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Tree-related Microhabitats and Trees Outside Forest along the Urban-Rural Gradient in Kathmandu Valley

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Abstract

Trees Outside Forests (TOF) are found in all strata as urban, suburban and rural. Some TOF serve as Tree Related Micro Habitats (TreMs). We conducted the assessment of TreMs on TOF in Kathmandu valley of central Nepal. Inventory was performed in 209 randomly selected points by Excel using circular plots with 20 m radius. Out of 6210 individuals of 150 tree species recorded from the study area, 1038 TOF of 64 species were found to serve as TreMs. 4 forms, 5 groups and 14 types of TreMs were recorded. Habitat types per tree varied from 1 to 6. 1, 2, 3, 4 and 5 habitat types were found in 665 (64.07 %), 293 (28.23 %), 67 (6.45 %), 8 (0.77 %) and 4 (0.38 %) trees respectively. 6 habitat types were found in one *Cinnamomum camphora* tree (0.10 %) with 8.60 m height and 75 cm DBH. Out of all the forms, groups and types, all were found in Urban TOF, one type (mistletoe) in suburban TOF and one form (fruiting bodies of saproxylic fungi and slime moulds) along with three types (mistletoe, invertebrate nest and sap run) were absent in rural TOF. The study explored the TreMs on TOF in Kathmandu valley. It provides the baseline data useful for micro habitats as well as biodiversity conservation.

Keywords: Cavity, Co-occurrence, Lichens, Nests, Orchids, Polypores

Introduction

Tree-related microhabitats (TreMs) are distinct structure present on trees that act as habitat for one or more species during at least a part of their life cycle to develop, feed, shelter or breed. Tree microhabitats are not born by all trees (Larrieu et al., 2018). The TreMs formation rate and number depends upon the size of the tree (Courbaud et al., 2021). Generally, invertebrates or vertebrates make habitat on trees (Larrieu et al., 2018). Number and types of microhabitats per tree vary depending upon the tree species and the maturity of the tree because this increase markedly with increased tree diameter. Therefore, very large trees are significant because they host almost all microhabitat types (Larrieu & Cabanettes, 2012). TreMs come under supporting ecosystem service (Bishop et al., 2010) which also help in biodiversity. Depending upon the landscape, frequency of occurrence of the microhabitat on either living or dead trees varies (Butler et al., 2020). Due to the limited life span, however, a new microhabitat can be formed after the death or decay of one type of microhabitat (Butler et al., 2021). Though TreMs are not the main indicator for species richness, they can be considered better than other established indicators (Magg et al., 2019; Noss, 1990). The new concept of TreMs as a surrogate biodiversity indicator is of special interest (Asbeck et al., 2021; Martin et al., 2022). There is a growing knowledge about TreMs by virtue of increasing research done in, especially forest ecosystems (Großmann et al., 2020; Regnery et al., 2013; Vuidot et al., 2011; Winter & Moller, 2008), yet all TreMs are not studied due to inconsistency in TreMs definitions in the available dataset. Furthermore, some TreMs are rarely recorded (Larrieu et al., 2021). But now experts have developed a typology of TreMs in forestry practice (Butler et al., 2021) as 7 forms, 15 groups and 47 types (Larrieu et al., 2018). The seven forms are - 1. Cavities, 2. Injuries expose sapwood, 3. Crown deadwood, 4. Excrescences, 5. Fungal fruiting bodies and slime moulds, 6. Epiphytic and epixylic structures and 7. Exudates.

Another aspect of TreMs is the co-occurrence patterns, which is poorly investigated. It is the co-dependency of more than one organism on the same tree. Tree species, DBH and state of the tree seem to be the crucial drivers of co-occurrence patterns (Courbaud et al., 2021; Larrieu & Cabanettes, 2012; Larrieu et al., 2014; Paillet et al., 2017). Though some TreMs such as dendrothelms (Kitching, 1971) or cavities (Wesołowski, 2007) have been well studied, several TreMs types are not studied yet, implying the existence of many knowledge gaps (Martin et al., 2022).

The retention of trees as TreMs in forests managed for timber production is essential for fulfilling the objectives of biodiversity conservation (Basile et al., 2020; Frey et al., 2020). Furthermore, biodiversity conservation should be done by keeping in mind the future of TreMs formation too (Courbaud et al., 2017; Courbaud et al., 2021). Study and assessment of these by providing guidelines to the concerned can play the important role for sustainable management of forest ecosystems regarding biodiversity conservation (Khanalizadeh et al., 2020; Martin et al., 2022).

Trees can be found in a wide range of patterns in human-influenced landscapes where ecological conditions are favorable to their growth (Bellefontaine et al., 2002). Trees Outside Forests (TOF) is one of them. Food and Agriculture Organization of the United Nations (FAO, 1998) defined TOF as "the plants on the land that fulfils the requirements of forest and other wood land except that the area is less than 0.5 ha, scattered trees in permanent meadows and pastures; permanent tree crops such as fruit trees and coconut; trees in park and gardens, around buildings and in lines along streets, roads, railways, rivers, streams and canals; trees in shelterbelts of less than 20 m width and 0.5 ha area". TOF comprises both trees and shrubs, and tree ranging from a single discrete tree to systematically managed trees (Foresta et al., 2013; Kleinn, 2000). Nowadays, due to many issues, urban areas have expanded rapidly so as the inventory efforts of assessments of all the trees both within and outside forest areas across the urban–rural gradient (Westfall et al., 2018). Urbanization is one of the major causes for plant diversity loss at the local and regional scale (Wang et al., 2020). The urban-rural gradient explores the changes in plants from the rural area to the core urban (Ranta & Viljanen, 2011).

In the context of planted tree in Kathmandu Valley, King Jayasthithi Malla was the first recorded King to give order to plant trees alongside roads, water wells, in the divine domain and outer circle which was continued through the Rana period (Poudel, 2010). Rana Prime Minister Chandra Shamsher (1901-1929 A.D.) started a trend to plant the trees along Valley's roadsides and palaces. Trees were also planted along the highway from Kathmandu to Bhaktapur. Plantation of pipal (*Ficus religiosa*) trees in rural parts of the Valley is common to afford a convenient resting spots. In the 1980s, three-line tree planting was started forming a green belt around the Ring Road. But trees were continued to be felled for road expansion. Now the residents of Kathmandu Valley in association with civil society organizations and local governments are planting the trees even on the narrow pavements, resulted due to road expansion (Sharma, 2021).

Trees are important for the likelihood of future TreMs formations which helps in biodiversity conservation (Courbaud et al., 2021). TreMs assessments have been done in the developed countries. Though few researches have been done on species diversity, DBH class and volumes of TOF, TreMs on TOF is new to Nepal. Thus, to assess the TreMs abundance and richness on TOF along the urban-rural gradient in Kathmandu valley, this research had been done. This will provide the baseline data useful for micro habitat as well as biodiversity conservation.

Materials and Methods

Study area

The study was carried out in Kathmandu valley (area ~ 66,500 ha.) of Bagmati Province, situated in the middle hill region of central Nepal. It includes three districts Kathmandu, Lalitpur and Bhaktapur (Figure 1). It lies between 27°32'13" N to 27°49'10" N latitude and 85°11'31" E to 85°31'38" E longitude at an altitude of 1,300 m. The climate is of sub-tropical type and is influenced by distinct monsoon climate with hot, wet summers and cold, dry winters (International Centre for Integrated Mountain Development [ICIMOD], 2007). January and June are the coldest and hottest months with the annual average minimum and maximum temperatures as 3°C and 29.8°C respectively. Annual average rainfall is 1509 mm (data between 2000 – 2018) (GoN, DHM, airport station, 2021).

Site selection and sampling

A two-phase sampling strategy was applied for data collection (Lister et al., 2011). First phase included the listing up of TOF by aerial photos (image interpretation i.e., Google Earth) and second phase included the field survey. For this, grids of 500 m×500 m were prepared (n = 2800) in the entire study area (Figure 1) (Dida et al., 2016). Stratified random sampling method was used to identify the locations of TOF in the grids (Department of Forest, Research and Survey [DFRS], 2011). From visual interpretation of Google Earth Image, 1,046 TOF sites were identified under three strata as urban, suburban and rural on the basis of population (Central Bureau of Statistics [CBS], 2014) (Figure 1). Twenty percent of randomly selected by Excel of the total TOF sites identified (i.e., 209 sites) were used to collect data (Tang et al., 2016). A map of the study area with sampling location points was prepared (Figure 1). In the second phase data were collected using a circular plot with 20 m radius (area = 0.13 ha) (DFRS, 2011). Total area of 26.27 ha was studied in the study area. Tree level characteristics of woody plants with height > 1.3 m and diameter at breast height (DBH) ≥ 5 cm were recorded. DBH was measured at 1.3 m above the ground using diameter tape and the tree height was assessed using clinometer (Suunto PM-5/360 PC). Other organisms making one or more habitats or support on the TOF species were also enumerated. Nests and cavities if present were noted along with the organism types. Sap or resin if present was also recorded.

Identification of plants was done from herbarium specimen prepared following standard procedure (Bridson & Forman, 1998). The vernacular names

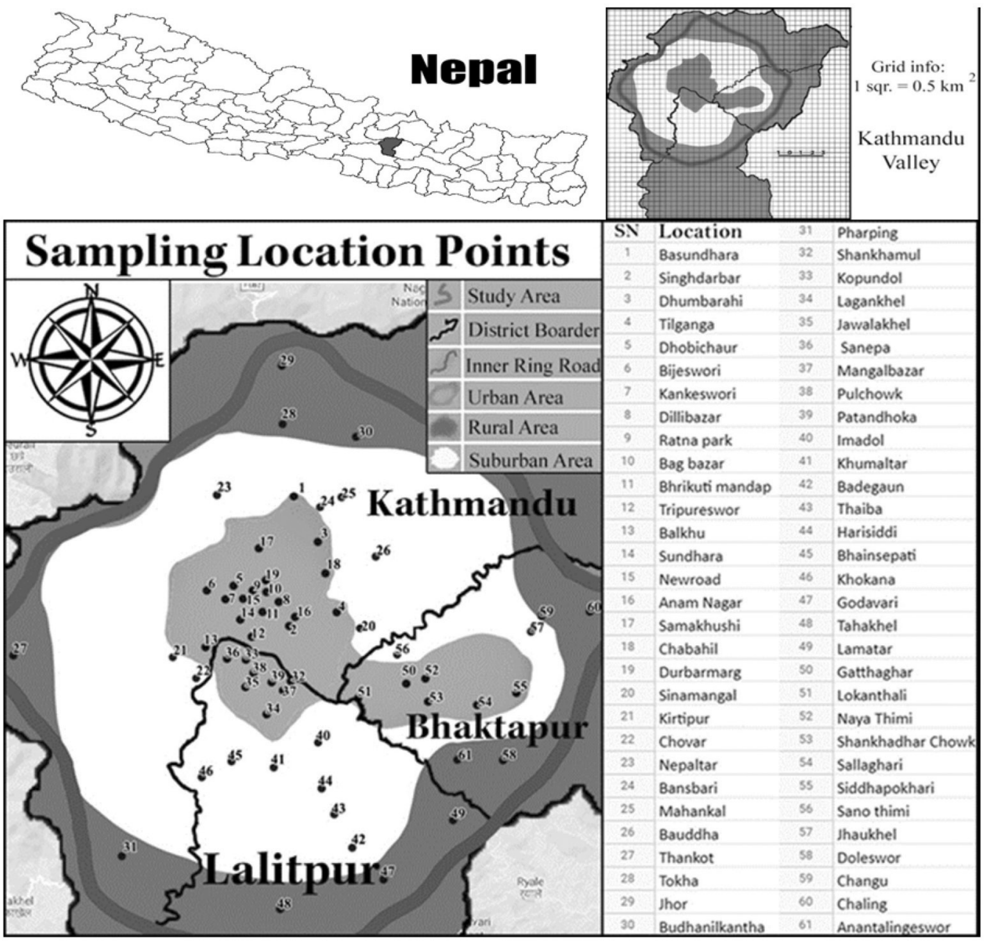

Figure 1: Map of the study area with sampling location points

were recorded with the help of local people and Sharma (2014). Scientific names were determined after identification by using literatures such as Flora of Kathmandu Valley (Malla et al., 1986), and after comparison with identified specimens previously deposited at Tribhuvan University Central Herbarium (TUCH), Nepal. Press et al. (2000), Shrestha et al. (2022) and Plants of the World Online (https://powo.science.kew.org/) were followed for plant nomenclature. The collected lichen samples were segregated according to their growth forms and further grouped according to the type of fruiting bodies. Then the lichen species was identified through morphological, anatomical studies with the help of micro and macro-lichens identification keys of Awasthi (2007), Baniya & Bhatta (2021) and Baniya et al. (2022). Fungi identification was done with the help of relevant Website (biodiversity library.org; Index fungorum; Jstor.org; Mycobank.org; Scircus; tropicos.org; Agaricus in the Pacific Northwest; Boletes in the Pacific Northwest) and Singer (1986). Similarly, orchids were identified through morphological studies with the help of Rokaya et al. (2013), Rajbhandari (2015) and Rajbhandari & Rai (2017).

Means and standard deviation of test variables were estimated following standard procedures. Variables related to TreMs were subjected to test of normality and were found not normal. Kruskal-Wallis tests were applied for multiple comparisons using SPSS (26).

Results and Discussion

In the study area

Trees Outside Forests (TOF) play an important role for the habitat conservation of ferns, mosses, lichens, fungi, and other phanerogams including orchids and parasitic plants. While TOF provide support to the climber plants, these are equally important for the habitat conservation of animals, insects and birds. In this study, a total of 6210 individuals (density = 236.35 ha^{-1}) of trees outside forests (TOF) with 150 species were recorded in the study area. Out of which 1038 individuals (density = 39.51 ha^{-1}) of TOF representing 64 species were found to serve as tree related microhabitats (TreMs) (Table 1) in 150 plots. After the enumeration of 2482 trees (>20 cm DBH), Winter and Moller (2008) found less number of microhabitat trees (571) in lowland beech forests in Germany. According to Khanalizadeh et al. (2020), microhabitats (272) were less of the five microhabitat types but individual trees (3382) were more in Oriental beech (*Fagus orientalis* L.) dominated forests in Iran. Both are due to enumeration of only the selected microhabitats. But in their international study of temperate and boreal forests from Northern Iran to Western Europe, Larrieu et al. (2021) found quite higher value as 70,958 individual trees of 78 tree species as TreMs in 2052 plots. Similarly, Piechnik et al. (2022) also observed the high number of TreMs density (46 ha^{-1}) in the Niepołomice Forest of S. Poland. It was due to enumeration of six selected trees species with only > 20 cm DBH in 94 plots covering 42.30 ha area. Out of 7 forms, 15 groups and 47 types of TreMs (Larrieu et al., 2018), 4 forms, 5 groups and 14 types were found in the present study (Table 2). Vuidot et al. (2011) found the presence of more microhabitat types as ivy, non-woodpecker cavities, conks, woodpecker cavities, canker, dead crown, cracks, bark pockets, bark losses and bryophytes in five French forests.

TreMs types per plot varied from 1 to 7. Some TOF had more than one habitant types. Due to co-occurrence, habitant type per tree varied from 1 to 6. 6 habitants were found in only one tree of *Cinnamomum camphora* with 8.6 m height and 75 cm DBH (Table 1). Larrieu et al. (2021) found TreMs co-occurrence for 11 TreMs groups. He found six

Table 1: Number and density of TreMs, numbers of trees with habitant numbers in the study area

Number of TOF with TreMs	Density of TOF with TreMs (ha^{-1})	6 habitants	5 habitants	4 habitants	3 habitants	2 habitants	1 habitants
1038	39.51	1	4	8	67	293	665

Note : TOF = Trees Outside Forests

co-occurrences between broad leaves and conifers. These variations with our study might be due to enumeration of more number of living trees (70,958) including 54,740 broadleaves, 16,218 conifers from 2,052 plots. Vuidot et al. (2011) reported the Oaks with a significantly larger number of microhabitats per tree (2.66) in five French forests.

Tree height and DBH are the main elements for TreMs distribution. Height and DBH of the habitat trees in our study area varied from 1.5 to 26 m with an average of 7.12 ± 3.63 m and 5 to 181 cm with an average of 29.86 ± 23.53 cm respectively (Table 4). In his survey of trees with > 7.5 cm DBH, Khanalizadeh et al. (2020) reported the range of 7.5–170 cm with an average of 33.6 cm. Similarly, in the study of trees only > 20 cm DBH, Piechnik et al. (2022) also found a mean DBH of 37 cm. In addition, microhabitat occurrence and DBH have been reported significantly and positively correlated in fir beech trees (Larrieu et al., 2012). Larrieu and Cabanettes (2012) found the first microhabitat occurrence at 41 and 60 cm DBH (median values) for beech and fir respectively. But in contrast, all microhabitats including heavy resinosis and resin drops were more abundance in young stands in Douglas-fir forests of different stand ages and management histories in the Pacific Northwest, U.S.A (Michel & Winter, 2009).

Number of individuals and species of TOF as TreMs with habitat types that were found in the study area are described below.

17 individuals of 13 TOF species had 17 cavities without animal signs (Table 3, Figure 2A) in 14 plots. Cavity as the microhabitat is the most studied TreMs worldwide. Height and DBH of the cavity trees varied from 2.50 to 15 m with an average of 8.55 ± 6.40 m and 18.90 to 95.30 cm with an average of 44.41 ± 23.03 cm respectively (Table 4). Michel & Winter (2009) reported cavities as the low abundant microhabitat on Douglas-fir trees. It was due to the high decay-resistant of resinous wood. Vuidot et al. (2011) reported the increase of non-woodpecker cavities significantly with tree diameter. Bhusal et al. (2015) reported the presence of cavity in 50 trees of eight tree species in the subtropical lowlands of the inner Terai region, south-central Nepal. This higher tree number but lesser species number was due to the study of all cavity types in the Sal forest. They found the similar average values of DBH (38.7 and 47.7 cm) of cavity occurring trees. Woodpecker cavity trees had higher average DBH value (63.13 cm) in the southern part of the Black Forest (south-western Germany) (Basile et al., 2020). Hussain et al. (2013) also reported higher number of cavity-bearing trees (34) in a coniferous forest of Dhirkot, Azad Jammu and Kashmir part of Pakistan which was due to study of all cavity types in the forest.

Eight fungi species (7 of Basidiomycetes and 1 of Corticiaceae) were enumerated in 12 individuals of 6 TOF species (Table 5) in 7 plots. Perennial and annual polypores were also found (Figures 2B and 2C). Mosses were found on 332 individuals

Table 2: Forms, groups and types of TreMs found in the study area

S.N.	Form	Group	Type
1	Cavities	Rot holes	Trunk base rot hole
2	Fruiting bodies of saproxylic fungi and slime moulds	Ephemeral fungal fruiting bodies and slime moulds	Perennial polypores
			Annual polypores
			Cortiaceae
3	Epiphytic, epixylic and parasitic structures	Epiphytic or parasitic crypto- and phanerogams	Bryophytes
			Crustose, foliose and fruticose lichens
			Ivy
			Ferns
			Mistletoe
			Orchids
			Other phanerogams
		Nests	Vertebrate nest
			Invertebrate nest
4	Fresh exudates	Fresh exudates	Sap run

of 31 TOF species (Table 6) in 54 plots. 15 lichen species were found on 377 individuals of 42 TOF species (Figure 2D, Table 7) in 46 plots. 11 ivy (climber) species were found on 65 individuals of 27 TOF species (Figure 2E, Table 8) in 28 plots. 5 fern species were found on 166 individuals of 35 TOF species (Figure 2F, Table 9) in 49 plots. 2 Mistletoe as epiphytic parasitic species were found on 2 individuals of 2 TOF species (Table 10) in 2 plots. 5 orchid species were found on 36 individuals of 22 TOF species (Figure 3G, Table 11) in 16 plots. 12 other phanerogam species were found on 40 individuals of 15 TOF species (Figure 3H, Table 12) in 32 plots.

Similarly, 199 bird nests were found on 139 individuals of 26 TOF species (Figure 3I, Table 3) in 86 plots. 115 individuals of 25 tree species had one

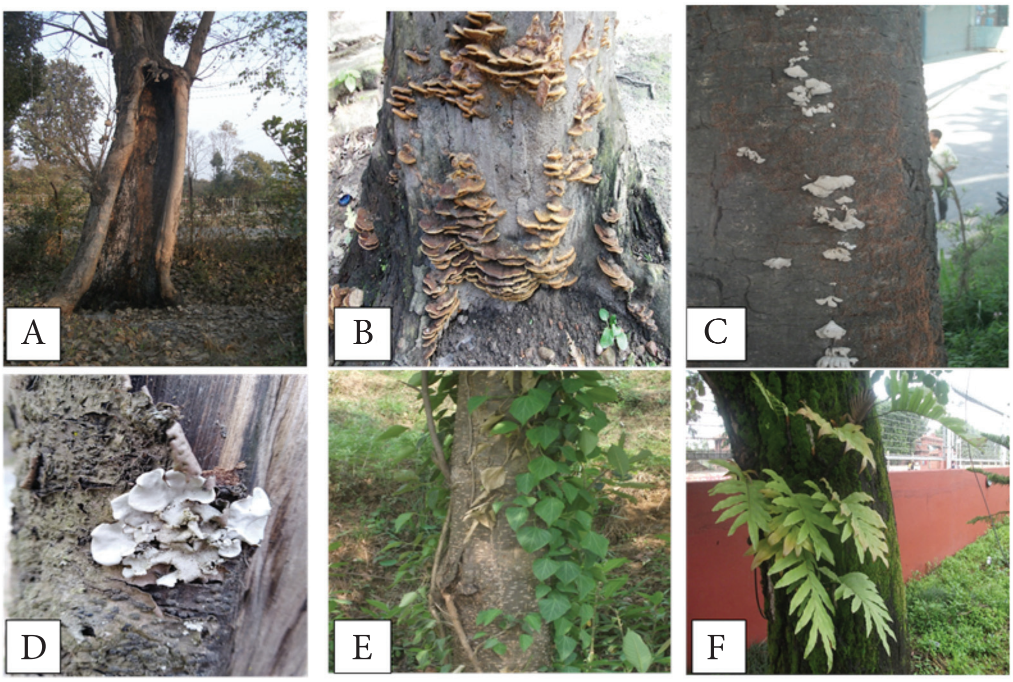

Figure 2: TreMs for, **A.** cavity, **B.** fungi (Perennial polypore), **C.** fungi (Annual polypore), **D.** lichens, **E.** ivy (climber), **F.** ferns

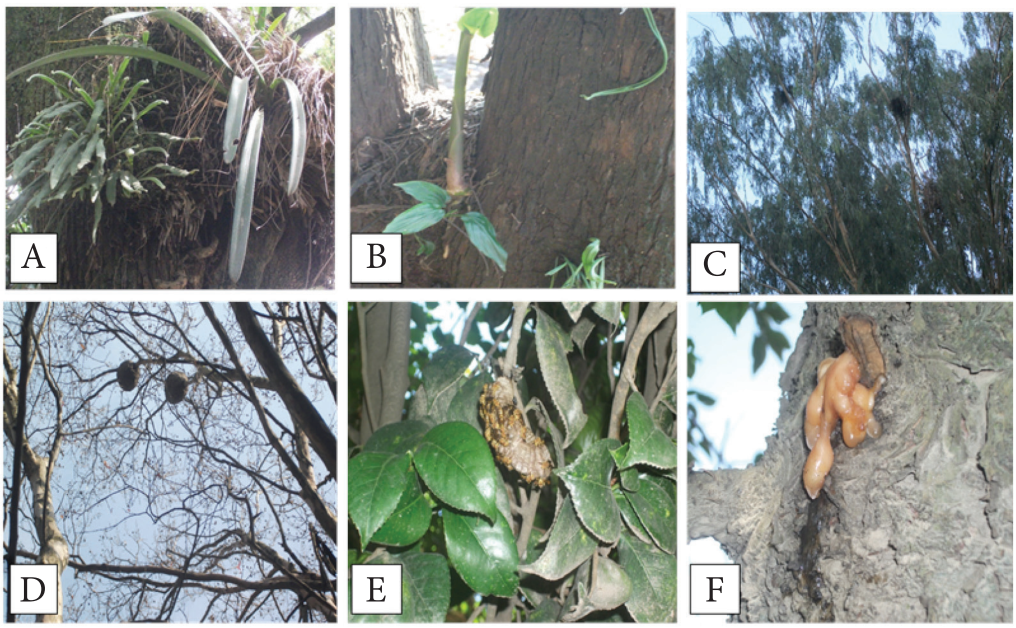

Figure 3: TreMs for, **A.** orchids, **B.** other phanerogams, **C.** bird nest, **D.** ant nest, **E.** bee hive, **F.** sap run

nest in 130 plots, 19 individuals of 11 tree species had two nests in 16 plots, 9 individuals of 6 tree species had three nests in 7 plots and 1 individual of 1 tree species had four nests in 1 plot. 8 individuals of 4 tree species had one ant nest, 1 individual of 1 tree species had more than one ant nest on them (Figure 3J, Table 3) while 3 individuals of 3 tree species had one beehive in each (Figure 3K, Table 3).

27 individuals of 9 TOF species had sap runs (Figure 3L, Table 3) in 13 plots. Michel & Winter (2009) reported drops of resin as the most abundant microhabitat on Douglas-fir trees. It was due to the resinous wood.

Besides the habitats, Seven live animal species were also found in the study area (Table 13).

Table 3: TOF Species showing the presence of cavity, nests, ant nest, beehive and sap run in the study area

S.N.	TOF species	Cavity	1 nest	2 nests	3 nests	4 nests	Ant nest	Bee hives	Sap run
1	*Alnus nepalensis* D. Don		+						
2	*Araucaria bidwillii* Hook.		+						
3	*Araucaria heterophylla* (Salisb.) Franco		+						
4	*Bougainvillea glabra* Choisy	+							
5	*Callistemon citrinus* (Curtis) Skeels	+	+	+					+
6	*Camellia japonica* L.							+	
7	*Casuarina equisetifolia* L.	+							
8	*Cedrus deodara* (Roxb. ex D. Don) G. Don								+
9	*Celtis australis* L.		+	+	+		+		
10	*Choerospondi asaxillaris* (Roxb.) B.L.Burtt		+						
11	*Cinnamomum camphora* (L.) J. Presl		+	+	+	+			+
12	*Dalbergia sissoo* Roxb.		+						
13	*Eucalyptus camaldulensis* Dehn.		+	+	+				
14	*Ficus benghalensis* L.		+						
15	*Ficus benjamina* L.		+						
16	*Ficus elastica* Roxb.		+						
17	*Ficus religeosa* L.		+	+	+				
18	*Grevillea robusta* A. Cunn. ex R. Br.		+	+			+	+	+
19	*Jacaranda mimosifolia* D. Don	+	+		+				+
20	*Juglans nigra* L.		+						
21	*Juglans regia* L.	+							
22	*Lagerstroemia indica* L.		+				+		
23	*Litsea monopetala* (Roxb.) Pers.			+					
24	*Melia azedarch* L.		+	+					
25	*Magnolia champaka* L.								+
26	*Myrica esculenta* Buch-Ham. ex D. Don	+							
27	*Persea americana* Mill.		+						
28	*Pinus roxburghii* Sarg.		+						+
29	*Populus jacquemontiana* Dode.	+	+	+	+				+
30	*Prunus domestica* L.	+							
31	*Pyrus pashia* Buch-Ham. ex D. Don.	+	+						

S.N.	TOF species	Cavity	1 nest	2 nests	3 nests	4 nests	Ant nest	Bee hives	Sap run
32	*Pyrus pyrifolia* (Burn.) Nak.	+							
33	*Rhododendron arboretum* Smith	+							
34	*Salix tetrasperma* Roxb.	+	+						
35	*Syzygium cumini* (L.) Skeels		+	+					
36	*Thuja orientalis* L.	+	+	+			+		+
37	*Ziziphus incurva* Roxb.							+	

Table 4: Minimum, maximum and average height and DBH of trees with TreMs and cavity trees in the study area

TOF with TreMs (n=1038)			Cavity tree (n=17)		
	Height	DBH		Height	DBH
Minimum	1.5	5	Minimum	2.5	18.9
Maximum	26	181	Maximum	15	95.3
Average ± sd*	7.12 ± 3.63	29.86 ± 23.53	Average ± sd	8.55 ± 6.40	44.41 ± 23.03

Note: sd* = standard deviation

Table 5: Fungi occurring TOF species and total fungi recorded in the study area

TOF species	Fungi species
1. *Buddleja asiatica* Lour.	1. *Coriolus* sp.
2. *Grevillea robusta* A. Cunn. ex R. Br.	2. *Fomes fomentarius* L. (Fr.)
3. *Litsea monopetala* (Roxb.) Pers.	3. *Inonotus radiates* (Sowerby) P. Karst
4. *Populus jacquemontiana* Dode.	4. *Schizophyllum commune* Fr.
5. *Pyrus pashia* Buch-Ham. ex D. Don.	5. *Schizophyllum commune* Fr.
6. *Thuja orientalis* L.	6. *Stereopsis* sp.

Table 6: Moss occurring TOF species in the study area

TOF species	TOF species
1. *Alnus nepalensis* D. Don	17. *Lagerstroemia indica* L.
2. *Albizia julibrissin* Durazz.	18. *Litsea monopetala* (Roxb.) Pers.
3. *Borassus flabellifer* L.	19. *Mangifera indica* L.
4. *Buddleja asiatica* Lour.	20. *Manglietia insignis* (Wall.) Blume
5. *Callistemon citrinus* (curtis) Skeels	21. *Melia azedarch* L.
6. *Casuarina equisetifolia* L.	22. *Nyctanthes arbor-tristis* L.
7. *Celtis australis* L.	23. *Phoenix humilis* Royle.
8. *Choerospondias axillaris*(Roxb.) B. L. Burtt	24. *Pinus roxburghii* Sarg.
9. *Cinnamomum camphora* (L.) J. Presl	25. *Populus jacquemontiana* Dode.
10. *Eucalyptus camaldulensis* Dehn.	26. *Pyrus pyrifolia* (Burn.) Nak.
11. *Ficus benjamina* L.	27. *Salix tetrasperma* Roxb.
12. *Ficus religeosa* L.	28. *Schima wallichii* (DC.) Korth.
13. *Grevillea robusta* A. Cunn. ex R. Br.	29. *Syzigium cumini* (L) Skeels
14. *Jacaranda mimosifolia* D. Don	30. *Syzigium jambos* (L.) Alston
15. *Juglans nigra* L.	31. *Thuja orientalis* L.
16. *Juniperus recurva* Buch-Ham. ex D. Don	

Table 7: Lichens occurring TOF species and total lichen species recorded in the study area

TOF species	Lichen species
1. *Alnus nepalensis* D. Don	1. *Canoparmelia* sp.
2. *Araucaria heterophylla* (Salisb.) Franco	2. *Chrysothrix candelaris* (L.) J. R. Laudon
3. *Borassus flabellifer* L.	3. *Dirinaria aegiliata* (Afzel. ex Ach.) B. J. Moore
4. *Buddleja asiatica* Lour.	4. *Graphis stenotera* Vain.
5. *Caryota urens* L.	5. *Candelaria concolor* (Ach.) Flot.
6. *Celtis australis* L.	6. *Herpothallon* sp.
7. *Choerospondias axillaris* (Roxb.) B.L.Burtt	7. *Hyperphyscia adglutinata* (C. Knight) Mull. Arg.
8. *Cinnamomum camphora* (L.) J. Presl	8. *Lepraria* sp.
9. *Citrus aurantifolia* (Christm) Swingle	9. *Parmotrema praesorediosum* (Nyl) Hale.
10. *Citrus maxima* (Burm.) Herr.	10. *Pertusaria* sp.
11. *Eucalyptus camaldulensis* Dehn.	11. *Physcia crispa* (Nyl)
12. *Ficus religiosa* L.	12. *Physcia dubia* (Hoffm.) Lettau
13. *Fraxinus floribunda* Wall.	13. *Physcia sorediosa* (Vain.) Lynge
14. *Grevillea robusta* A. Cunn. ex R. Br.	14. *Pyrenula* sp.
15. *Ilex excelsa* (Wall.) Hook. Fil.	15. *Pyxine* sp.
16. *Jacaranda mimosifolia* D. Don	
17. *Juglans regia* L.	
18. *Juniperus recurve* Buch-Ham. ex D. Don	
19. *Lagerstroemia indica* L.	
20. *Litchi chinensis* Sonner	
21. *Litsea monopetala* (Roxb.) Pers.	
22. *Magnolia soulangeana* Soul.	
23. *Mangifera indica* L.	
24. *Manglietia insignis* (Wall.) Blume	
25. *Magnolia fuscata* Bl.	
26. *Morus alba* L.	
27. *Myrica esculenta* Buch-Ham. ex D. Don	
28. *Nerium indicum* Miller	
29. *Nyctanthes arbor-tristis* L.	
30. *Persea americana* Mill.	
31. *Persea duthiei* (King ex Hook. F.) Kosterm.	
32. *Phoenix humilis* Royle.	
33. *Pinus roxburghii* Sarg.	
34. *Prunus cerasoides* D. Don	
35. *Prunus domestica* L.	
36. *Prunus persica* (L.) Batsch	
37. *Pyrus pyrifolia* (Burn.) Nak.	
38. *Quercus glauca* Thumb.	
39. *Schefflera impress* (C. B. Clarke) Harms	
40. *Schima wallichii* (DC.) Korth.	
41. *Syzygium jambos* (L.) Alston	
42. *Thuja orientalis* L.	

Table 8: Ivy occurring TOF species and total ivy (climbers) species recorded in the study area

TOF species	Climber species
1. *Senegalia catechu* (L.f.) P.J.H.Hurter & Mabb.	1. *Cucurbita maxima* Duchesne
2. *Albizia julibrissin* Durazz.	2. *Dioscore aalata* L.
3. *Alnus nepalensis* D. Don	3. *Diplocyclos palmatus* (L.) C. Jeffrey
4. *Araucaria heterophylla* (Salisb.) Franco	4. *Hedera nepalensis* K. Koch
5. *Bauhinia variegata* L.	5. *Lagenaria siceraria* (Molina) Standl.
6. *Callistemon citrinus* (curtis) Skeels	6. *Macfadyena unguis-cati* (L.) Miers
7. *Celtis australis* L.	7. *Monstera deliciosa* Liebm.
8. *Choerospondias axillaris* (Roxb.) B.L.Burtt	8. *Oplismenus burmannii* (Retz.) P. Beauv.
9. *Cinnamomum camphora* (L.) J. Presl	9. *Sechium edule* (Jacq.) Sw.
10. *Citrus maxima* (Burm.) Herr.	10. *Syngonium podophyllum* Schott
11. *Eucalyptus camaldulensis* Dehn.	11. *Bougainvillea glabra* Choisy
12. *Ficus lacor* Buch-Ham.	
13. *Ficus semicordata* Buch- Ham. ex Sm.	
14. *Grevillea robusta* A. Cunn. ex R. Br.	
15. *Jacaranda mimosifolia* D. Don	
16. *Melia azedarach* L.	
17. *Magnolia champaka* L.	
18. *Phoenix humilis* Royle.	
19. *Pinus roxburghii* Sarg.	
20. *Platanu sorientalis* L.	
21. *Prunus cerasoides* D. Don	
22. *Prunus domestica* L.	
23. *Prunus persica* (L.) Batsch	
24. *Psidium guajava* L.	
25. *Pyrus pashia* Buch-Ham. ex D. Don.	
26. *Pyru spyrifolia* (Burn.) Nak.	
27. *Thuja orientalis* L.	

Table 9: Fern occurring TOF species and total fern species recorded in the study area

TOF species	Fern species
1. *Senegalia catechu* (L.f.) P.J.H.Hurter & Mabb.	1. *Drynaria* sp.
2. *Albizia julibrissin* Durazz.	2. *Dryopteris* sp.
3. *Araucaria heterophylla* (Salisb.) Franco	3. *Microsorum* sp.
4. *Areca catechu* L.	4. *Nephrolepis* sp.
5. *Buddleja asiatica* Lour.	5. *Onychium japonicum* (Thumb.) Kunze. Nom.
6. *Callistemon citrinus* (curtis) Skeels	
7. *Cassia fistula* L.	
8. *Casuarina equisetifolia* L.	
9. *Celtis australis* L.	
10. *Choerospondias axillaris* (Roxb.) B. L. Burtt	
11. *Cinnamomum camphora* (L.) J. Presl	
12. *Dalbergia sissoo* Roxb.	
13. *Eucalyptus camaldulensis* Dehn.	
14. *Ficus benghalensis* L.	
15. *Grevillea robusta* A. Cunn. ex R. Br.	
16. *Jacaranda mimosifolia* D. Don	

TOF species	Fern species
17. *Juglans nigra* L. 18. *Juglans regia* L. 19. *Juniperus recurva* Buch-Ham. ex D. Don 20. *Lagerstroemia indica* L. 21. *Mangifera indica* L. 22. *Manglietia insignis* (Wall.) Blume 23. *Melia azedarach* L. 24. *Phoenix humilis* Royle. 25. *Phyllanthus emblica* L. 26. *Pinus roxburghii* Sarg. 27. *Populus jacquemontiana* Dode. 28. *Prunus cerasoides* D. Don 29. *Psidium guajava* L. 30. *Pyrus pashia* Buch-Ham. ex D. Don. 31. *Pyrus pyrifolia* (Burn.) Nak. 32. *Rhododendron arboreum* Smith 33. *Salix tetrasperma* Roxb. 34. *Schima wallichii* (DC.) Korth. 35. *Thuja orientalis* L.	

Table 10: Mistletoe occurring TOF species and total mistletoe species recorded in the study area

TOF species	Mistletoe species
1. *Callistemon citrinus* (curtis) Skeels	1. *Cuscuta* sp.
2. *Populus jacquemontiana* Dode.	2. *Viscum album* L.

Table 11: Orchids occurring TOF species and total orchid species recorded in the study area

TOF species	Orchid species
1. *Senegalia catechu* (L.f.) P.J.H.Hurter & Mabb. 2. *Albizia julibrissin* Durazz. 3. *Albizia procera*(Roxb.) Benth. 4. *Bougainvillea glabra* Choisy 5. *Callistemon citrinus* (curtis) Skeels 6. *Celtis australis* L. 7. *Choerospondias axillaris* (Roxb.) B. L. Burtt 8. *Cinnamomum camphora* (L.) J. Presl 9. *Dalbergia sissoo* Roxb. 10. *Eucalyptus camaldulensis* Dehn. 11. *Ficus religeosa* L. 12. *Grevillearo busta* A. Cunn. ex R. Br. 13. *Jacaranda mimosifolia* D. Don 14. *Juglans nigra* L. 15. *Juglans regia* L. 16. *Juniperus recurva* Buch-Ham. ex D. Don 17. *Litchi chinensis* Sonner 18. *Melia azedarach* L. 19. *Platanus orientalis* L. 20. *Podocarpus neriifolius* D. Don 21. *Prunus cerasoides* D. Don 22. *Thuja orientalis* L.	1. *Bulbophyllum* sp. 2. *Cleisostoma* sp. 3. *Dendrobium* sp. 4. *Pholitoda* sp. 5. *Vanda* sp.

Table 12: TOF species with other phanerogams and total recorded other phanerogams in the study area

TOF species	Other phanerogams
1. *Areca catechu* (L.F.) Willd.	1. *Alnus nepalensis* D. Don
2. *Callistemon citrinus* (curtis) Skeels	2. *Dischidia* sp.
3. *Casuarina equisetifolia* L.	3. *Ficuslacor* Buch-Ham.
4. *Celtis australis* L.	4. *Ficus religiosa* L.
5. *Cinnamomum camphora* (L.) J. Presl	5. *Fragaria* sp.
6. *Eucalyptus camaldulensis* Dehn.	6. *Hedychium coronarium* J. Koenig
7. *Ficus religiosa* L.	7. *Lycopersicum esculentum* L.
8. *Grevillea robusta* A. Cunn. ex R. Br.	8. *Malvaviscus arboreus* Cav.
9. *Jacaranda mimosifolia* D. Don	9. *Mangifera indica* L.
10. *Mangifera indica* L.	10. *Peperomia pellucida* (L.) A. Dietr
11. *Melia azedarach* L.	11. small herbs (unidentified)
12. *Phoenix humilis* Royle.	12. *Solanum aculeatissimum* Jacq.
13. *Prunus cerasoides* D. Don	
14. *Thespesia lampas* (Cav.) Dalz. & Gibs.	
15. *Thuja orientalis* L.	

Table 13: Total animal species recorded on TOF in the study area

Animal species	English common name
1. *Cornu aspersum* Muller	1. Garden snail
2. Catterpiller	2. Catterpiller
3. *Lasiusniger* L.	3. Black garden ant
4. *Tamias sp.* Illiger	4. Squirrel
5. Tarantula	5. Spider
6. *Apis* sp.	6. Bee
7. *Corvus splendens* Viellot	7. Crow

In the strata

Distribution of TreMs types were not found uniform along the urban rural gradient in the study area. Plotwise average numbers of cavities, fungi, mistletoe, other phanerogams and invertebrate nests were found higher in the urban stratum (Table 14). Average numbers of lichens, vertebrate nests and sap runs were found higher in the suburban stratum. In urban areas, there are reports of decreasing lichen abundance due to higher level of air pollution (Bergamaschi et al., 2007). In case of vertebrate avain richness, there is reduction with increased urbanization (Chace & Walsh, 2006).

Khanalizadeh et al. (2020) found the cavity as the most abundant microhabitat type in both managed (16.5 per ha.) as well as in recently unmanaged (14.2 per ha.) forests. Distribution of cavities depends upon the tree species and tree DBH of different altitudes. Hussain (2013) found more tree population (647) but less cavity bearing trees (5.3%) in upper elevation (2042 m) than less tree population (493) but more cavity bearing trees (10.0% of trees) in lower elevation (1066 m). Similarly, average numbers of moss, ivy, ferns and orchids were found higher in the rural stratum. Vuidot et al. (2011) reported significantly lower occurrence of bryophytes in Fontainebleau than at all the other sites. He stated that presence of bryophytes increased with diameter at a higher rate for "other species" than for oaks or for fir and spruce. Kruskal-Wallis tests of lichens have shown the significant difference between urban-rural strata ($p > 0.05$) (Table 14). Vuidot et al. (2011) found the presence of only ivy was highest in Auberive (14.3%) which significantly differed from Fontainebleau (2.9%). Kruskal-Wallis tests of ferns have shown the significant differences between urban-suburban strata ($p > 0.05$) (Table 14). Similarly, the same test of other phanerogams have shown the significant differences between all the strata ($p \leq 0.05$) (Table 14).

Number of vertebrate nests varied from 1 to 4. Kruskal-Wallis tests of vertebrate nests have shown the significant difference between urban-

Table 14: Plotwise average numbers of TreMs types with SD (±) found in different strata of the study area. Different letters across rows indicate significant difference at $p \leq 0.05$ (Kruskal-Wallis tests), (n=209)

S.N.	TreMs (Forms)	TreMs (Types)	Urban	Suburban	Rural
1	Cavities	Trunk base rot hole	0.09±0.3 **a**	0.07±0.25 **a**	0.08±0.4 **a**
2	Fruiting bodies of saproxylic fungi and slime moulds	Annual and perennial polypores of Basidiomycetes, Corticiaceae	0.14±0.5 **a**	0.01±0.12 **a**	0
3	Epiphytic, epixylic and parasitic structures	Bryophytes (moss)	1.47±3.6 **a**	1.12±2.71 **a**	2.52±5.7 **a**
		Crustose, Foliose and fruticose lichens	0.42±1.3 **a**	3.14±15.0 **ab**	2.31±4.9 **b**
		Ivy	0.33±0.9 **a**	0.23±0.79 **a**	0.40±1.6 **a**
		Ferns	0.94±2.2 **a**	0.32±1.01 **b**	1.25±3.4 **ab**
		Mistletoe	0.02±0.15	0	0
		Orchids	0.06±0.2 **a**	0.16±0.76 **a**	0.40±1.6 **a**
		Other phanerogams	0.36±0.7 **a**	0.08±0.28 **b**	0.04±0.2 **c**
		Vertebrate nest	0.55±0.7 **a**	0.63±0.66 **a**	0.19±0.4 **b**
		Invertebrate nest	0.10±0.7 **a**	0.04±0.20 **a**	0
4	Fresh exudates	Sap run	0.14±0.4 **a**	0.21±0.99 **a**	0

rural as well as suburban-rural strata ($p \leq 0.05$) (Table 14). Michel & Winter (2009), in his study found a significant difference of the total number of microhabitats/ha only in between the clear cut stands and the managed young, natural mature, and natural old-growth stands, respectively. On the basis of individual microhabitat types and total number of microhabitats, Khanalizadeh et al. (2020) did not find any significant difference between managed and recently unmanaged forests.

From the present results, the work cannot provide the complete discussion on microhabitat key factors. But, the number and occurrence of microhabitat types were mainly influenced by tree characteristics. From the present findings it can be concluded that lichens were the dominating habitant on TOF, followed by mosses and birds.

Conclusion

This study provides fundamental information about the importance of both TOF and TreMs in terms of biodiversity and its conservation in Kathmandu valley, Nepal. Lichens are the dominating habitant on TOF, followed by mosses and birds microhabitat types are species specific. *Cinnamomum camphora* as individual tree of rural stratum served maximum habitat types (6). Habitat types might or might not be dependent on DBH of the tree. Generally, co-occurrence of microhabitat is more common on trees with greater DBH. Microhabitats are also strata specific because maximum habitat types (7) were found in urban and rural strata. Both urban and rural TOF contributes significantly to biodiversity conservation because maximum habitat types (7) were found in both the strata.

Author Contributions

All authors were involved in concept development, research designing, defining of intellectual content and literature research. B. K. Sharma and B. Shrestha collected the data. B. Shrestha analyzed data and prepared manuscript. R. K. P. Yadav and B. K. Sharma analyzed data and reviewed the manuscript. B. Shrestha, as a corresponding author, is the guarantor for this article.

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References

Asbeck, T., Großmann, J., Paillet, Y., Winiger, N., & Bauhus, J. (2021). The use of tree-related microhabitats as forest biodiversity indicators and to guide integrated forest management. *Current Forestry Reports*, *7*(1), 59-68. https://doi.org/10.1007/s40725-020-00132-5

Awasthi, D. D. (2007). *A compendium of the macrolichens from India, Nepal and Sri Lanka*. Bishen Singh Mahendra Pal Singh.

Baniya, C. B., & Bhatta, P. (2021). Exploration of lichen in Nepal. *Journal of Plant Resources, 19*, 18-54.

Baniya, C. B., K. C., A, & Tamang, R. (2022). *Checklist of lichens of Nepal*. National Herbarium and Plant Laboratories.

Basile, M., Asbeck, T., Pacioni, C., Mikusinki, G., & Storch, I. (2020). Woodpecker cavity establishment in managed forests: Relative rather than absolute tree size matters. *Wildlife Biology*, 1-9. https://doi.org/:10.2981/wlb.00564

Bellefontaine, R., Petit, S., Plain-Orcet, M., Deleforte, P., & Bertault, J. G. (2002). *Trees outside forests, towards a better awareness*. FAO conservation guide no 35 (pp. 335). FAO. ISBN 92-5-104656-5. www.fao.org/docrep/005/y2328e/y2328e00.HTM

Bergamaschi, L., Rizzio, E., Giaveri, G., Loppi S., & Gallorini, M. (2007). Comparison between the accumulation capacity of four lichen species transplanted to an urban site. *Environmental Pollution, 148*, 468-476.

Bhusal, P., Czeszczewik, D., Walankiewicz, W., Churski, M., Baral, R., Lamichhane, B. R., & Mikusiñski, G. (2015). Availability of tree cavities in a sal forest of Nepal. *iForest Biogeosciences and Forestry, 9*, 217-225. https://doi.org/10.3832/ifor1493-008.

Bishop, J., Bertrand, N., Evison, W., Gilbert, S., Grigg, A., Hwang, L., Kallesoe, M., Vakrou, A., van der Lugt, C., & Vorhies, F. (2010). *TEEB -The economics of ecosystems and biodiversity - Report for Business - Executive Summary,* United Nations Environment Programme.

Bridson, D., & Forman, L. (1998). *The herbarium hand book* (3rd ed.). Royal Botanic Garden, Kew.

Butler, R., Lachat, T., Krumm, F., Kraus, D., & Larrieu, L., (2020). *Field guide to tree-related microhabitats. descriptions and size limits for their inventory* (pp. 59). Birmensdorf, Swiss Federal Institute for Forest, Snow; Landscape Research WSL.

Butler, R., Lachat, T., Krumm, F., Kraus D. & Larrieu, L. (2021). *Know, protect and promote habitat trees*. [Fact Sheet] WSL 64.

Central Bureau of Statistics. (2014). *Population monograph of Nepal*. National Planning Commission Secretariat.

Chace, J. F., & Walsh, J. J. (2006). Urban effects on native avifauna: a review. *Landscape and Urban Planning*, *74*, 46-69.

Courbaud, B., Pupin, C., Letort, A., Cabanettes, A., & Larrieu, L. (2017). Modelling the probability of microhabitat formation on trees using cross-sectional data. *Methods in Ecology and Evolution*, *8*(10), 1347-1359. https://doi.org/10.1111/2041-210X.12773

Courbaud, B., Larrieu, L., Kozak, D., Kraus, D., Lachat, T., Ladet, S., Müller, J., Paillet, Y., Sagheb-Talebi, K., Schuck, A., Stillhard, J., Svoboda, M., & Zudin, S. (2021). Factors influencing the rate of formation of tree-related microhabitats and implications for biodiversity conservation and forest management. *Journal of Applied Ecology,* 1-12. https://doi.org/10.1111/1365-2664.14068

Department of Forest Research and Survey (2011). *Field manual for Assessment of Trees outside Forests* (*TOF*). FRA-Nepal.

Dida, J. J. V., Quinton, K R. F., & Bantanyan, N. C. (2016). Assessment of trees outside forests as potential food source in second district, Makati city, Philippines. *Ecosystems & Development, 6*(1), 10-14.

Food and Agriculture Organization of the United Nations. (1998). Terms and definitions: Forest resources assessment programme working paper no. 1. Rome. Forest. *Unasylva, 51*(200), 3-10.

Foresta, de. H., Somarriba, E., Temu, A., Gauthier, Boulanger, D., Feuilly, H., & Taylor, D. (2013) *Towards the assessment of trees outside forests a thematic report.* FRA working paper 183. FAO.

Frey, J., Asbeck, T., & Bauhus, J. (2020). Predicting tree-related microhabitats by multi sensorclose-range remote sensing structural parameters for the selection of retention elements. *Remote Sensing*, *12*(867), 1-20.

GoN, DHM (2021). Government of Nepal. Department of Hydrology and Meteorology, Kathmandu, Nepal.

Großmann, J., Pyttel, P., Bauhus, J., Lecigne, B., & Messier, C. (2020). The benefits of tree wounds: Microhabitat development in urban trees as affected by intensive tree maintenance. *Urban Green*, *55*, 126817.

Hussain, I., Abbasi, S., Mirza, S. N., Anwar, M., Rais, M., & Mahamood, T. (2013). Tree cavities and associated vertebrate fauna in a coniferous forest of Dhirkot, Azad Jammu and Kashmir part of Pakistan. *Turkish Journal of Zoology*, *37*, 647-658. https://doi.org/10.3906/zoo-1209-32.

International Centre for Integrated Mountain Development. (2007). *Kathmandu valley environment outlook.*

Khanalizadeh, A., Rad, J. E., Amiri, G. Z. Zare, H., Rammer, W., & Lexer, M. J. (2020). Assessing selected microhabitat types on living trees in Oriental beech (*Fagus orientalis* L.) dominated forests in Iran. *Annals of Forest Science*, *77*(91), 1-13. https://doi.org/10.1007/s13595-020-00996-4

Kitching, R. L. (1971). An ecological study of water-filled tree-holes and their position in the woodland ecosystem. *Journal of Animal Ecology*, *40*(2), 281. https://doi.org/10.2307/3247

Kleinn, C. (2000). On large-area inventory and assessment of trees outside the forest. *Unasylva, 51*(200), 3-10.

Larrieu, L., & Cabanettes, A. (2012). Species, live status, and diameter are important tree features for diversity and abundance of tree microhabitats in subnatural montane beech-fir forests. *Canadian Journal of Forest Research*, *42*(8), 1433-1445. https://doi.org/10.1139/x2012-077

Larrieu, L., Cabanettes, A., Brin, A., Bouget, C., & Deconchat, M. (2014). Tree microhabitats at the stand scale in montane beech-fir forests: Practical information for taxa conservation in forestry. *Europian Journal of Forest Research*, *133*(2), 355–367. https://doi.org/10.1007/ s10342-013-0767-1

Larrieu, L., Cabanettes, A., Courbaud, B., Goulard, M., Heintz, W., Koz´ak, D., Kraus, D., Lachat, T., Ladet, S., Müller, J., Paillet, Y., Schuck, A., Stillhard, J., & Svoboda, M. (2021). Co-occurrence patterns of tree-related microhabitats: A method to simplify routine monitoring. *Ecological Indicators, 127*, 107757. https://doi.org/10.1016/j.ecolind.2021.107757

Larrieu, L., Paillet, Y., Winter, S., Butler, R., Kraus, D., Krumm, F., Lachat, T., Michel, A. K., Regnery, B., & Vandekerkhove, K. (2018). Tree related microhabitats in temperate and Mediterranean European forests: A hierarchical typology for inventory standardization. *Ecological Indicators*, *84*, 194-207. https://doi.org/10.1016/j.ecolind.2017.08.051

Lister, A. J., Scott, C.T., & Rasmussen, S. (2011). Inventory of trees in nonforest areas in the great plains states. *Environmental Monitoring and Assessment*, *184*(4), 2465-2474. https://doi.org/10.1007/s10661-011-2131-6

Magg, N., Ballenthien, E., & Braunisch, V. (2019). Faunal surrogates for forest species conservation: A systematic niche-based approach. *Ecological Indicators*, *102*, 65-75.

Malla, S. B., Rajbhandari, S. B., Shrestha, T. B., Adhikari, P. M., & Adhikari, S. R. (Ed.). (1986).

Flora of Kathmandu Valley. Department of Medicinal Plants.

Martin, M., Paillet, Y., Larrieu, L., Kern, C. C., Raymond, P., Drapeau, P., & Fenton, N. J. (2022). Tree-related microhabitats are promising yet underused tools for biodiversity and nature conservation: A systematic review for international perspectives. *Frontiers in Forests and Global Change*, *5*, 818474. https://doi.org/10.3389/ffgc.2022.818474

Michel, A. K., & Winter, S. (2009). Tree microhabitat structures as indicators of biodiversity in Douglas-fir forests of different stand ages and management histories in the Pacific Northwest, U.S.A. *Forest Ecology and Management*, *257*(6), 1453-1464. https://doi.org/10.1016/j.foreco.2008.11.027

Noss, R. F. (1990). Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology*, *4*, 355-64.

Paillet, Y., Archaux, F., Boulanger, V., Debaive, N., Fuhr, M., Gilg, O., Gosselin, F., & Guilbert, E., (2017). Snags and large trees drive higher tree microhabitat densities in strict forest reserves. *Forest Ecology and Management*, *389*, 176-186.

Piechnik, L., Holeksa, J., Ledwon, M., Kurek, P., Szarek-Lukaszewska, G., & Zywiec, M. (2022). Stand composition, tree-related microhabitats and birds – A network of relationships in a managed forest. *Forests*, *13*(1), 103. https://doi.org/10.3390/f13010103

Poudel, K. (2010, August). Green streets: the trees of Kathmandu. *ECS Nepal , 1,* 25. http://ecs.com.np/features/green-streets-the-trees-of-kathmandu.

Press, J. R., Shrestha, K. K., & Sutton, D. A. (2000). *Annotated checklist of the flowering plants of Nepal*. The Natural History Museum.

Rajbhandari, K. R., (2015). *A handbook of the orchids of Nepal.* Department of Plant Resources.

Rajbhandary, K. R., & Rai, S. K. (2017). *A handbook of the flowering plants of Nepal* (Vol. 1). Department of Plant Resources.

Ranta, P., & Viljanen, V. (2011). Vascular plants along an urban-rural gradient in the city of Tampere, Finland. *Urban Ecosystem*, *14*(3), 361-376. DOI 10.1007/s11252-011-0164-9

Regnery, B., Couvet, D., Kubarek, L., Julien, J. F., & Kerbiriou, C. (2013). Tree microhabitats as indicators of bird and bat communities in Mediterranean forests. *Ecological Indicators*, *34*, 221-30.

Rokaya, M. B., Raskoti, B. B., Timsina, B., & Münzbergová, Z. (2013). An annotated checklist of the orchids of Nepal. *Nordic Journal of Botany*, *31,* 511-550, https://doi.org/10.1111/j.1756-1051.2013.01230.x.

Sharma, B. K. (2014). *Bioresources of Nepal*. Subidhya Sharma.

Sharma, U. R. (2021). The Ill-Planned roadside plantation in Kathmandu. https://myrepublica.nagariknetwork.com/news/the-ill-planned-roadside-plantation-in-kathmandu/ Assessed on 9/19/2022

Shrestha, K. K., Bhandari, P., & Bhattarai, S. (2022). *Plants of Nepal (Gymnosperms and Angiosperms)*. Heritage Publishers & Distributors Pvt. Ltd.

Singer, R. (1986). *The Agaricales in modern taxonomy* (4th ed.). Bishen Singh Mahendra Pal Singh.

Tang, Y. J., Chen, A. P., & Zhao, S. Q. (2016). Carbon storage and sequestration of urban street trees in Beijing, China. *Frontiers in Ecology and Evolution, 4*(53), 1-8. https://doi.org/10.3389/fevo.2016.00053

Vuidot, A., Paillet, Y., Archaux, F., & Gosselin, F. (2011). Influence of tree characteristics and forest management on tree microhabitats. *Biological Conservation*. *144*(1), 441-450. https://doi.org/10.1016/j.biocon.2010.09.030

Wang, M., Li, J., Kuang, S., He, Y., Chen, G., Huang, Y., Song, C., Anderson, P., & £owicki, D. (2020). Plant diversity along the urban-rural gradient and its relationship with urbanization degree in Shanghai, China. *Forests*, *11*(2), 171. http://doi.org/10.3390/f11020171

Wesolowski, T. (2007). Lessons from long-term hole-nester studies in a primeval temperate forest. *Journal of Ornithology*, *148(*S2), 395-405. https://doi.org/10.1007/s10336-007-0198-1

Westfall, J. A., Patterson, P. L., & Edgar, C. B. (2018). Integrating urban and national forest inventory data in support of rural-urban assessments, *Forestry: An International Journal of Forest Research*, *91*(5), 641-649. https://doi.org/10.1093/forestry/cpy023

Winter, S., & Moller, G. C., (2008). Microhabitats in lowland beech forests as monitoring tool for nature conservation. *Forest Ecology and Management*, *255*(3-4), 1251-1261. https://doi.org/10.1016/j.foreco.2007.10.029