (MLP).

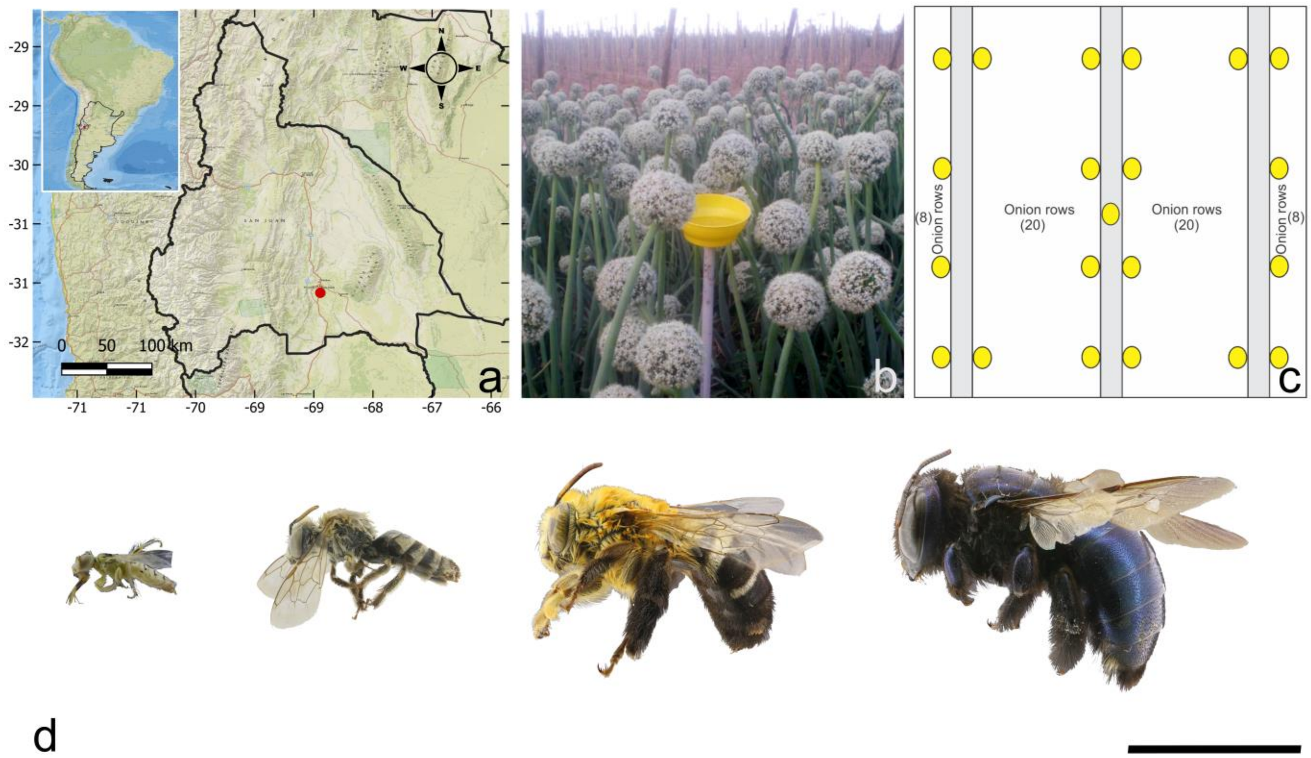

Fig. 1. a. Location of study area (indicated by red circle) in the department of Rawson, Tulum Valley, San Juan, Argentina. b. Elevated pan trap used to collect bees in the crop plot. c. Representative diagram showing the disposition of the pan traps (yellow circles) inside the onion crop. d. Body sizes: left to right: Very small (*Callonychium leleji* Gonzalez & Engel), Small (*Acamptopoeum prinii* (Holmberg)), Medium (*Svastra flavitarsis* (Spinola)), and Large (*Xylocopa splendidula* Lepeletier). Scale bar= 10 mm.

Since bee size has been suggested as related to pollination efficiency through bee behavior within and between the flowers of different crops they visit (Hoehn et al., 2008; Devi et al. 2015; Ramello et al., 2024), the body size of each bee species was estimated by measuring the minimum intertegular distance (Cane, 1987) using an ocular micrometer attached to a Nikon SMZ745 stereomicroscope. Thus, bee species were classified into four categories following Ramello et al. (2024; Fig. 1d): *Large* (henceforth L), *Medium* (M), *Small* (S), and *Very Small* (VS). Measurements were taken from ten individuals collected of each species/morphospecies (average value) or from reference material for species with fewer individuals. Also, species were classified according to functional traits such as nesting biology (above or below ground), and sociality (solitary or social), following Michener (2007), Dalmazzo (2010), Danforth et al., (2019), and Lucia & Alvarez 2024. The georeferenced map was created using different tools from the QGIS 3.16 software (QGIS Development Team, 2024).

Traps collected 55 bee species/morphospecies, of which 21 wild bee species were new records for San Juan Province, belonging to five families and 35 genera (Table I). The family Apidae presented the highest richness observed (S= 22; henceforth, richness: “S”), followed by Andrenidae (S= 15) and Halictidae (S= 13; Table I). The most species-rich genera were *Lasioglossum* (*Dialictus*) Robertson (Halictidae) with six species, followed by *Psaenythia* Gerstaecker (Andrenidae) and *Diadasia* Patton (Apidae), both with four species each (Table I). During onion peak bloom, 33 species were captured, representing more than half of the species identified in the study (Table I). The great diversity of bees found responds to environmental conditions. Although bees are distributed worldwide, a great richness has been observed in xeric and warm temperate regions, such as central Chile and Argentina (Michener, 2007). In addition, arid regions support a great proportion of pollen specialist bees (Danforth et al., 2019), and this explains the observed oligolectic species such as *Arhysosage ochracea* (Friese)

(Andrenidae) (Ramos, 2013) and *Eremapis parvula* Ogloblin (Apidae) (Vossler, 2013). Although passive sampling (pan trap) is used as an efficient method to study the melittofauna present in diverse environments, the observed bee richness could be increased by using more colors of pan traps or entomological nets in future research (see Wilson et al., 2008), or even by direct observation during floral visitor studies on onion flowers.

Table I. Species and total abundance of bees collected during onion bloom in San Juan province, Argentina.

TAXA		Body size	Nesting biology	Sociality	Onion peak bloom	Abundance		
						Year		Total
						2014	2015	
ANDRENIDAE								
Calliopsini								
1	*Acamptopoeum prinii* Holmberg, 1884 ●	S	BG	Sol	+	7 (2)	1	8
2	*Arhysosage ochracea* (Friese, 1908)	S	BG	Sol		1	0	1
3	*Calliopsis (Ceroliopoeum)* aff. *laeta*	VS	BG	Sol		2	1	3
4	*Calliopsis (Ceroliopoeum) laeta* (Vachal, 1909) ●	VS	BG	Sol	+	10 (2)	3	13
5	*Calliopsis (Ceroliopoeum)* sp. 1	VS	BG	Sol		0	5	5
6	*Callonychium (Callonychium) mandibulare* (Friese, 1916) ●	VS	BG	Sol	+	8 (4)	0	8
7	*Callonychium (Paranychium) minutum* (Friese, 1906)	VS	BG	Sol	+	19 (4)	0	19
8	*Callonychium (Paranychium) leleji* Gonzalez & Engel, 2016 ●	VS	BG	Sol	+	19 (3)	0	19
9	*Liopoeum argentina* (Jörgensen, 1912)	S	BG	Sol	+	1	0	1
10	*Liopoeum mendocina* Jörgensen, 1912 ●	S	BG	Sol		0	1	1
11	*Liopoeum* sp. 1	S	BG	Sol		1	0	1
Protandrenini								
12	*Psaenythia picta* Gerstaecker, 1868 ●	S	BG	Sol		1	0	1
13	*Psaenythia* sp. 1	VS	BG	Sol	+	0	1	1
14	*Psaenythia* sp. 2	VS	BG	Sol		1	0	1
15	*Psaenythia* sp. 3	VS	BG	Sol	+	1	0	1
APIDAE								
Apini								
16	*Apis mellifera* Linnaeus, 1758	M	AG	Soc	+	622 (252)	174 (62)	796
Centridini								
17	*Centris (Penthemisia) brethesi* Schrottky, 1902	L	BG	Sol	+	2 (1)	0	2
Emphorini								
18	*Alepidosceles filitarsis* (Vachal, 1904) ●	S	BG	Sol		3	2	5
19	*Diadasia pereyrae* (Holmberg, 1903)	S	BG	Sol	+	2 (2)	9 (2)	11
20	*Diadasia patagonica* (Brèthes, 1910) ●	M	BG	Sol	+	5 (2)	6 (3)	11
21	*Diadasia hirta* (Jörgensen, 1912) ●	M	BG	Sol		3	0	3
22	*Diadasia* sp. 1	M	BG	Sol	+	4 (2)	6 (1)	10
23	*Diadasina distincta* (Holmberg, 1903) ●	S	BG	Sol	+	1 (1)	1	2
24	*Melitoma nudipes* (Burmeister, 1876) ●	S	BG	Sol		1	0	1
25	*Melitoma* aff. *segmentaria*	S	BG	Sol	+	1	1 (1)	2
26	*Ptilothrix tricolor* (Friese, 1906) ●	M	BG	Sol	+	9 (2)	5	14
Eucerini								
27	*Alloscirtetica brethesi* (Jörgensen, 1912) ●	M	BG	Sol		1	0	1
28	*Melissodes (Ecplectica) rufithorax* Brèthes (1910) ●	S	BG	Sol		1	0	1
29	*Melissoptila argentina* Brèthes, 1910 ●	S	BG	Sol		2	0	2
30	*Svastra (Svastra) flavitarsis* (Spinola, 1851)	M	BG	Sol	+	8 (1)	0	8
31	*Svastrides zebra* (Friese, 1908)	L	BG	Sol		2	1	3
Exomalopsini								
32	*Anthophorula (Isomalopsis) truncata* González-Vaquero & Roig-Alsina, 2005 ●	VS	BG	Sol	+	10 (2)	0	10
33	*Exomalopsis solitaria* Brèthes, 1910	VS	BG	Sol	+	11 (4)	20 (10)	31
Protepeolini								
34	*Leiopodus abnormis* (Jörgensen, 1912) ●	VS	-	Sol*	+	1 (1)	0	1
Teratognathini								
35	*Ancyloscelis apiformis* (Fabricius, 1793)	S	BG	Sol	+	27 (8)	7 (2)	34
36	*Eremapis parvula* Ogloblin, 1956	VS	BG	Sol	+	28 (7)	0	28
Xylocopini								
37	*Xylocopa (Schonnherria) splendidula* Lepeletier, 1841	L	AG	Soc		1	0	1
COLLETIDAE								
Colletini								
38	*Colletes bicolor* Smith, 1879 ●	M	BG	Sol	+	1 (1)	0	1
Eulonchopriini								
39	*Nomiocolletes jenseni* (Friese, 1906)	M	BG	Sol		1	0	1
40	*Pygopasiphae wagneri* (Vachal, 1909) ●	M	BG	Sol	+	0	2 (1)	2
Xeromelissini								
41	*Chilicola* sp.	S	AG	Sol	+	1 (1)	0	1
HALICTIDAE								
Augochlorini								
42	*Augochlora (Augochlora) phoemonoe* (Schrottky, 1909) ●	S	AG	Soc		0	3	3

43	*Augochloropsis* sp.	S	BG	?	+	21 (8)	7 (2)	28
Halictini								
44	*Lasioglossum (Dialictus) autranellus* Vachal, 1904	VS	BG	Soc	+	2 (1)	5	7
45	*Lasioglossum (Dialictus)* sp. 1	VS	BG	?	+	3 (2)	0	3
46	*Lasioglossum (Dialictus)* sp. 2	VS	BG	?	+	8 (4)	6 (1)	14
47	*Lasioglossum (Dialictus)* sp. 3	VS	BG	?	+	88 (29)	5 (1)	93
48	*Lasioglossum (Dialictus)* sp. 4	VS	BG	?		1	0	1
49	*Lasioglossum (Dialictus)* sp. 5	VS	BG	?	+	277 (90)	216 (40)	493
Caenohalictini								
50	*Caenohalictus thamyris* (Jörgensen, 1912)	VS	BG	Sol		0	4	4
51	*Pseudagapostemon (Pseudagapostemon) pampeanus* (Holmberg, 1886) ●	VS	BG	Sol	+	39 (16)	8 (1)	47
52	*Pseudagapostemon (Pseudagapostemon)* sp. 1	S	BG	Sol		1	3	4
53	*Pseudagapostemon (Pseudagapostemon)* sp. 2	S	BG	Sol	+	1 (1)	0	1
Sphecodini								
54	*Sphecodes (Austrosphecodes)* sp.	VS	-	*Sol		0	1	1
MEGACHILIDAE								
Megachilini								
55	*Megachile (Chrysosarus) infima* Vachal, 1909	S	AG	Sol		0	1	1
TOTAL						**1260**	**505**	**1765**

*Functional traits: Body Size (L = Large; M = Medium; S = Small; VS = Very Small), Nesting biology (AG: Above ground, BG: Below ground), Sociality (Sol: Solitary, Soc: Social, ?: unknown; *Par: Parasite); Onion peak bloom: + = bee species trapped when 80% and 100% of flowers of each inflorescence were open in both years (mid-November) samplings. Abundance () = number of specimens collected during the onion peak bloom. ● new record for San Juan province, Argentina.*

In terms of abundance, traps collected a total of 1,765 individuals, with the families Apidae and Halictidae being the most frequently captured (Table I). *Apis mellifera* (Apidae) was the most abundant species during both years, representing 45.1 % of all bees collected. On the other hand, wild bees represented the majority of the specimens sampled, and about 63 % of them were identified as *Lasioglossum* (*Dialictus*) sp. 3 or *L.* (*Dialictus*) sp. 5 (Table I). The three bee species mentioned above comprised 76.7 % of the total individuals collected and were also particularly abundant at peak bloom (Table I). The abundance observed for the family Halictidae could be associated with their social habits, nesting aggregation behavior and the phenology peak of some species that coincided with the sampling period (Michener, 2007; Dalmazzo et al., 2014; Nelson et al., 2023).

Among functional traits, body sizes varied from VS to L among families (Table I; Fig. 1d), and traps captured a great richness of S and VS, reaching 76 % of all identified bee species (S= 20, and VS= 22, respectively). Regarding nesting biology and sociality, we observed that 87.3 % of bees nest below ground and 78 % were solitary (Table I). The results obtained are in agreement with previous local and global research which reported that the majority of bee species are solitary, being soil excavation their main nesting strategy (Danforth et al., 2019; Michelette & Camargo, 2000). In addition, species of the genus *Lasioglossum* Curtis were observed entering the onion flowers to obtain either pollen or nectar, or both; this behavior triggers the staminal column, causing the release of pollen (Korichi et al., 2021). In particular, we observed a great diversity of subgenus *L.* (*Dialictus*), which comprised 63 % of the wild bee individuals collected and their activity period match with flowering peak of onion (Table I). The observed dominance of *Lasioglossum* suggests that environmental conditions of this area provide adequate nesting and foraging resources. Due to the fact that some species of this genus display social behavior, which generally implies many individuals per nest (Michener, 2007; Danforth et al., 2019) and given the importance of them as a flower visitor across a wide range of crops (Nelson et al., 2023), future studies are needed to assess the species of *Lasioglossum* as pollinator of onion crop.

Since several species of bees were reported visiting onion flowers and improving pollination of the crop (Parker, 1982; Saeed et al., 2008; Devi et al., 2015; Korichi et al., 2021), the high diversity of species surveyed in this research is relevant for further pollination studies. Previous reports in the study area have identified about 60 species of wild bees visiting flowers of both wild and cultivated plant species, including at least seven species observed in onion crops (Michelette & Camargo, 2000; Allasino et al., 2023). Therefore, the new records found for the San Juan province emphasize the wide range of wild bees in arid areas of Argentina and highlight the lack of bee diversity studies conducted in such environments. Furthermore, the bee diversity documented in the present study increases the knowledge about the melittofauna in the surveyed area and provides a baseline for further ecological, conservation, and agricultural studies.

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