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A Review of Habitat and Distribution of Common Stingless Bees and Honeybees Species in African Savanna Ecosystems

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Abstract

Background and Research Aims: Globally, concerns over a decline in insect pollinator abundance have been raised. Although bees were noted to be key pollinating agents for approximately 52 of the leading 115 global food commodities, they are currently exposed to risks ranging from a variety of diseases and environmental threats emanating from changes in land use, farming practices and climate change. The study reviewed the habitat and distribution of common stingless bees and honeybees species in African savanna ecosystems. The review focused mainly on (i) profiling stingless bee and honeybee species, habitat and distribution within African savanna ecosystems and (ii) assessing factors affecting stingless bees and honeybees in habitat selection within the savanna ecosystem.

Methods: A meta-synthesis of existing literature with a qualitative orientation was used for the review process and 90 published documents were consulted between 1970 and 2021.

Results: The review findings indicated that there are 19 stingless bee species and 13 subspecies of Apis mellifera found in Africa. The A. mellifera scutellata and A. mellifera adansonii were reported to be widely distributed across the African savanna ecosystem.

Conclusion: The migration and swarming of bees play a pivotal role in the general stingless bees and honey bees distribution within the savanna ecosystem.

Implications for Conservation: The persistence of stingless bees and honeybees within savanna ecosystems depends on the adoption of the best conservation policies derived from economic and ecological services associated with bee conservation.

Keywords
ecosystem, honeybees, savanna, stingless bees, species

Introduction

Globally there are approximately 25,000 described bee species and there are estimated to be 40,000 bee species existing in total (Ascher & Pickering, 2010; Eardley, 2004; Nkoba et al., 2016). The first honeybees are believed to have evolved from a wasp-like ancestor known as spheciod about 100 million years ago (Hepburn & Radloff, 1998). Honeybees (*Apis mellifera*) are the most widespread bee species in the African savanna ecosystem (Hepburn & Radloff, 1996, 1998; Moritz et al., 2005; Ruttner, 1988; Schmidt et al., 1995). Protected and non-protected African savanna has

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enormous and diverse ecosystems which support honeybees and stingless bees habitats. Several sustainable management initiatives have been implemented to ensure the effective conservation of honeybees and stingless bees in both protected and non-protected areas (Fitzpatrick et al., 2007). Apiculture (beekeeping) and meliponiculture (stingless beekeeping) are common practices in Africa which allows utilisation of honey from bees at the same time conserving them (Chuma et al., 2013; Rodríguez-Pose & Hardy, 2015). The intensity of both apiculture and meliponiculture influences honeybees and stingless bees habitat and distribution. An understanding of honeybees and stingless bees biology, ecology, diversity, habitat and distribution is critical to ensure effective conservation (Fitzpatrick et al., 2007)

Honeybees play a critical role in pollinating almost three-quarters of the world's flowering plants (Deyrup et al., 2002; Free, 1970; Gels, 2002; Gupta, 2014; Hepburn & Radloff, 1998; Kevan & Viana, 2003; Knight et al., 2005). Modern agriculture values honeybee pollination services to be greater than 14 million dollars (De Lange et al., 2013; Free, 1993; Gallai et al., 2009; Morse & Calderone, 2000; Potts et al., 2010; Rigg, 2006; Riley et al., 1996). Honeybees are effective bio-indicators of the state of the environment since they interact strongly with water, air and vegetation (Henry et al., 2012; Porrini et al., 1996, 2002). The conservation of honeybees in African savanna ecosystems faces a myriad of threats emanating mainly from pests and diseases, climate change, deforestation, industrialisation and urbanisation, agrochemicals from various agricultural activities (Bailey et al., 1983; De Lange et al., 2013; Genersch, 2010; Oldroyd, 2007; Patiny & Michez, 2007; Vet, 2001). Threats to honeybees and stingless bees habitats affect their population distribution.

Stingless bees have vestigial stings and they are generally small to medium-sized bees which stores honey and pollen in perennial colonies (Eardley, 2004; Kajobe, 2007; Nkoba et al., 2016). In African savanna ecosystems, there are several stingless bees species which differ significantly in colour, colony and body sizes (Eardley, 2004; Kajobe, 2007). Stingless bees are classified as generalist feeders in terms of nests sites selection. Stingless bees feed on a wide range of flowers and can nest in artificial and natural structures, for example, felled trees, earthen banks, rocks and crevices. Stingless bees habitat and nesting requirements differ from one species to the other and this generally affects their distribution within the African savanna ecosystems (Fabre Anguilet et al., 2018; Kajobe, 2007; Nkoba et al., 2016). Nests architecture may differ significantly but in most cases, the brood cells could be horizontally or vertically, semi-combs or clustered cells (Kajobe, 2007). Many species of stingless bees species especially those from warm moist tropics are unable to survive chilling temperatures and this generally affects their spatial distribution (Eardley, 2004; Nkoba et al., 2016). Stingless bees survive adverse weather conditions through effective adaption for example they have excellent insulation capabilities to protect exposed nests (Kajobe, 2007).

Habitat suitability plays a pivotal role in affecting honeybees and stingless bees species distribution within African savanna ecosystems (Kajobe, 2007; Naug, 2009; Schmidt et al., 1995; Strickland, 1982). Habitat provides food, water, cover, space and areas to reproduce for both honeybees and stingless bees (Brodschneider & Crailsheim, 2010). Both natural and anthropogenic factors within the habitat positively or negatively affect honeybees and stingless bees distribution. Indigenous forage species produce more nectar and pollen suitable to support several bees species in natural ecosystems (Gardiner, 2004; Hutton-Squire, 2014; Johannsmeier, 2001, 2007; Rukuni et al., 2006). On the other hand, artificial plantations and forests play a pivotal in supporting several bees species conservation. Alteration of both natural and artificial forage grounds directly or indirectly affects honeybees and stingless bees species in African savanna ecosystems (Kearns et al., 1998; Lietaer, 2009; Oldroyd, 2007; Strickland, 1982). This review focused mainly on reviewing common stingless bees and honeybees habitat and distribution in African savanna ecosystems

Methods

Research approach

This review analysed the honeybee species and stingless bees habitat and population distribution in African savanna ecosystems. A review of relevant literature was used to gather data on the habitat and distribution of common stingless bees and honeybees species in African savanna ecosystems. To provide an in-depth insight into bee species habitat and population distribution in savanna ecosystems a narrative approach was used by engaging in literature and document analysis. Thematic analysis was used to analyse stingless bees and honeybees habitat and population distribution (Bowen, 2009; Thomas, 2006). Online academic data searches such as Google Scholar were used to collect data from several repositories, journals and databases. The search was done systematically through the use of focused keywords search including 'honeybees', 'savanna ecosystem', 'stingless bees', 'nesting preferences', 'bees nest sites', 'habitat', 'sub-species', 'bees forage', 'population distribution' and various combinations of such terms/phrases. The geographical location of the study sites and observation of such bees species was the main inclusion criteria used in the literature gathering. Publications and published observations of stingless bees and honeybees within African savanna ecosystems were reviewed. The retrieved literature included reports, books, journal articles, and conference proceedings. Literature was also obtained by the use of and/or employing the backward snowballing approach of literature identification through which relevant peer-reviewed articles in leading journals were identified and analysed. After the rigorous screening of a

Table 1. Summary of types of stingless bee species found in the African savanna ecosystem.

Scientific name	Geographical distribution	Physical Characteristics	Habitat	Diagnosed dimensions (mm) H	S	F	B
Cleptotrigona cubiceps (Friese, 1912)	South Africa, Democratic Republic of Congo, South Africa, Tanzania, Sierra Leone	-Dark brown integument often with a reddish tinge, to black -Pale appendages and ventral surfaces of tarsi are sometimes yellow. Pale long hairs	-Nests in trees and forages widely	1.3	0.8	3.2	3.5–4.0
Dactylurina staudingeri (Gribodo, 1893)	Angola, Ghana, Democratic Republic of Congo, Cameroon, Liberia, Nigeria, Sierra Leone, Tanzania, Togo, Uganda	-The fave worker is sparsely covered -Male genitalia- Gonostyli narrow	-Forages on a wide range of flowers, for example, *Ageratum* spp., *Boerhavia, Combretum Platycerium, Jatropha multifidi, Zea mays, Urena lobate* etc.	na	na	na	na
Dactylurina schmidti (Stadelmann, 1895)	Tanzania, Gabon	-Worker face completely and densely clothed with plumose-white vestiture -Male genitalia- Gonostyli wide	-Forages on a wide range flowers, for example, *Combretum splendens, Commelina benghalensis, Hibiscus sabdariffa, Ipomea* spp., *Mangifera indica* etc.	na	na	na	na
Plebeina hildebrandti (Friese, 1900)	South Africa, Zimbabwe, Democratic Republic of Congo, Botswana Tanzania, Kenya, Uganda, Nigeria, Ghana	-White venture, the integument of head and mesosoma completely black or brownish. Frons not elongated, mandible with a broad tooth	-Nests in termites cavities	1.4–2.0	1.0–1.6	3.8–5.1	3.3–5.2
Meliponula bocandei (Spinola, 1853)	Uganda, Democratic Republic of Congo, Namibia, Mozambique, Angola, Cameroon, Nigeria, Cote D'Ivoire, Ghana	-Black to reddish head with yellow on ventral margin of clypeus. Black to reddish-black mesosoma except for the dorsal region - Orange vestiture, with frons not elongated	-Widely distributed due to high adaptation to different habitats. Forages in flowers such as *Asystasia ganagetica, Averrhoa carambola, Cyperus* spp., *Urena lobate*, etc.	2.6	1.9	6.6	7.0
Meliponula ferruginea (Lepeletier, 1841)	Democratic Republic of Congo, Cote D'Ivoire, Cameroon, Uganda, Kenya, Zambia, Malawi, Kenya, Nigeria, South Africa, Ghana, Togo, Benin, Ghana	- Can be either completely black or black with red metasoma. Medium-sized	-Widely distributed in a tropical savanna ecosystem. Known to forage in flowers like; *Ageratum conyzoides, Antigonon, leptopus, Zea mays, Citrus* spp., *Cyperus* spp., *Urena lobata*	1.9–2.1	1.4–1.6	5.4–6.0	5.1–5.9
Meliponula cameroonensis (Friese, 1900)	Nigeria, Benin, Uganda, Democratic Republic of Congo, Cameroon, Ghana	-Large and appears blue-black. Little yellow near the epistomal suture and on the ventral margin of the clypeus	-Confirmed mainly to the Central and West of Africa savanna ecosystem and known to forage flowers of *Cajanus cajan*	2.5	1.8	7.4	7.1
Meliponula beccarii (Gribodo, 1879)	South Africa, Zimbabwe, Namibia, Cameroon, Sierra Leon, Ethiopia, South Sudan, Eritrea, Ghana	- Black integument with reddish distal tarsal segments, yellow maculation on clypeus, with very pale vestiture and orange on the ventral surface of tarsi	-Widely distributed within savanna ecosystems except for West Africa and known to forage in daylilies	2.0–2.1	1.7–1.8	5.6–6.1	5.8–6.6
Meliponula ogouensis (Vachal, 1903)	Tanzania, Zimbabwe, Democratic Republic of Congo, Zimbabwe, Angola, Ethiopia, Cameroon	-Yellow integument and maculation on parocular area occupying most of the lower half. Yellow scutellum with vestiture on the head and white scutum	-Well distributed to the South of Africa and find forage within daylilies	na	na	na	na
Meliponula nebulata (Smith, 1854)	Cameroon, Angola, Democratic Republic of Congo, Ghana	-Yellow markings on the pronotal lobe and black mesosoma. Long vestiture on vertex, scutum and metasomal	-Widely distributed and known to forage flowers such as; *Vernonia conferta, Urena lobate, Ipomea* spp., *Borreria verticillata, etc.*	na	na	na	na
Meliponula lendliana (Friese, 1900)	Democratic Republic of Congo, Tanzania, Cameroon, Togo, Nigeria	-Black integument with reddish distal tarsal segments and yellow maculation on clypeus. Very shot scutum, dense, blackish vestiture and few densely vestiture	-Found in selected habitats and found to forage in flowers of; *Mangifera indica, Haronga madagascariensis, Dacryodes edulis, Gouania longipetala*	1.4–1.5	1.1–1.2	3.9–4.0	4.1–5.2
Meliponula griswoldorum (Eardley, 2004)	Zambia	White scutum, with very short dense, simple vestiture. Long weakly plumose hairs	na	na	na	na	na

(continued)

Table 1. (continued)

Scientific name	Geographical distribution	Physical Characteristics	Habitat	Diagnosed dimensions (mm)			
				H	S	F	B
Hypotrigona gribodoi (Magretti, 1884)	South Africa, Mozambique, Democratic Republic of Congo, Tanzania, Angola, North Sudan, South Sudan, Nigeria, Togo, Ghana	-Black integument with reddish-yellow mandible, antenna and distal tarsal segments. White vestiture and very sparse mainly on the lower region of the face. Scutum is highly punctate	-Widely distributed across tropical savanna ecosystem and commonly found foraging flowers of; *Accacia senegalesis, Antigonon leptopus, Acacia tortilis, Borreria verticillata, Cissus* spp., *Dialium soyauxii, Indigofera* spp., *Mangifera indica, Ficus umbellatus, Spirostachys Africana, Solenostemon*	0.9–1.1	0.6–07	2.1–2.8	2.2–2.9
Hypotrigona ruspolii (Magretti, 1898)	South Africa, Zambia, Tanzania, Kenya, Uganda, Democratic Republic of Congo, Angola, Cameroon, Nigeria, Ghana, North Sudan, Sierra Leone	-Weakly pinnate head and scutal vestiture, moderately shiny scuttal punction, scutum and notaulus usually conspicuous	-Widely distributed across savanna ecosystem and nests in trees, for example, in *Ficus umbellatus*	na	na	na	na
Hypotrigona araujoi (Michener, 1959)	South Africa, Mozambique, Zambia, Malawi, Tanzania, Kenya, Democratic Republic of Congo, Angola, Namibia, Cameroon, Nigeria, Togo, Ghana	-Dull scutum and slightly shiny in between punctures, black mandible and labrum, vestiture on vertex and scutum weakly plumose	-Widely distributed within savanna ecosystem and known to forage flowers of *Oleander* spp., *Monopetanthus le-testui*	na	na	na	na
Liotrigona bottegoi (Magretti, 1895)	South Africa, Mozambique, Zimbabwe, Namibia, Tanzania, South Sudan	Moderately punctate scutum with reticulate sculpture and simultaneously shiny	Unevenly distributed in West, Central, East and Southern Africa savanna ecosystem. Found foraging in several flowers of; *Annona muricata, Borassus aethiopicum, Cesalpinia pulcherrima, Carica papaya, Entada mannii, Eucalyptus* spp., *Luffa* spp., *Euphorbia* spp., *Terminalia glauscescens Zea mays*	na	na	na	na
Liotrigona parvula (Darchen, 1971)	South Africa, Zimbabwe, Namibia, Angola, Zambia, Democratic Republic of Congo, Cameroon	Sparsely puncte smooth and shiny scutum	-Sparsely distributed in West, Central, and Southern Africa. Found foraging in several flowers of; *Andropogon* spp., *Borassus aethiopicum, Combretum* spp., *Entada mannii, Dalbergiella welwitchii, Hyparrhenia* spp., *Lippia* spp., *Terminalia glaucescens, Vitex doniana*	na	na	na	na
Hypotrigona penna (Eardley, 2004)	Ghana	Black to orangish-yellow mandible and labrum, legs and metasoma. Dull scutum to slightly shiny punctures	-Mostly confined on the western part of Africa and found foraging in flowers of *Borassus aethiopicum, Combretum* spp.	0.9–1.1	0.6–0.7	2.1–2.8	2.2–2.9
Meliponula roubiki (Eadley, 2004)	Ghana, Gabon	Yellow integument with maculation on parocular area occupying most of lower half	-Mostly confined on the western part of Africa and found foraging in flowers of *Cissus* spp., *Dialium soyauxii, Indigofera* spp	na	na	na	na
Cleptotrigona cubiceps (Friese, 1912)	Ghana, Gabon	-Very small and dark brown stingless bee without a corbicula -Velvety vestiture on the scutum -Relatively large and shiny head	-Mostly confined on the western part of Africa -Mostly found wherever its host occurs since it cleptoparasitises on *Hypotrigona*	1.3	0.8	3.2	3.5–4.0
Liotrigona gabonensis (Pauly and Anguilet 2013)	Ghana, Gabon	Black to orangish-yellow mandible and labrum, legs and metasoma. Dull scutum to slightly shiny punctures	-Nests in trees -Mostly confined to the western part of Africa	na	na	na	na

Note. **H** – head, S- scutum, **F** – forewing, **B** – body, **na** – non-available data. Source: Aidoo et al. (2011); Eardley (2004); Nkoba et al. (2016); Wille (1983); Kerr and Maule (1964); Pauly and Fabre Anguilet (2013).

pool of initially selected documents, the study used a total of 90 relevant documents which were then used for this review. This study reviewed literature covering 44 years (from 1977 to 2021).

Findings and Discussion

Stingless bees species habitat and distribution within African savanna ecosystems. Stingless bee species are quite small in size and look like small flies (Ascher & Pickering, 2010; Crewe et al., 1994; Eardley, 2004). The review showed that stingless bees are widely distributed within the African savanna ecosystem and their range does not extend into the Palaearctic region of Africa (Ascher & Pickering, 2010, Eardley, 2004; Kerr & Maule, 1964) (Table 1). A study by Eardley (2004) established that stingless bees belong to the *Meliponini* tribe and are social insects. There are six genera of stingless bees, comprised of 19 species that have been recorded in Africa (Eardley, 2004; Nkoba et al., 2016). Five of the stingless bees genera, that is, *Meliponula* (Cockerell), *Dactylurina* (Cockerell), *Plebeina* (Moure), *Liotrigona* (Moure) *and Hypotrigona* (Cockerell) workers collect nectar and pollen from flowers (Ascher & Pickering, 2010; Eardley, 2004; Nkoba et al., 2016). The genus *Cleptotrigona* (Moure) is known for robbing honey and pollen from other stingless bee species (Eardley, 2004). These bee species differs significantly in colour, size and other characteristics, for example, *H. gribodoi* is pale in colour while *M. lendliana* is black. *Meliponula ferruginea* has two distinctive colours, that is, black and brown. *Meliponula nebulata* has black in colour with a distinctive yellow spot on the head. In terms of sizes, *Meliponula bocandei* (9 mm) and *M. nebulata* (7 mm) are generally bigger species and *H. gribodoi* is smaller (2–3 mm) (Kajobe, 2007). Stingless bees have different nests sites

Figure 1. *Plebeina hildebrandti* nesting sites and nest architecture within savanna ecosystem: (a) steep-sided termite mound, (b) stingless bees nest within termite mound, (c) *Plebeina hildebrandti* entrance tube on a termite mound. Source: Namu (2008).

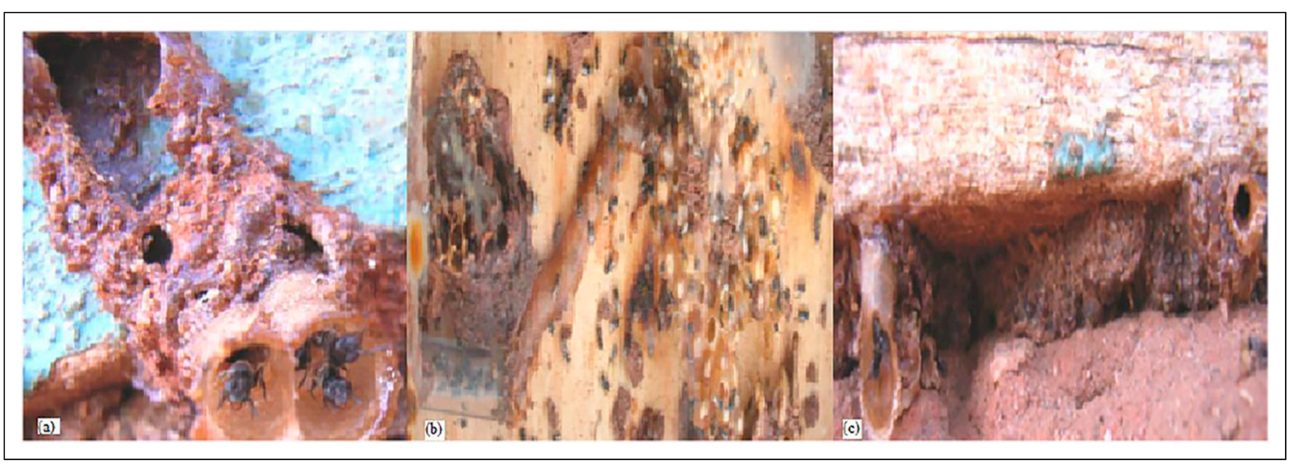

Figure 2. *Hypotrigona gribodoi* nesting sites and architecture within savanna ecosystem: (a) *Hypotrigona gribodoi* nest entry, (b) *Hypotrigona gribodoi* wooden nests, (c) *Hypotrigona gribodoi* colonies on the wall. Source: Namu (2008).

Table 2. Summary of *A. mellifera* sub-species species native to African savanna ecosystem.

Common English name	Scientific name	Geographical distribution	Physical characteristics	Tongue length (mm)	Behaviour			
					T	**S**	**A**	**Ab**
East African bees	*A.m. scutellata* (Lepeletier, 1836)	Burundi, Ethiopia, Kenya, South Africa, Tanzania, Zimbabwe	Small and slender body with intense yellow colour	5.9	St	St	St	St
Telian bees	*A.m.intermissa* (Buttel-Reepen, 1906)	South Africa	Long body, dark pigment and sparse hairs	6.4	St	St	St	St
	A.m. littorea (Smith, 1961)	Kenya, Tanzania	Small bees with relatively slender body having yellow tergites	5.7	St	St	St	St
Mountain Bees/ East African bees	*A.m. monticola* (Smith, 1961)	Mount regions of Ethiopia Kenya, Tanzania	Long body, with dark colour and long hairs	6.2	L	St	St	M
Cape bee	*A.m. capensis* (Eschscholtz, 1822)	Endemic to South Africa	Small with slender body and dark in colour	5.9	M	M	M	M
	A.m.nubica (Ruttner, 1988)	Sudan	Small with slender body and intense yellow colour	5.4	St	St	St	Na
Madagascar honeybee	*A.m. unicolor* (Latreille, 1804)	Madagascar	Small slender, body and dark in colour	5.6	L	L	L	M
Egyptian bees	*A.m. lamrckii* (Cockerell, 1906)	Sudan	Medium-sized, intense yellow colour and broad moments	5.7	M	M	M	St
West African bees	*A.m. adansonii* (Latreille, 1804)	Nigeria, Cote D'Ivoire, Cameroon, Nigeria, Uganda, Tanzania, Zambia, Sudan, Zimbabwe	Medium-sized, broad body with yellow markings	6.2	St	St	St	St
Arabian honeybee	*A.m.jemenitica* (Ruttner, 1988)	Uganda, Somalia, Sudan, Chad	Small, shorter setae and more yellow in colouration	5.3	Na	Na	Na	Na
Ethiopia honeybee	*A.m. simensis*	Ethiopia	Longer broad wings, larger than the *A.m. monticola and A.m.lamarckii*	5.8	Na	Na	Na	Na
	A.m. major (Ruttner, 1988)	Ethiopia	Body long, broad and dark with yellow markings	7.0	M	St	St	Na
	A.m.sahariensis (Baldensperger, 1932)	Ethiopia, Sudan	Bees are medium-sized, with a slender body with yellow markings	6.3	St	St	St	L
Dwarf honeybee	*Apis florea* (Frabricius, 1787)	Kenya	Dwarf shaped, a worker is typically 7–10 mm in body length and its overall colouration is red-brown	3.37	Na	Na	Na	Na

Note. **T** – temperament, **A** – aggressiveness, **S** – swarming, **Ab** – absconding, **St** – strong, **M** – medium, **L** – low, **Na** – non-available data Source: Gupta (2014); Hepburn et al. (2005); Neumann and Moritz (2002); Koeniger (1976).

preferences, design and architecture. Nest entrance diameter ranges from 2mm to 20 mm. In most cases, the entrances for *M. bocandei* are funnel-shaped or V-shaped whereas the entrance of other species for example *H. ferruginea*, *M. lendliana* and *M. nebulata* are circular shaped (Kajobe, 2007).

Stingless bees nest in tree cavities, mounds, burrowed soil surfaces, man-made structures like walls of mud or cracks of buildings, drainage pipes, and poles among others (Figure 2) (Eardley, 2004; Nkoba et al., 2016; Tarakini et al., 2021). In natural habitats, trees form the major sources of nest sites (Kajobe, 2007). *M. bocandei* and *M. lendliana* have a wide range of nesting sites as they can nest in both tree cavities, termite mounds and the ground within protected areas and non-protected areas ecosystems (Fabre Anguilet et al., 2018; Gikungu, 2006; Kajobe, 2007). Some of the stingless bees nests are very difficult to locate due to their small sizes (Gikungu, 2006; Nkoba et al., 2016). Most stingless bees nests are clustered in small uniform globular cells of wax and their larva are reared within these cells (Eardley, 2004; Nkoba et al., 2016; Namu, 2008) (Figures 1 and 2). Apart from that, many stingless bees species store pollen and honey in conspicuously large oval cells which are constructed close to the brood cell clusters

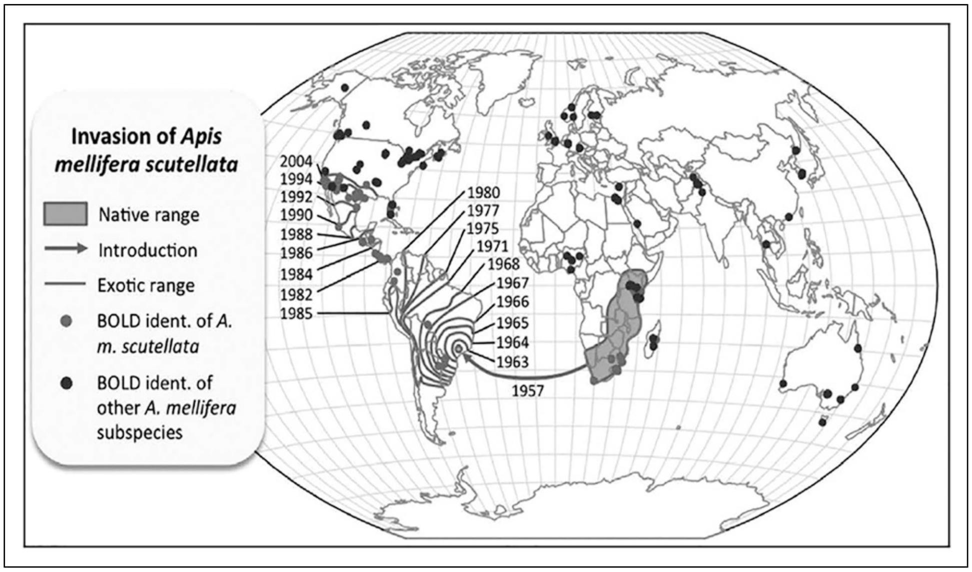

Figure 3. Distribution and invasion of *Apis m scutellata* and their subspecies in Africa and other parts of the world Source: Moritz et al. (2005).

(Figure 1b) (Crewe et al., 1994; Eardley, 2004; Macharia et al., 2007; Roubik, 1999). Nests sites for other species, for example, the *M. bocandei* and *M. lendliana* are not sheltered from rain and other adverse weather conditions however their nests entry tubes can divert water away and the nests will be insulant (Gikungu, 2006; Kajobe, 2007, 2008). In terms of altitude and nest height selection, *M. bocandei* and *M. ferruginea* generally prefers higher altitude and higher nesting sites (Fabre Anguilet et al., 2018; Njoya, 2009). Nests sites selection is mainly determined by the availability of forage and protection from natural hazards and predators (Kajobe, 2007, 2008).

Meliponula beccarii finds habitat in both protected and non-protected areas. *M. beccarii* prefer to nets in Eucalyptus plantations and open farmlands in non-protected areas (Kajobe, 2007, 2008). These bee species are known of their ability to cohabit with small white ants and some little beetles, however, it is not known if it is able to construct the cavities from which they fix their nests (Kajobe, 2007, 2008; Njoya, 2009). *M. beccarii* are built in the soil and exhibit architectural features which are typical to other genera which nest on the ground, for example, the *Plebeina*. The *Dactylurina staudingeri* in trees with exposed nests. *D. staudingeri* colonies are sited in fruit trees near bushes or infrastructures (Kajobe, 2007, 2008). The bee species is generally aggressive and in some cases, birds nests close to *D. staudingeri* nests for protection (Kajobe, 2007, 2008).

Meliponula ferruginea and *M. bocandei* nests in tree cavities and slightly above ground surfaces (Njoya, 2009; Roubik, 1999). In some cases, *M. ferruginea* and *M. bocandei* nest in artificial hollow hives used for honeybees (Njoya, 2009). The *M. ferruginea* species are capable of making their own cavities inside tree trunks (Njoya, 2009). The *M. bocandei* prefers warm temperature habitats especially savanna bushes with sparse tree distribution (Njoya, 2009). *M. bocandei* collects a wide range of pollen from the surrounding habitats (Njoya, 2009; Pauly & Hora, 2013). *Liotrigona bottegoi* species are capable of nesting in a wide range of sites for example crevices, walls bamboos and roofs of houses and abandoned hives (Njoya, 2009; Pauly & Hora, 2013). *Hypotrigona gribodoi* prefers to nest in tree branches and forages on a wide range of flowers (Njoya, 2009; Kajobe, 2008. *H. gribodoi* also nests in wall crevices in close proximity to each other and this suggests that there is limited intra-specific nesting competition (Aidoo et al., 2011; Kajobe, 2007; Kajobe, 2008; Njoya, 2009). The African savanna ecosystem is endowed with several stingless bees and honeybee species (Gupta, 2014; Nkoba et al., 2016). Some bee species are native in some parts of African countries, others are endemic to certain regions and others could have migrated naturally due to high capabilities of adaption. This review established a total of 21 stingless bee species in African savanna ecosystems (Table 1)

Honeybee species, habitat and distribution within African savanna ecosystems

The first scientific reports on African races of honeybees were given at the beginning of the 19th century (Gupta, 2014; Ruttner, 1988; Moritz et al., 2005). Most reports on honeybees within the savanna ecosystem were mere short, imprecise descriptions and no diagnosis was made. The first meaningful honeybees clarification using nomenclature principles was done by German entomologist von Buttel-Reepen in 1906 (Ruttner, 1988). Literature reveals that there are 12 subspecies of *A. mellifera* which are found within the savanna ecosystem (Gupta, 2014; Amssalu et al., 2004; Ruttner, 1988) (Table 2 and Figure 3). Ruttner (1988) ascertained that flora and climate affected honeybee behaviour and morphology. The geographical races of honeybees are a result of natural selection and they are not the result of choice or breeding (Amssalu et al., 2004; Gupta, 2014). Geographical races are distinct units, representing different genotypes adapted to different environments (Ruttner, 1988). The eastern, western and southern part of the African savanna ecosystem is dominated by East African bees (*A.m. scutellata*) and Western African bees (*A. m. adansonii*) bee species (Ascher & Pickering, 2010; Michener, 2007; Neumann & Moritz, 2002). These species are smaller compared to the European honeybees and their colonies have more swarms (Meixner, 2010). The Egyptian bee (*A. mellifera lamarckii*) is a relatively defensive race commonly found in the lower Nile valley and has black with yellow abdominal bands. The Tellian bees (*A. m. intermissa*) were found in marginal areas of the Sahel and savanna ecosystem (Michener, 2007). *A. m. intermissa* is black and produces more propolis than *A.m. scutellata*. *A.m. scutellata* is the most commonly used species in beekeeping due to its ability to produce more honey, swarms less and it is not very aggressive like the *A m lamarckii* (Corner, 1985; Gallmann & Thomas, 2012; Gupta, 2014).

Accurate and precise differentiation between honeybee races of similar appearance is critical (Corona et al., 2005; Gupta, 2014; Taylor, 1977). Due to close similarities of some races of European honeybees and Asian honeybees with African honeybees races, a genetic assessment was recommended to effectively distinguish honeybee species (Meixner, 2010). The genus *Apis* had a great ability to colonise a wide variety of environments, ranging from tropical to cool temperate due to its capability to adapt to different environments and ecosystems (Gupta, 2014; Tarakini et al., 2021; Taylor, 1977).

Threats to habitat and distribution of common stingless bees and honeybee species in African savanna ecosystems.

Threats to stingless bees and honeybee species in African savanna ecosystems are mainly from habitat loss and predation (Greenleaf et al., 2007). Anthropogenic activities such as industrialisation, expansion of agricultural activities and human settlement, poaching destroy habitats needed by stingless bees and honeybees species (Alkire & Foster, 2011; Eardley, 2004; Gallai et al., 2009; Lazarina et al., 2017; Tarakini et al., 2021). Human activities such as honey harvesting destroy or disrupt bee colonies in their habitats (Brown et al., 2017; Byrne & Fitzpatrick, 2009; Fabre Anguilet et al., 2018; Isack & Reyer, 1989). Poor honey harvesting methods associated with predation from chimpanzees (*Pan troglodytes*) and honey badgers (*Mellivora capensis*) (De Lange et al., 2013; Kajobe et al., 2007) can contribute to the depopulation of certain species of bees species thus affecting their general distribution (Fabre Anguilet et al., 2018; Hobbs, 2004; Kajobe, 2008). More research needs to be conducted in African savanna ecosystems on the loss of bee colonies from the predation of nests and other wild animals. However, some countries have developed commercial and subsistence apiculture and meliponiculture projects and this has helped to reduce the impacts of predation. Despite threats from both humans and wildlife, intensive apiculture and meliponiculture projects positively affect the habitat and distribution of common stingless bees and honeybees species in African savanna ecosystems (Fabre Anguilet et al., 2018; Gibbs & Muirhead, 1998; Klein et al., 2007).

Pests and diseases pose a threat to the habitat and distribution of bee species in African savanna ecosystems. Prevalence of pests and diseases such as small hive beetles, invasive varroa mite and American Foulbrood (AFB) in African ecosystems affects bee colonies survival thus affecting their general distribution. A study in Tanzania bee colonies observed a high presence of varroa and there is limited data in other savanna African countries on pests and diseases prevalence and their impact on both honeybees and stingless bees. Although there is limited data on the extent of the impact of pests and diseases on both honeybees and stingless in African savanna ecosystems, there is a need for research into entomopathogens and parasites of such bee species on the continent (Fabre Anguilet et al., 2018; Kremen et al., 2007)

Agrochemicals pose a serious threat to stingless bees and honeybees species habitat and distribution in African savanna ecosystems (Donovan, 1980; Kearns & Inouye, 1997; Porrini et al., 1996; Seeley, 1995, 2003; Visscher & Seeley, 1989). Intensive agriculture has resulted in the high use of agrochemicals such as pesticides to control pests and diseases and herbicides to control weeds. The use of neonicotinoids poses a threat to bee conservation in both wild and agro-ecosystems. Neonicotinoids damage the central nervous systems of insects, causing paralysis, tremors and deaths in bees at very low doses. Agrochemicals cause impaired odour discrimination, poor communication dances and this affects honeybees general foraging behaviour (Kearns & Inouye, 1997; Porrini et al., 1996). Exposure to agrochemicals reduces worker bees foraging performance, especially pollen collection efficiency (Kearns & Inouye, 1997; Porrini et al., 1996). Agrochemicals are also associated with reduced brood development and colony success (Kearns & Inouye, 1997; Porrini et al., 1996). Reduced colony success and high mortalities from direct or indirect poisoning greatly affect stingless bees and honeybees distribution within savanna ecosystems (Kearns & Inouye, 1997; Porrini et al., 1996).

Multiple factors associated with climate change affect honeybees and stingless bees habitat and their distribution. Climate change destroys habitats or creates inhospitable conditions for many bee species (Tarakini et al., 2021). Variations in vegetation as a result of climate changes alter vegetation flowering times thus drastically reducing the chances of some bee species to forage on the pollen of certain plant species. An increase in temperature affects brooding thus affecting the bee colonies, low temperatures associated with overwintering increase bee mortalities thus affecting bee colony sizes (Fabre Anguilet et al., 2018).

Conclusion

African savanna ecosystems are endowed with several stingless bees and honeybee species. Some stingless bee species are widely distributed across the savanna ecosystem and some are confirmed within limited regions of the ecosystem. There have been limited studies on stingless bees and honeybee species in many African savanna ecosystems. Information on bee habitat and distribution is critical in establishing databases on species absence or presence and updating inventories. Morphological description has allowed the identification of many stingless bees and honeybee species; however, the molecular analysis will help to resolve taxonomic challenges. The study revealed a total of 21 stingless bee species, 13 honeybee subspecies and one honeybee species found within the African savanna ecosystem. Due to limited studies in some African savanna ecosystems, stingless bees and honeybees were not reported in such countries thus causing bias in formation on their population and distribution. More studies on potential treats to stingless and honeybees should be strengthened in Africa considering the challenges of high habitat degradation. Anthropogenic activities from urbanisation, use of agrochemicals in agriculture and deforestation need to be closely monitored on their impact on bee habitat and distribution. Natural factors such as climate change, pests and diseases pose a threat to bee habitat and distribution and their impact must be assessed in many African savanna ecosystems. In addition, predation of stingless bees and honey bees from wild animals like honey badgers and chimpanzees as well as from humans needs to be evaluated to assess the impact. The future of stingless and honeybees conservation depends on the understanding of economic and ecological benefits through the formulation of policies that ensures the protection of habitats and best environmental management practices within savanna ecosystems.

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References

Aidoo, K., Kwapong, R. C., & Karikari, I. A. (2011). Stingless bees in Ghana. *Bees for Development Journal*, *100*, 10-11. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.663.530&rep=rep1&type=pdf. Accessed 10 January 2022.

Alkire, S., & Foster, J. (2011). Understandings and misunderstandings of multidimensional poverty measurement. *The Journal of Economic Inequality*, *9*(2), 289-314. http://dx.doi.org/10.1007/s10888-011-9181-4.

Amssalu, B., Nuru, A., Radloff, S. E., & Randall Hepburn, H. (2004). Multivariate morphometric analysis of honeybees (*Apis mellifera*) in the Ethiopian region. *Apidologie*, *35*(1), 71-81. http://dx.doi.org/10.1051/apido:2003066

Ascher, J.S., & Pickering, J. (2010). Bee species guide (Hymenoptera: Apoidea: Anthophila). https://www.discoverlife.org/mp/20q?guide=Apoidea_species. (accessed on 20 July 2021).

Bailey, L., Ball, B. V., & Perry, J. N. (1983). Association of viruses with two protozoal pathogens of the honey bee. *Annals of Applied Biology*, *103*(1), 13-20. https://doi.org/10.1111/j.1744-7348.1983.tb02735.x

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27-40. https://doi.org/10.3316/qrj0902027

Brodschneider, R., & Crailsheim, K. (2010). Nutrition and health in honey bees. *Apidologie*, *41*(3), 278-294. https://doi.org/10.1051/apido/2010012

Brown, J., York, A., Christie, F., & McCarthy, M. (2017). Effects of fire on pollinators and pollination. *Journal of Applied Ecology*, *54*(1), 313-322. https://doi.org/10.1111/1365-2664.12670

Byrne, A., & Fitzpatrick, Ú. (2009). Bee conservation policy at the global, regional and national levels. *Apidologie*, *40*(3), 194-210. https://doi.org/10.1051/apido/2009017

Chuma, M., Mushuku, A., Chirenje, L., Chitongo, L., & Mudyariwa, R. (2013). Livelihood resilient strategies through beekeeping in Chitanga village, Mwenezi District, Zimbabwe. *Sustainable Agriculture Research*, *2*, 526-201637897. http://dx.doi.org/10.22004/ag.econ.231342.

Corner, J. (1985). Apiculture and bee management problems in African countries. Nov *1984/hosted by the Government of Kenya; convened by* (pp. 41-44). : *the International Bee Research Association. Proceedings of the Third International Conference on Apiculture in Tropical Climates*. https://agris.fao.org/agris-search/search.do?recordID=US201302067416. Accessed 05 February 2022.

Corona, M., Hughes, KA., Weaver, DB., & Robinson, GE. (2005). Gene expression patterns associated with Queen honey bee longevity. *Mechanisms of Aging and Development*, *126*(11), 1230-1238. https://doi.org/10.1016/j.mad.2005.07.004

Crewe, R. M., Hepburn, H. R., & Moritz, R. F. A. (1994). Morphometric analysis of 2 southern African races of honey bee. *Apidologie*, *25*(1), 61-70. https://doi.org/10.1051/apido:19940107

De Lange, WJ, Veldtman, R, & Allsopp, MH (2013). Valuation of pollinator forage services provided by Eucalyptus cladocalyx. *Journal of Environmental Management*, *125*, 12-18. https://doi.org/10.1016/j.jenvman.2013.03.027

Deyrup, M, Ediringhe, J, & Norden, B (2002). The diversity and floral hosts of bees at the Archbold Biological Station, Florida (Hymenoptera: Apoidea). *Insecta Mundi*, *16*, 87-120. https://digitalcommons.unl.edu/insectamundi/544. Accessed 05 February 2022.

Donovan, R.E. (1980). *Hunting wild bees*. Winchester Press. https://www.cabdirect.org/cabdirect/abstract/19820213164. Accessed 05 February 2022.

Eardley, C.D (2004). Taxonomic revision of the African stingless bees (Apoidea:Apidae:Apinae): Meliponini. *African Plant Protection*, *10*(2), 63-96. http://zoologie.umons.ac.be/hymenoptera/biblio/01000/eardley2004_3234.pdf. Accessed 05 February 2022.

Fabre Anguilet, E. C., Alabi, T., Nguyen, B. K., Ndong Bengone, T., Haubruge, É., & Francis, F. (2018). Stingless Bees (Hymenoptera, Apoidea, Meliponini) from Gabon. *Pot-pollen in stingless bee melittology* (pp. 179-188). : Springer. http://dx.doi.org/10.1007/978-3-319-61839-5_13

Fitzpatrick, U, Murray, TE, Paxton, RJ, & Brown, MJ (2007). Building on IUCN regional red lists to produce lists of species of conservation priority: a model with Irish bees. *Conservation Biology*, *21*(5), 1324-1332. https://doi.org/10.1111/j.1523-1739.2007.00782.x

Free, J. B. (1970). *Insect pollination of crops*. Academic Press. https://doi.org/10.1017/S0014479700023401.

Free, J. B. (1993). *Insect pollination of crops* (p. 768). Academic Press. https://www.cabdirect.org/cabdirect/abstract/19930233533. Accessed 06 February 2022.

Gallai, N., Salles, J.-M., Settele, J., & Vaissière, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics*, *68*(3), 810-821. https://doi.org/10.1016/j.ecolecon.2008.06.014

Gallmann, P., & Thomas, H. (2012). *Beekeeping and honey production in southwestern Ethiopia* (pp. 1-24). Ethiopia Honey Bee Invest. https://silo.tips/download/beekeeping-and-honey-production-in-southwestern-ethiopia. Accessed 06 February 2022.

Gardiner, R. A. W. (2004). Current trends regarding Eucalyptus species for commercial use and nectar production. *South African Bee Journal*, *76*, 44-47. https://wcba.co.za/wp-content/uploads/2020/03/gumreport.pdf. Accessed 06 February 2022.

Gels, JA, Held, DW, & Potter, DA (2002). Hazards of Insecticides to the Bumble Bees Bombus impatiens (Hymenoptera: Apidae) Foraging on Flowering White Clover in Turf. *Journal of Economic Entomology*, *95*(4), 722-728. https://doi.org/10.1603/0022-0493-95.4.722

Genersch, E (2010). Honey bee pathology: current threats to honey bees and beekeeping. *Applied Microbiology and Biotechnology*, *87*(1), 87-97. https://doi.org/10.1007/s00253-010-2573-8

Gibbs, D. M., & Muirhead, I. F. (1998). The economic value and environmental impact of the Australian beekeeping industry. *A Report Prepared for the Australian Beekeeping Industry*, *30*.

Gikungu, M. W. (2006). Bee diversity and some aspects of their ecological interactions with plants in a successional tropical community. PhD Dissertation (p. 201). University of Bonn. https://nbn-resolving.org/urn:nbn:de:hbz:5N-08385. Accessed 10 February 2022.

Greenleaf, SS, Williams, NM, Winfree, R, & Kremen, C (2007). Bee foraging ranges and their relationship to body size. *Oecologia*, *153*(3), 589-596. http://dx.doi.org/10.1007/s00442-007-0752-9

Gupta, R. K. (2014). Beekeeping for Poverty Alleviation and Livelihood Security. In R. K Gupta, W Reybroeck, J. W van Veen, & A Gupta(Eds), *Beekeeping for poverty alleviation and livelihood security*. : Springer. [Internet] https://doi.org/10.1007/978-94-017-9199-1.

Henry, M, Béguin, M, Requier, F, Rollin, O, Odoux, JF, Aupinel, P, Aptel, J, Tchamitchian, S, & Decourtye, A (2012). A common pesticide decreases foraging success and survival in honey bees. *Science*, *336*(6079), 348-350. https://doi.org/10.1126/science.1215039

Hepburn, H. R., & Radloff, S. E. (1996). Beeswax exports and rainfall in the savanna woodlands of east-central Africa. *Apidologie*, *27*(6), 473-478. https://doi.org/10.1051/apido:19960606

Hepburn, H. R, & Radloff, S. E. (1998). *Honey bees of Africa* (p. 370). Springer-Verlag. https://doi.org/10.1007/978-3-662-03604-4.

Hepburn, H. R., Radloff, S. E., Otis, G. W., Fuchs, S., Verma, L. R., Ken, T., Chaiyawong, T., Tahmasebi, G., Ebadi, R., & Wongsiri, S. (2005). Apis florea: morphometrics, classification and biogeography. *Apidologie*, *36*(3), 359-376. https://doi.org/10.1051/apido:2005023

Hobbs, R. J. (2004). The Working for Water Programme in South Africa: the Science behind the success. *Diversity and Distribution*, *10*(5-6), 501-503. http://dx.doi.org/10.1111/j.1366-9516.2004.00115.x

Hutton-Squire, J. P. (2014). Historical relationship of the honeybee (Apis mellifera) and its forage; and the current state of beekeeping within South Africa. Doctoral dissertation. : Stellenbosch University. http://hdl.handle.net/10019.1/96092. Accessed 10 February 2022.

Isack, HA, & Reyer, HU (1989). Honeyguides and honey gatherers: interspecific communication in a symbiotic relationship. *S*cience, *243*(4896), 1343-1346. https://doi.org/10.1126/science.243.4896.1343

Johannsmeier, M. F. (2001). Honey sources of the South-Western Cape as inferred from pollen analysis of honey samples. *South African Bee Journal*, *73*, 31-35.

Johannsmeier, M. F. (2007). Notes on trees as beeplants in South Africa. *South African Bee Journal*, *79*, 59-64. https://www.semanticscholar.org/paper/Beeplants-of-South-Africa%3A-sources-of-nectar%2C-and-Johannsmeier/a88189e6c6d44b67bf9b52f5bd375770988bd22e. Accessed 10 February 2022.

Kajobe, R. (2007). Nesting biology of equatorial Afrotropical stingless bees (Apidae; Meliponini) in Bwindi Impenetrable National Park, Uganda. *Journal of Apicultural Research*, *46*(4), 245-255. https://doi.org/10.1080/00218839.2007.11101403

Kajobe, R. (2008). *Foraging behaviour of equatorial afrotropical stingless bees: Habitat selection and competition for resources. Doctoral dissertation*. Utrecht University repository. https://mafiadoc.com/download/foraging-behaviour-of-equatorial-afrotropical-stingless-beeshabitat-_5a7804781723dd4a0abf9fae.html. Accessed 10 February 2022.

Kearns, C. A., & Inouye, D. W. (1997). Pollinators, flowering plants, and conservation biology. *Bioscience*, *47*(5), 297-307. http://dx.doi.org/10.2307/1313191

Kearns, C. A., Inouye, D. W., & Waser, N. M. (1998). Endangered mutualisms: the conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics*, *29*(1), 83-112. http://dx.doi.org/10.1146/annurev.ecolsys.29.1.83

Kerr, W. E., & Maule, V. (1964). Geographic distribution of stingless bees and its implications (Hymenoptera: Apidae). *Journal of the New York Entomological Society*, *72*, 2-18.

Kevan, P. G., & Viana, B. F. (2003). The global decline of pollination services. *Biodiversity*, *4*, 38. https://doi.org/10.1080/14888386.2003.9712703

Klein, AM, Vaissière, BE, Cane, JH, Steffan-Dewenter, I, Cunningham, SA, Kremen, C, & Tscharntke, T (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303-313. https://doi.org/10.1098/rspb.2006.3721

Knight, ME, Martin, AP, Bishop, S, Osborne, JL, Hale, RJ, Sanderson, RA, & Goulson, D (2005). An interspecific comparison of foraging range and nest density of four bumblebee (*Bombus*) species. *Molecular Ecology*, *14*(6), 1811-1820. https://doi.org/10.1111/j.1365-294X.2005.02540.x

Koeniger, N. (1976). Interspecific competition between Apis florea and Apis mellifera in the tropics. *Bee World*, *57*(3), 110-112. https://doi.org/10.1080/0005772X.1976.11097604

Kremen, C, Williams, NM, Aizen, MA, Gemmill-Herren, B, LeBuhn, G, Minckley, R, Packer, L, Potts, SG, Roulston, T, Steffan-Dewenter, I, Vázquez, DP, Winfree, R, Adams, L, Crone, EE, Greenleaf, SS, Keitt, TH, Klein, AM, Regetz, J, & Ricketts, TH (2007). Pollination and other ecosystem services provided by mobile organisms: conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299-314. https://doi.org/10.1111/j.1461-0248.2007.01018.x

Lazarina, M., Sgardelis, S. P., Tscheulin, T., Devalez, J., Mizerakis, V., Kallimanis, A. S., Papakonstantinou, S., Kyriazis, T., & Petanidou, T. (2017). The effect of fire history in shaping diversity patterns of flower-visiting insects in post-fire Mediterranean pine forests. *Biodiversity and Conservation*, *26*(1), 115-131. https://doi.org/10.1007/s10531-016-1228-1

Lietaer, C. (2009). Impact of beekeeping on forest conservation, preservation of forest ecosystems and poverty reduction. (pp. 18-23). XIII world forestry congress. https://www.semanticscholar.org/paper/Impact-of-beekeeping-on-forest-conservation%2C-of-and-Lietaer/3e6bfbff0fd288a8d1c28fad769ed9e70d80ff04. Accessed 10 February 2022.

Macharia, J., Raina, S., & Muli, E. (2007). Stingless Bees in Kenya. *Bees for Development Journal*, *83*, 1-9.

Meixner, M. D. (2010). A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology*, *103*, S80-S95. https://doi.org/10.1016/j.jip.2009.06.011.

Michener, C. D. (2007). *The bees of the world* (p. 913). The John Hopkins University Press. https://jhupbooks.press.jhu.edu/title/bees-world. Accessed 10 February 2022.

Moritz, R. F. A., Härtel, S., & Neumann, P. (2005). Global invasions of the western honeybee (Apis mellifera) and the consequences for biodiversity. *Ecoscience*, *12*(3), 289-301. http://dx.doi.org/10.2980/i1195-6860-12-3-289.1

Morse, R. A, & Calderone, N. W. (2000). The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture*, *128*, 1-15.

Namu, F. N. (2008). The possible role of stingless bees in the spread of banana Xanthomonas wilt. *Uganda and the nesting biology of Plebeina hildebrandti and Hypotrigona gribodoi (Hymenoptera-Apidae-Meliponini)*. PhD dissertation. University of Bonn.

Naug, D. (2009). Nutritional stress due to habitat loss may explain recent honeybee colony collapses. *Biological Conservation*, *142*(10), 2369-2372. https://doi.org/10.1016/j.biocon.2009.04.007

Neumann, P., & Moritz, R. (2002). The Cape honeybee phenomenon: the sympatric evolution of a social parasite in real time?. *Behavioural Ecology and Sociobiology*, *52*(4), 271-281. https://doi.org/10.1007/s00265-002-0518-7

Njoya, M. T. M. (2009). *Diversity of stingless bees in Bamenda Afromontane forests– Cameroon: Nest architecture, behaviour and labour calendar*. Doctoral dissertation. Hohen Landwirtschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität zu Bonn. http://hss.ulb.uni-bonn.de/2010/1993/1993.pdf.

Nkoba, K., Raina, S. K., & Langevelde, F. (2016). A vertical compartmented hive design for reducing post-harvest colony losses in three afrotropical stingless bee species (*Apidae: Meliponinae*). *International Journal of Development Research*, *6*, 9026-9034.

Oldroyd, BP (2007). What's killing American honey bees?. *Plos Biology*, *5*(6), e168. https://doi.org/10.1371/journal.pbio.0050168

Patiny, S., & Michez, D. (2007). Biogeography of bees (Hymenoptera, Apoidea) in Sahara and the Arabian deserts. *Insect Systematics & Evolution*, *38*(1), 19-34. https://doi.org/10.1163/187631207788784012.

Pauly, A., & Fabre Anguilet, E. (2013). Description de Liotrigona gabonensis sp. nov., et quelques corrections à la synonymie des espèces africaines de mélipones (Hymenoptera: Apoidea: Apinae: Meliponini). *Belgian Journal of Entomology*, *15*, 1-13.

Pauly, A., & Hora, Z. A. (2013). Apini and Meliponini from Ethiopia (Hymenoptera: Apoidea: Apidae: Apinae). *Belgian Journal of Entomology*, *16*, 1-35.

Porrini, C, Colombo, V, & Celli, G. (1996). The honey bee (Apis mellifera L.) as pesticide bioindicator. Evaluation of the degree of pollution by means of environmental hazard indexes. In: Proceedings XX International Congress of Entomology, Firenze, Italy, August 25, 1996, 444.

Porrini, C., Ghini, S., Girotti, S., Sabatini, A. G., Gattavecchia, E., & Celli, G. (2002). *Use of honey bees as bio-indicators of environmental pollution in Italy* (pp. 186-247). : Taylors & Francis Inc..

Potts, SG, Biesmeijer, JC, Kremen, C, Neumann, P, Schweiger, O, & Kunin, WE (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution*, *25*(6), 345-353. https://doi.org/10.1016/j.tree.2010.01.007

Rigg, J. (2006). Land, farming, livelihoods, and poverty: rethinking the links in the rural South. *World Development*, *34*(1), 180-202. https://doi.org/10.1016/j.worlddev.2005.07.015

Riley, J. R., Smith, A. D., Reynolds, D. R., Edwards, A. S., Osborne, J. L., Williams, I. H., Carreck, N. L., & Poppy, G. M. (1996). Tracking bees with harmonic radar. *Nature*, *379*(6560), 29-30. https://doi.org/10.1038/379029b0

Rodríguez-Pose, A, & Hardy, D (2015). Addressing poverty and inequality in the rural economy from a global perspective. *Applied Geography*, *61*, 11-23. https://doi.org/10.1016/j.apgeog.2015.02.005.

Roubik, D. W. (1999). The foraging and potential outcrossing pollination ranges of African honey bees (Apiformes: Apidae; Apini) in Congo Forest. *Journal of the Kansas Entomological Society*, *72*, 394-401.

Rukuni, M., Tawonezvi, P., Munyuki-Hungwe, M., & Matondi, P. B. (Eds), *Zimbabwe's agricultural revolution revisited* (2006). Harare: University of Zimbabwe publications.

Ruttner, F. (1988). Morphometric Analysis and Classification. *Biogeography and taxonomy of honeybees* (pp. 66-78). : Springer. https://doi.org/10.1007/978-3-642-72649-1_6

Schmidt, L. S., Schmidt, J. O., Rao, H., Wang, W., & Xu, L. (1995). Feeding preference and survival of young worker honey bees (Hymenoptera: Apidae) fed rape, sesame and sunflower pollen. *Journal of Economic Entomology*, *88*(6), 1591-1595. https://doi.org/10.1093/jee/88.6.1591

Seeley, T. D. (1995). *The wisdom of the hive*. Harvard University Press. https://www.hup.harvard.edu/catalog.php?isbn=9780674953765. Accessed 10 February 2022.

Seeley, T. D. (2003). Consensus building during nest-site selection in honey bee swarms: the expiration of dissent. *Behavioral Ecology and Sociobiology*, *53*(6), 417-424. https://doi.org/10.1007/s00265-003-0598-z

Strickland, S. S. (1982). Honey hunting by the Gurungs of Nepal. *Bee World*, *63*(4), 153-161. https://doi.org/10.1080/0005772x.1982.11097889

Tarakini, G, Chemura, A, Tarakini, T, & Musundire, R (2021). Drivers of diversity and community structure of bees in an agroecological region of Zimbabwe. *Ecology and Evolution*, *11*(11), 6415-6426. https://doi.org/10.1002/ece3.7492

Taylor, O. R. Jr (1977). The past and possible future spread of Africanized honeybees. *Americas.* Bee World, *58*(1), 19-30. https://doi.org/10.1080/0005772X.1977.11097632

Thomas, D. R. (2006). A general inductive approach for analysing qualitative evaluation data. *American Journal of Evaluation*, *27*(2), 237-246. https://doi.org/10.1177%2F1098214005283748

Vet, L. E. M. (2001). Parasitoid searching efficiency links behaviour to population processes. *Applied Entomology and Zoology*, *36*(4), 399-408. https://doi.org/10.1303/aez.2001.399

Visscher, P.K, & Seeley, T.D. (1989). Bee-Lining as a Research Technique in Ecological Studies of Honeybees. *American Bee Journal*, *129*, 536-539. https://www.cabi.org/ISC/abstract/19900228410. Accessed 10 February 2022.

Wille, A. (1983). Biology of the stingless bees. *Annual Review of Entomology*, *28*(1), 41-64. https://doi.org/10.1146/annurev.en.28.010183.000353