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Honey Bee Diversity in Urban and Peri-urban Agriculture and Urban Forest- Outlook Study from Bengaluru-Silicon Valley of India: A Review

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ABSTRACT

The "Silicon Valley" of India, Bengaluru is one of the fastest growing cities, with many middle-class residents growing fruits and vegetables in their private spaces. This kind of Localized food systems (LFS) has been considered not only for obtaining mental pleasure and health consciousness, but also food for home consumption. This outlook study examined the honey bee diversity and possibilities of integrating different honey bees in urban agriculture and forests across the Bengaluru city. The urban forestry study across the Bengaluru city revealed presence of 374 species with the highest species diversity in parks (291) followed by residential areas and layouts (164) showing species richness. *Polyalthia sp*. and *Pongamia glabra* were found to be the most dominated tree species around the Bangaluru city. Majority of the plant_species were offering good_foraging sources for honey bees, including *Apis indica*, *Apis dorsata*, *Apis florea* and *Trigona iridipennis*. The urban agriculture and urban forest system in the Bengaluru was ideal for bee-keeping, especially stingless bees, which could be easily reared with limited space and care. Thus, the urban agro-ecosystem and the possible pollination services through integrating honey bees could be very much useful in making the cities more sustainable and resilient.

Key words: Honey bee, Localized food system, Pollination services, Urban and peri-urban agriculture, Urbanization.

The pre-historic relationship between humans and honey bees exists based on long-standing interest (Cardinal and Danforth 2011; Kraft and Venkataraman 2015) of increasing crop production through pollination and maintain ecosystem stability, environmental quality and biodiversity (Abrol 2013). The Indian bee-keepers rear honey bees in a traditional system under semi-domesticated conditions amended with modern scientific practices (Kraft and Venkataraman 2015). Rearing of honey bees and harvesting of honey dates back to 7000 BC. and also known for the production of bee wax, bee venom, royal jelly and propolis besides production of honey. Honey bees plays an important role in natural pollination of cultivated as well as wild species of crop plants. Around 1/3rd of the total cultivated crops of the world were pollinated by different species of bees, of which, honeybees were the most effective and reliable ones (Abrol 2013). Even though bee keeping is considered as an agricultural activity, they do not require land or compete with other farm animals and possible in areas with flowering plants for nectar and pollen. Different forest sites, agricultural farms, fruit orchards, poly-houses, green-houses and recreational parks could be utilized effectively for beekeeping. Stingless bees are the eusocial insects like other honey bees and quite appreciated for the value of the honey, pollen as well as various ecosystem services. Stingless bees differ from other honey bees due to the presence of a vestigial sting, lack of venom, mass provisioning for larvae and multiple queen system and lack of wax glands. Meliponiculture is the beekeeping method of stingless bees usually undertaken by traditional communities or local people (Vazhacharickal and Jose 2016). Honey, pollen and resin are the important source of income in meliponiculture. The nests of stingless bees could be seen in building foundations, mud walls, stone walls and tree cervices. *Tetragonula iridipennis* is an important species of stingless bees, whose name appears due to triangular abdomen and iridescent wings. For building nest, they collect resins from trees which makes them called as Dammer bees (Vazhacharickal and Jose, 2018). Much importance are given to the large scale production of *Apis indica* and *Apis*

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mellifera in Karnataka. Very little scientific studies were conducted in stingless bees in Bengaluru (Roopa *et al*. 2020). Stingless bees were much far ahead of medicinal properties of honey and plant pollination when compared to other honey bee.

Urbanization

Urbanization is a rapid process with historic transformation on a global scale with the replacement of rural culture with urban culture. Migration has a key role in this transitions, which is mainly governed by push factors and pull factors (Cohen 2006; Timalsina 2007; Satterthwaite *et al*. 2010; Vazhacharickal 2014). Urbanization brings spatial, economic, social, demographic and environmental changes with positive and as well as negative aspects (Weber and Puissant 2003; Nath 2007; Vazhacharickal 2014). According to UN (United Nations), it was predicted that 68% of the world population occupy in the urban areas by the year 2050 (UN 2019).

Urban and peri-agriculture

Urban and peri-urban agriculture (UPA) can be broadly defined as the production, processing and distribution of foodstuff from crop and animal production, fish and ornamental flowers within and around urban areas (Mougot 2000). The acronym UPA has been introduced by the Food and Agricultural Organization (FAO) and UPA mainly focuses on perishable and highly valuable products in limited spaces (Nugent 2000; De Zeeuw *et al*. 2011). The UPA fills the hunger gaps by enhancing the access and distribution of food in urban areas (Lee-Smith 2010). Currently, urban agriculture is being practiced for meeting subsistence needs, as a market-oriented activity, for recreation, or as a combination of all these components (Vazhacharickal *et al*., 2020).

Bengaluru: The silicon valley of India

Bengaluru, the capital of Karnataka State, is a rapidly growing megacity with a population > 10 million. The study area (2182 km^2) comprises of the Bengaluru Urban district, situated at an altitude between 875 and 940 m above sea level (a.s.l) (Fig 1). The climate is favourable with a mean annual rainfall of approx. 880 mm and a monsoon season lasting from June to October (Ramachandra and Kumar, 2008). Due to its large number of open green spaces and a

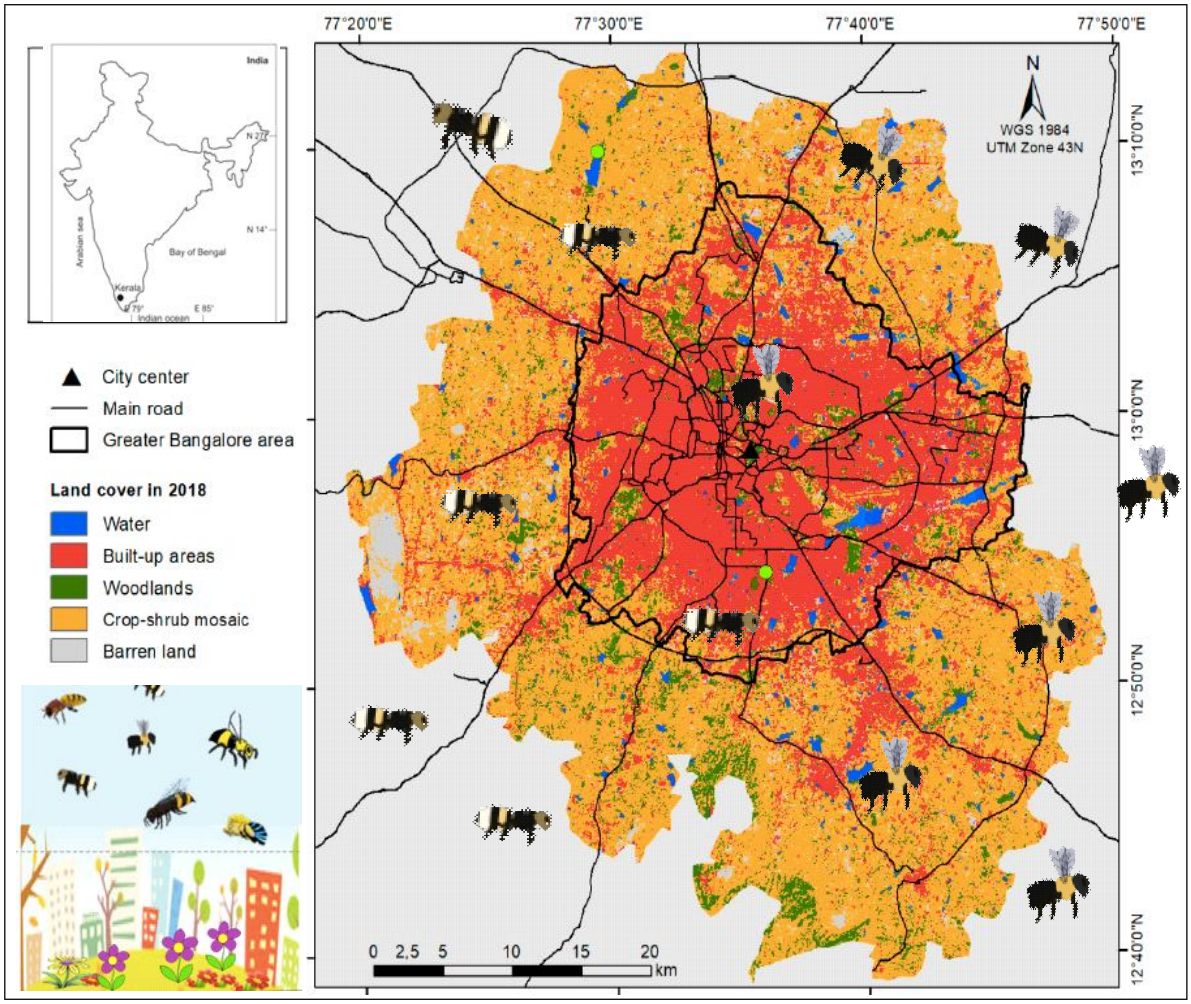

Fig 1: Overview of the Bengaluru urban districts showing the land cover classification. Modified after: Brinkmann *et al*. (2020).

large series of partly interconnected wetlands and water bodies, the city was historically well known as the "Garden City" or "City of Lakes" (Sudhira *et al*., 2007).

Urban and peri-urban agriculture: Bengaluru scenarios

Little is known about the various UPA productions systems in Bengaluru. A study conducted by Gowda *et al*. (2012) on Magadi; one of the true peri-urban area with strong agricultural base show that the proportion of the net income from agriculture and livestock to the total income raised. The cooperative horticultural marketing by HOPCOMS in Bengaluru is an example of collective marketing by farmers in the peri-urban areas. Urban agriculture in Bengaluru flourish with the support of Garden City Farmers Trust; NGO which support urban farming, which is similar to Dr. Doshi's city garden methods suitable to reduced spaces such as balconies and terraces which depend on locally available materials like sugarcane wastes, polyethylene bags and household organic wastes and are targeted towards mainly domestic consumption ((Vazhacharickal and Buerkert 2011). The need for housing increases the value of agricultural land in urban and peri-urban areas and leads to their rapid transformation (Vazhacharickal 2014; Hoffmann *et al*., 2017; Vazhacharickal *et al*., 2020).

Localized food systems

In the context of increasing urbanization and globalization of agricultural production and marketing, localized food systems (LFS) have emerged as a theoretical framework to imagine and order methods to address the effects and impacts. Growing cities can have profound positive or negative impacts on their surrounding food producing areas and trend that is most often observed, negative impacts on food and nutrition security resulting especially from increasing pressure on the natural resources required to feed the urban population (Grinspan 2015). Another opportunity of UPA to contribute to the localization of the food system rises from its direct access to urban consumers and markets, which facilitates the expansion of direct marketing arrangements (Vazhacharickal *et al*. 2020).

Middle class urban gardening

Gardening is becoming fashionable among people of the new middle-classes and Urban gardening has long been a

Fig 2: Description of the urban agriculture and urban forest across Bengaluru a) and d) avenue trees in GKVK and residential area; b: community park in flats; c) *Ricinus communis* in waste lands; e) and g) balcony gardens; f) terrace garden.

working-class practice in places such as Bengaluru (Fig 2, 3; Frazier 2018). India's new middle-class is elusive and consists of a heterogenous group of people who are generally high educated and well-travelled and who carve out a social position between elite and working classes through consumption and leisure practices (Fernandes and Heller 2006; van Holstein 2019; Vazhacharickal *et al*. 2020).

Organic terrace gardeners (OTGians)

An increasing number of middle class residents in Bengaluru are growing fruits and vegetables for home consumption, motivated primarily by concerns about worsening health and food safety conditions and secondarily by declining green spaces in the city. organic terrace gardeners, most of whom self-describe as "OTGians", a title that originated with the Organic Terrace Gardening (OTG) Facebook group. OTGians have created a vibrant community dedicated to sharing resources and knowledge about urban gardening, with the goal of reworking existing relations of food production and consumption in the city. Communication among members is mainly mediated through the group's FaceBook page and group identity is largely built on that platform (Grinspan 2015; Frazier 2018; Vazhacharickal *et al*. 2020).

Garden City Farmers Trust (GCF)

Garden City Farmers Trust (GCF) is officially registered as trust and started in activity way back in the year 1995 with the promotional work of its founder, Dr. B. N. Vishwanath. GCF's current major focus area is on promoting organic terrace and home gardening in the city of Bengaluru by conducting trainings and workshops, connecting

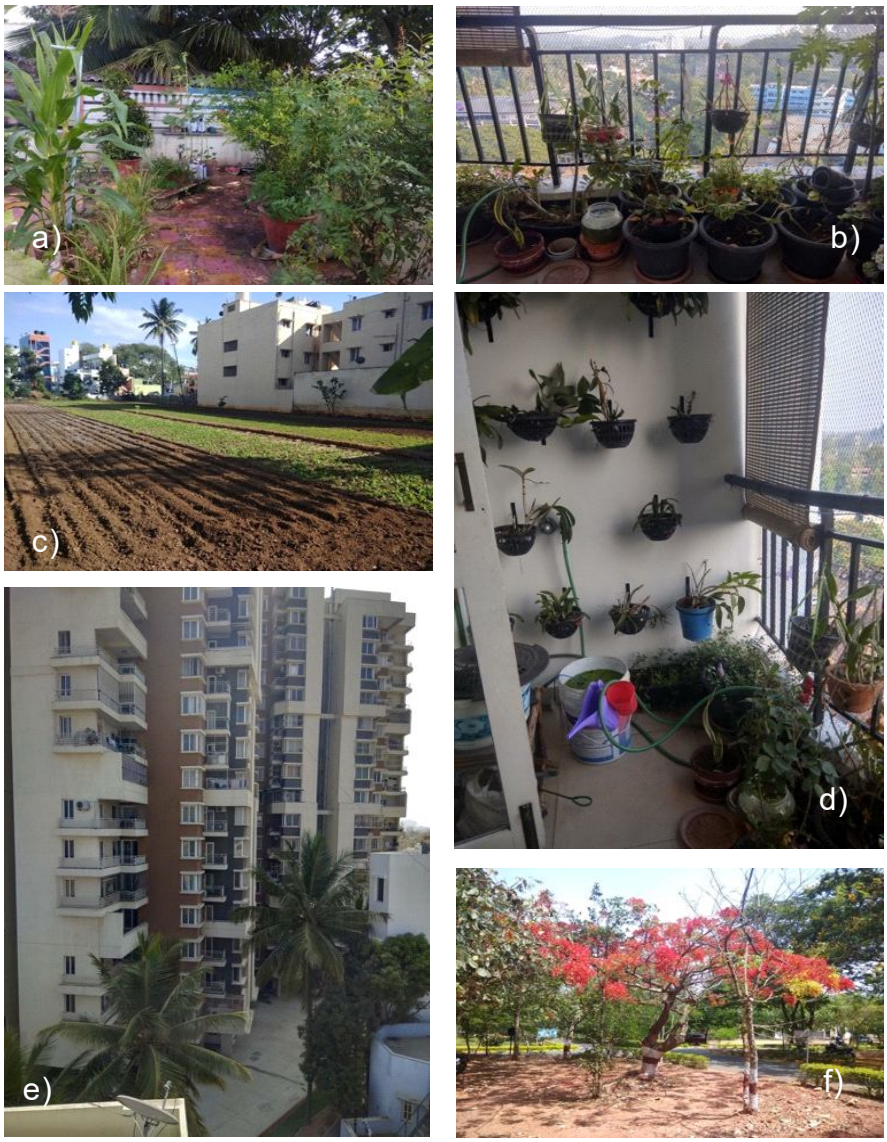

Fig 3: Description of a) terrace garden b) and d) balcony gardens c) urban agriculture practiced in vacant lands near to apartments e) flats showing balconies f) avenue trees with full blossom.

practitioners and resources and promoting awareness of urban food growing through national and state-level seminars with a motto “Grow What You Eat and Eat What You Grow”. The event “Oota From Your Thota” (or Food From Your Garden) is a quarterly event with a two-fold purpose: to bring urban practitioners and other interested people together to share their experiences and knowledge; and to connect urban gardeners and re-source provider (Grinspan 2015; Frazier 2018; Vazhacharickal *et al*. 2020).

Balcony and terrace gardens in Bengaluru

The Kannada term kaithota (literally “hand garden”) refers to kitchen gardens that are common in rural house-holds, where women plant a few fruits and vegetables for consumption and flowers for religious worship near the edges of their home. The term kaithota and the broader term thota, meaning garden or plantation, are sometimes used to describe urban home gardens. Most of the urban gardeners have their garden on the terrace/balconies of their house or apartment of flats (Fig 2, 3). Usually majority of the terrace gardens are container gardens which focus on ornamental plant and food plants especially vegetables, aromatic plants and fruit trees. The major input use and provisions include compost (kitchen waste and other brought outside), water (household supply), containers (plastic drums, vegetable wooden crats, used cement bags, old tyres and various styrofoam packing materials), cow dung and urine, neem oil cake and coco peat (Grinspan 2015; Frazier 2018; Vazhacharickal *et al*. 2020).

Urban green spaces

Urban green space provide an opportunity to increasing urban population to observe and interact with nature. Urban greenery and vegetations has a major role in providing ecosystem services, mental pleasure, satisfaction and social well-being of stressful urban life. Urban vegetation includes

Table 1: Trees recorded from single domestic gardens and shared apartment gardens in Bengaluru that are consumed as food and/or have medicinal use and/or religious significance and provision of foraging sources for honey bees. Modified after Jaganmohan *et al*. (2012).

Scientific name	Common name	Consumed as food	Medicinal use	Religious significance	Foraging source for honey bees
Aegle marmelos	Bael	X		X	X
Aracardium occidentale	Cashew	X			X
Annona reticulata	Ramaphal	X			X
Annona squamosa	Sitaphal	X			X
Artocarpus altilis	Breadfruit	X			X
Artocarpus heterophyllus	Jackfruit	X			X
Azadirachta indica	Neem		X	X	X
Bergera koenigii	Curry leaf	X			X
Citrus maxima	Grapefruit	X			X
Citrus medica	Nimbu	X	X	X	X
Citrus reticulata	Mandarin orange	X		X	X
Cocos nucifera	Coconut	X		X	X
Litchi chinensis	Lychee	X			X
Mangifera indica	Mango	X		X	X
Manilkara zapota	Sapota	X			X
Moringa oleifera	Drumstick				X
Muntingia calabura	Singapore cherry	X			X
Persea americana	Avocado	X			X
Phoenix sylvestris	Wild date palm	X		X	X
Phyllanthus acidus	Malay gooseberry	X			X
Phyllanthus emblica	Indian gooseberry	X			X
Pithecellobium dulce	Manila tamarind	X			X
Prunus domestia	Plum	X			X
Psidium guajava	Guava	X			X
Punica granatum	Pomegranate	X			X
Pyrus spp.	Pear	X			X
Santalum album	Sandalwood		X	X	
Sapindus trifolatus	South Indian ritha		X	X	
Syzygium cumini	Indian blackberry	X			X
Syzigium jambos	Pannnerale	X			
Tamarindus indica	Indian tamarind	X		X	

large green open spaces such as parks, community gardens, remnant forest patches, sacred grooves, botanical gardens and institutional gardens. Domestic gardens refers to small patches of private gardens associated with residential homes, flats and township which contribute significantly to urban green spaces. Despite of the small size and heterogenous nature, urban domestic gardens contribute substantially to land use category. The plant and tree cover

Table 2: Plants (shrubs and herbs) recorded from single domestic gardens and shared apartment gardens in Bengaluru that are consumed as food and/or have medicinal use and/or religious significance and provision of foraging sources for honey bees. Modified after Jaganmohan *et al.* (2012).

Scientific name	Common name	Consumed as food	Medicinal use	Religious significance	Foraging source for honey bees
Abelmoschus esculentus	Lady's finger	X			X
Allium cepa	Onion	X			
Aloe vera	Aloe		X		
Ananas comosus	Pineapple	X			
Bergera koenigii	Curry leaves	X			X
Beta vulgaris	Beetroot	X			
Brassica juncea	Mustard	X			X
Brassica rapa	Turnip	X			
Capsicum spp.	Chilly	X			X
Carica papaya	Papaya	X			X
Cinnamomum verum	Cinnamon	X	X		
Citrus spp.	Lemon	X			X
Coccinia grandis	Ivy gourd	X			X
Coffea arabica	Coffee	X			X
Coriandrum sativum	Coriander	X	X		
Curcuma longa	Turmeric	X	X	X	
Cymbopogon citratus	Lemon grass	X	X		
Elettaria cardamomum	Cardamom	X			X
Hibiscus cannabinus	Gongura	X			X
Hibiscus rosa-sinensis	Hibiscus		X	X	X
Jasminum spp.	Jasmine			X	X
Lablab purpureus	Avarekalu	X			X
Lawsonia inermis	Mehendi		X	X	
Manihot esculenta	Tapioca	X			X
Mentha spicata	Mint	X	X		
Momordica charantia	Bitter gourd	X	X		X
Moringa oleifera	Drumstick	X			X
Musa paradisiaca	Banana				X
Ocimum tenuiflorum	Holy basil		X	X	X
Passiflora edulis	Passion Fruit	X			X
Piper betle	Betel	X	X	X	
Piper nigrum	Pepper	X	X		
Plectranthus amboinicus	Dodda patre		X		
Portulaca oleracea	Doddagoni soppu	X			
Raphanus sativus	Radish	X			
Rauvolfia serpentina	Sarpagandha		X		
Ruta chalepensis	Naagdali		X		
Saccharum officinarum	Sugar cane	X			
Solanum lycopersicum	Tomato	X			X
Solanum melongena	Brinjal	X			X
Spinacia oleracea	Spinach	X			
Vitis vinifera	Grapes	X			X
Zea mays	Corn	X			X
Zingiber officinale	Ginger	X			

in this garden provides habitats and sustain urban biodiversity including birds, insects, vertebrates and invertebrates. Domestic gardens also improve the synergy with adjacent locations and increase species richness in adjacent urban parks.

The study by Jaganmohan *et al*. (2012) revealed that rose (*Rosa spp*.), found in 23% of sampled locations, Anthuriums (*Anthurium spp*.), also encountered in 23% of sampled locations, Areca palm (*Chrysalidocarpus lutescens*), found in 26% ofsampled locations, Hibiscus (*Hibiscusrosa-sinensis*), found in 27% of sampled locations andholy basil or tulasi (*Ocimum tenuiflorum*), found in 41% of sampled locations, as well as onetree species, coconut (*Cocos nucifera*), found in 31% of locations across Bengaluru. The majority of species were ornamental. 35% of tree species (Table 1) and 23% of plant species (Table 2) were used for food or medicine, or had religious significance. The predominant use is for food, with 28 tree species and 36 plant species providing fruits, vegetables or spices used for cooking (Jaganmohan *et al*., 2012).

Parks, community spaces, institutions and avenues: Tree Diversity

The tree diversity is found to be rich Bengaluru and considered as an urban forest with high species richness in parks and residential areas (Fig 4). An urban forestry study revealed 374 species with highest species diversity in parks (291) followed by residential areas and layouts (164). *Polyalthia sp*. and *Pongamia glabra* are the most dominant species in parks though their relative density is lesser in the larger parks. *Polyalthia sp*. is also dominant in institutions and offices to the extent of a relative density of 21 to 34%. Institutions are dominated by fast growing species (*Polyalthia longifolia, Grevillea robusta*, *Bauhinia variegata*), decorative trees (*Delonix regia*, *Tabebuia argentea*) and shade-giving trees (*Samanea saman*) (Sudha and Ravindranath 2000).

Flat and apartments, open gardens and community spaces

Sudha and Ravindranath (2000) identified a total of 164 species in different residential areas in Bengaluru, the 10 dominant species accounted for 58% of the trees. The predominant species in the higher strata are *Cocos nucifera*, *Murraya koenigii*, *Psidium guajava* and *Polyalthia longifolia*. In the lower strata, the dominant species are *Cocos nucifera*, *Moringa oleifera*, *Musa paradisiaca* and *Mangifera indica* (Sudha and Ravindranath 2000).

Trees in house compounds

The top 15 predominant species in compounds of residences account to 77% of the total trees in compounds. *Cocos nucifera* is the predominant species, accounting for 18%, followed by *Murraya koenigii*, *Musa paradisiaca*. *Moringa oleifera* and *Carica papaya*. *Polyalthia longifolia* and *Michelia champaca*, which are ornamental and fruityielding varieties includes, *Cocos nucifera*, *Carica papaya*, *Psidium guajava*, *Mangifera indica*, *Punica granatum*, *Annona squamosa*, *Citrus limon* and *Artocarpus integrifolius*. Two species are used in cooking; *Moringa oleifera* as a vegetable and *Murraya koenigii* leaves for seasoning. *Ricinus communis* grows more as a weed in the compounds of houses of the higher income group and also in the wastelands around houses in the lower income areas (Fig 2; Sudha and Ravindranath 2000).

Avenue trees in residential areas

The avenue trees account for 28% of the trees in the residential land-use category of the 87 species, the top 15 tree species account for 80% of the total avenue trees. The trees most preferred by the Social Forestry Scheme are *Michelia champaca*, *Bauhinia variegata*, and *Pongamia glabra*. *Moringa oleiferais* found in abundance in the lower income residential areas along avenue (Sudha and Ravindranath 2000).

Honey bee diversity in Bengaluru

The identified honey bees include *Apis indica*, *Apis dorsata*, *Apis florea* and *Trigona iridipennis* (Fig 5, 6). The species nest with single comb include dwarf honey bee *Apis florea* and gaint honey bee *Apis dorsata.*

Apis florea

The *A. florea* species mainly distributed in warm climates. As its name implies, the dwarf honey bee is the smallest species of honey bee in body size and nest size. The nest of *A. florea* consist of a single comb whose upper part expands to form a crest that surround the branch. Most of the nests are hung from slender branches of trees or shrubs covered with relatively dense foliage usually from 1 to 8 meters above the ground. Combs of the dwarf honey bees are well covered with layers of worker clinging to form many layers. which act as a living protective curtain and shows shimmering movements when disturbed. In comparison with other honey bees, the amount of honey stored by *Apis florea* is very less accounting to 700 to 800 g depending on the locations and floral availability. The life cycle and behaviour of this species is fairly similar to other species of Apis.

Apis dorsat

oneybees are found near in or near forest and towns. *Apis dorsata* is the largest of all honey bees. The bee shares the open air and single comb nesting suspending its nest from the under surface of its support. Usually the *A. dorsata* tends to nest high in the air (3-25 meters above the ground). They also prefer long and branched trees as a safe nesting site and perfuse branching to avoid the access of terrestrial predators. Around three quarter of the worker population is employed for colony defence forming a protective curtain three to four bees thick. The nests are exposed and not hidden in dense foliage unlike in *A. florea*. Around 10-20 colonies can be seen in a single colony depending on the size and branching patter of the tree which is often referred as “bee tree”. The organization of the comb is similar to

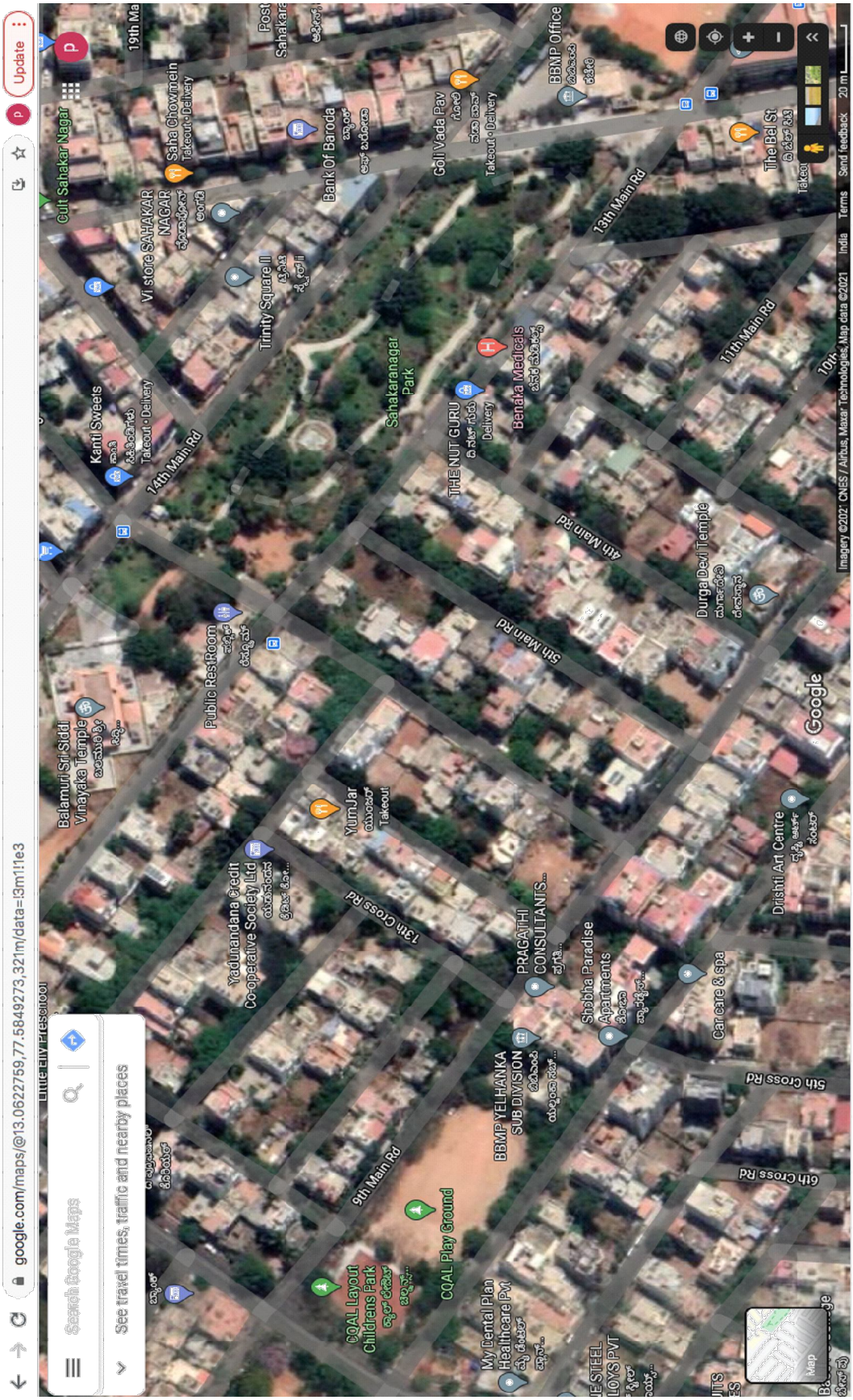

Fig 4: Google maps showing the urban greenery and urban parks in a residential area (Sahakaranagar) in Bengaluru

Apis indica; honey storage at the top, followed by pollen storage, worker brood and drone brood. The active area is the lower part of the nest called "mouth" were workers move frequently and communicate with bee dance mechanisms. In many places in Bengaluru, the arrival of *A. dorsata* is an annual event occurring at the end of the rainy season or at the beginning of the dry season. *A. dorsata* is famous for its ferociousness when its nest is disturbed due to predators or natural climatic disturbances. The defending workers can peruse attackers or nearby living things over long distances which is even fatal to human beings, livestock's or other wild animals even elephants. The intensification of the bee hunting and unscientific and crude collection methods often threat the existence of *A. dorsata* in Bengaluru. Rockbees can even forage during moonlit nights and flight range is more than 5 km.

Rockbees adapt themselves to living near human societies especially manufacturing factories, dams, high-rise buildings and temples, churches etc. Rockbee was has lower melting point (59.6°C) than *A. cerena* or *A. mellifera* bee wax. The pollen is usually wasted during honey collection could be used as a commercial product for food supplements as bee feed in apiculture, in dearth management, human therapeutics and nutrition. Rock bees can be considered as an important pollinator of many crops and agroforestry tress due to long proboscis, large flight range, larger workforce, ability to collect larger quantities of pollen and nectar. Its aggressive behaviour and migratory habit have serious problem in manipulating planned pollination programmes for field crops.

Apis cerana

The *Apis cerana* of the Asiatic honeybee (Eastern honey bee) are widely domesticated and cultivated in southern and south-eastern Asia. For many centuries the *Apis cerana* provide the mankind with honey, beewax and pollination of agricultural crops and various ecosystem services. *Apis cerena* distribution is much wider when compared to *A. florea* and *Apis dorsata* and found throughout tropical, subtropical and temperate zones of Asia. In the wild conditions, *Apis cerena* construct multiple-comb nest in dark enclosures such as caves, rock cavities and hollow tree trunks not more than 4-5 meters high above the ground. The combs of *A. cerena* are built parallel to each other with uniform distances known as "bee space". Following the invention of movable-frame hive for the European honeybee about a century ago, traditional bee keeping with *A. cerena* has been enriched with modern scientific methods in many Asian countries. In Karnataka and Tamil Nadu, there is a strong traditional beekeeping in Coorg and Marthandam. In Kerala, especially the rubber growing areas migratory bee keeping is practiced from a long time collect the extra floral nectar.

Apis mellifera

The Western Honeybee or European honeybee (*Apis mellifera*) is commonly domesticated and cultivated across the Europe and name "Mellifera" is from Latin and means honey carrying. These bees are widely introduced to many Asian countries for massive rearing and honey production. Outside Asia, beekeeping with *A. mellifera* is an integral part of modern agricultural systems with emphasis to pollination, ecosystem services, honey and bee wax production. The introduction of *A. mellifera* encountered many problem of inter-species transmission of diseases and pests and emergence of many new predators. However when comparing commercial viability, economic profitability and income generation to farmers; many successes stores were reported from various Asian countries including many parts across India. The European bee is similar to the Indian bee in its biology, nesting, foraging, colony defence and other behavioural features with some minor differences.

Fig 5: Description of the different honeybees identified in Bengaluru a) Rockbees; *Apis dorsata*b) *Apis florea* comb showing the brood; c) *Apis florea* brood showing honey storage area; d) *Apis dorsata* worker bee e) *Apis florea* worker bee f) *Apis cerena* colony showing brood and stored honey and pollen g) *Apis mellifera* collecting pollen and nectar.

***Trigona iridipennis* (Stingless bees)**

Usually stingless bees were seen in building foundations, mud walls, stone walls and tree cervices. They prefer tropical climate. Also seen in tropical places especially Mexico to Argentina and Indo-Australian regions especially India, Sri Lanka and Taiwan (Sakagami 1982; Wille *et al*. 1983). The most prominent stingless bees seen in India is *Trigona iridipennis* species (Swaminathan 2000). Before they were known as *Melipona iridipennis*. Now the species located in India and Sri Lanka belong to Trigona genus and this classification is widely accepted (Michener 1974; Sakagami 1978). These bees got the name *Trigona iridipennis* due to triangular abdomen and iridescent wings. For building nest, they collect resins from trees which makes them called as Dammer bees. In India especially villages and among tribal people of Kerala and Karnataka, stingless bees were domesticated but not much importance and attention were for the management of these bees. Much importance are given to the large scale production of *Apis indica* and *Apis mellifera* in Kerala and Karnataka. Stingless bees were much far ahead of medicinal properties of honey and plant pollination when compared to other honey bees (Garedew *et al*. 2004). Even though the stingless bee produce less quantity of honey (400-600 ml), due to high medicinal property of their honey, smooth taste and fragrance make them superior than other types of honey. The importance of stingless bee pollination is much higher than the value of their honey produced. There are lot of small plant that depend only on stingless bees for their pollination (Heard 1999). The body of the stingless bees were designed to collect pollen and nectar from very small flowers. The stingless bee travel only around 800 m radius for collecting pollen and nectar which make them suitable for controlled pollination. Stingless bees could be effectively used for green houses, poly houses and controlled farming techniques. The small bees do not get much appreciation and preferences for their valuable services. For house yard honey culture these small bees could be effectively utilized due to their special features and biodiversity in Kerala and Karnataka.

Pollen and nectar sources for honey bees

Honey bees collect nectar and pollen from a variety of plant species especially woody trees, fruit trees, ornamental and medical plants, weed plants and vegetable crops (Table 1, 2). Some of the plants supply nectar and pollen through-out the year while others are only seasonal. Due to the small size, the stingless bees can collect nectar and pollen from very small flowers where other honey bee species fail to do.

Natural habitat of stingless bees in Bengaluru

The stingless bees are found naturally abundant in stone walls, mud walls wooden logs, telephone posts, galvanized iron (GI) pipes in and around various areas in Bengaluru (Fig 6). They are abundant in GKVK campus, old churches made with stone and serval anthropogenic habitats. These are natural feral colonies which cannot be easily collected un-less special education techniques or destructive methods used (Vazhacharickal and Jose 2016, 2018).

Integration of honey bees and stingless bees in urban agriculture and urban forest

The adaptability of the bees, appropriate bee keeping technology, forage ecology and socio-economic suitability are very important in popularisation of apiculture. Stingless bees could be successfully integrated into the urban farming systems without much complications especially in balcony, terrace as well as kitchen gardens. In addition, they could be also use to serve the urban forests especially parks, roadside avenues, temples and other worshiping places, institutions with campus and even in the flats with community parks and gardens. The stingless bees needs minimum space and attention and could be easily handled by women, children and aged persons without any difficulty. The stingless bees could be placed on balconies, open terraces or in the garden which could marginally improve pollination,

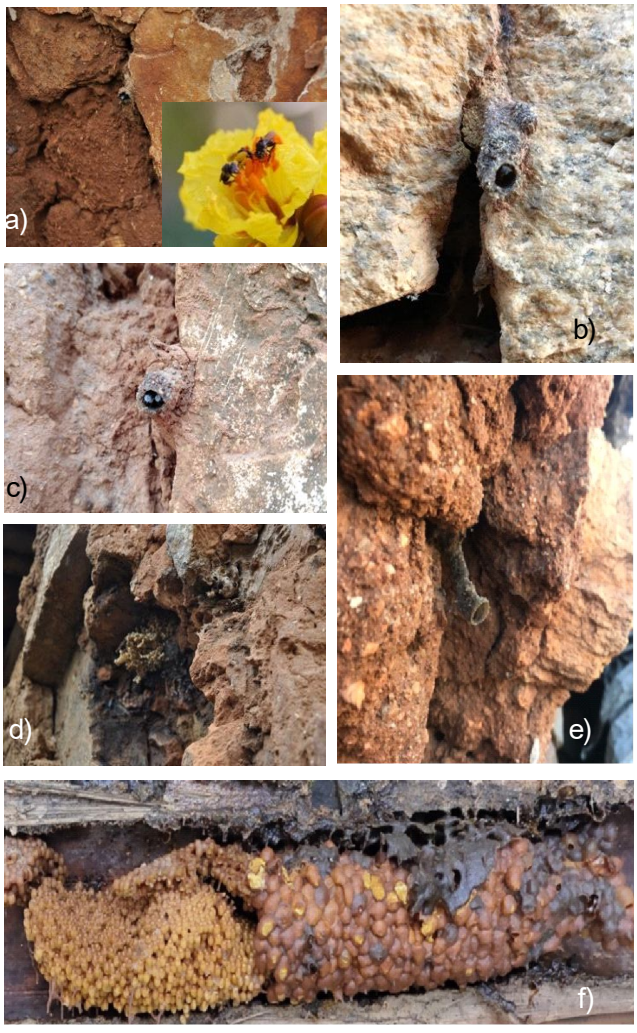

Fig 6: Description of the stingless bees across Bengaluru a) natural habitat on mud walls; b) habitat on stone walls; f) colony showing brood and stored honey and pollen.

crop yield and ecosystem services. A single stingless bee colony can yield 400-500 g of pure honey which can fetch to 18-20 US$ per yield (Vazhacharickal *et al*., 2020). Moreover, while integrating stingless bees into the urban environment; provide leisure time activity and mental enchantment for the retired persons and collection pure home honey with high medical properties.

Possible outcomes of integration

The urban agriculture and urban forest system in the Bengaluru are ideal for stingless bee keeping. These provide a wide variety for foraging sources for the stingless bees. Currently these floral resources are being underutilized; utilized only for aesthetic beauty and integration of stingless bees will definitely utilize the various floral resources. The pollination services proved by these bees will have a definitely impact on the urban agriculture productivity, size and quality of the fruit and better utilization the resources.

CONCLUSION

In conclusion, the outlook study provide insights into the unique importance of urban domestic gardens and urban forests for the support of biodiversity in a rapidly expanding urban area Bengaluru the silicon valley of India. They point to the importance of large gardens and of traditional practices of urban agriculture and gardening that encourage the planting of culturally important species, flowering plants and species of food value, but also indicate the changes that are taking place as many gardens shrink in size, disappear, or become converted to apartments which contain greater numbers of ornamental non-flowering plants and trees with diminished biodiversity value. These gardens can be very important at a coarse scale, acting as networks to support biodiversity, promote ecosystem services, provide nectar and pollen to honey bees and other pollinating and non-pollinating insects as well as birds. Urban agriculture and urban forest system in the Bengaluru are ideal for stingless bee keeping and provide them with nectar and pollen. Since natural feral stingless bees can been in many places in and around Bengaluru, they may be considered as resilient to the urban environment. The integration of stingless bees will definitely improve the pollination in the urban gardens and urban forest which in turn have a clear impact of the fruit productivity, fruit size and seed setting. Stingless bees could be easily reared with limited space and care and provide a leisure time activity for the retired person, women and children. More over the possible pollination services offered by integrating these little bees cannot be foreseen in the Silicon valley of India.

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Conflicts of interest

The authors do not have any conflict of interest.

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