https://doi.org/10.3126/banko.v32i2.50894 Banko Janakari, Vol 32 No. 2, 2022 Pp 19–36

Valuation of timber and firewood of trees outside forest along the urban–rural gradient in Kathmandu valley, Nepal

B. Shrestha[1*], B. K. Sharma[2], and R. K. P. Yadav[1*]

Received: 2, August 2022 Revised: 9, November 2022 Accepted: 14, December 2022 Published: 31, December 2022

This study aims to analyze diameter class, quality class, wood production potential and timber and firewood values of trees outside forest along the urban-rural gradient in Kathmandu valley of central Nepal. Inventory was performed in 209 randomly selected points. Circular plots of 20 m radius were used for inventory. All trees (height > 1.3 m and DBH ≥ 5 cm) in the plots were identified to species level and their height, DBH & quality class were recorded. In total 6,210 trees (236.35 ha^{-1}) of 150 species belonging to 111 genera and 57 families were recorded. The total merchantable timber volumes of timber class A and B, and total timber volumes were highest in the urban stratum (537.08, 84.88 and 621.96 cu ft ha^{-1} respectively) followed by rural (442.94, 66.82 and 509.76 cu ft ha^{-1} respectively) and suburban (250.04, 47.31 and 297.35 cu ft ha^{-1} respectively) strata. But due to higher merchantable price of tree species recorded in rural stratum, total market value of class A timber was higher in rural stratum (NPR 7,89,871/US$ 6,085), class B timber was higher in urban stratum (NPR 1,08,255/US$ 834), total timber was higher in rural stratum (NPR 8,70,410/US$ 6,706), firewood was higher in urban stratum (NPR 4,88,709/US$ 3,765) and total wood was higher in urban stratum (NPR 12,95,531/US$ 9,981). *Cinnamomum camphora* was found as tree species with highest market price of total wood value in the study area. The study provides the baseline data of useful timber species through TOF suggesting a need for appropriate timber producing species selection for plantation.

Keywords: Diameter class, merchantable timber, quality class, strata, wood

Trees are an essential part of our life. Trees can also be found outside of the forest areas. FAO (1998) has defined trees outside forest (TOF) as "the trees on the land that fulfils the requirements of forest and other wood land except that the area is less than 0.5 ha and the canopy is < 10%". For example, 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; and trees in shelterbelts of less than 20 m width and 0.5 ha area. TOF comprises all trees ranging from a single discrete individual tree to systematically managed trees (Kleinn, 2000). TOF includes both trees as well as shrubs (Foresta *at al*., 2013). Bamboo is a part of TOF that is merchantable for house construction (Bhusal & Bashyal, 2020). In some cases, total wood production from TOF is more than that from the forests (Krishnankutty *et al*., 2008). TOF has become an important source for timber globally but still there are no policies related to management, harvest, transit and marketing of timber from TOF (Ghosh & Sinha, 2018). It plays a significant role in meeting the challenges of resource sustainability, poverty

1 Central Department of Botany, Tribhuvan University, Kathmandu, Nepal; *E-mail: biobabita@gmail.com, rkp.yadav@cdbtu.edu.np
2 Conservation Development Foundation (CODEFUND), Nepal,

reduction, food security, lessening the pressure on forest resources, conserve farmland, increase agricultural productivity and food supplies (Foresta *et al*., 2013). Besides, TOF also provide the impetus to the growth of wood-based industries and employment opportunities by increasing the extent of area under forest (FSI, 2003) especially more jobs to rural communities (Asanzi *et al*., 2014). TOF are prominent features in many landscapes, strata (urban, suburban and rural) and substrata (linear, clumped and scattered tree formations) (Baffetta *et al*., 2010; DFRS, 2011) and serve a number of ecological and economic functions that might be similar to those of forests in different ways and extent (Kleinn, 2000).

Wood includes all timber, industrial wood, firewood and charcoal (Krishnankutty *et al*., 2008). It is still the most widely used fuel source in the developing countries (FAO, 1999a). A timber readily harvestable is the merchantable timber (Ouattara *et al*., 2014). According to DFRS (2015), a tree can be classified as: quality class A tree (high quality sound tree) - a live tree which would produce at least one 6 m long saw log; quality class B tree (sound tree) –a live tree which would produce at least one 3 m long saw log; and quality class C tree (cull tree) - a live tree not qualified as class A or class B but would produce fire wood only. Forests resources, particularly the timber, face an uncertain future because of high deforestation rate, rapid population growth, timber rights allocation system, forest fees, poor law enforcement, increasing demand for timber and energy and sawmills being export oriented (Oduro et *al*., 2014).

Generally, single trees in areas with lower density attain a larger diameter at breast height (DBH) and as a consequence, greater volume (Bembenek *et al*., 2014). Stem volume is an important parameter to estimate the monetary value of timber (Crecente-Campo *et al*., 2009). Categorization of TOF on the basis of diameter class and timber quality class is necessary for the valuation of the wood (Pompa-García, *et al*., 2009; Bembenek *et al*., 2014). Merchantable value of the wood depends on the species (Mejia *et al*., 2015). Merchantable value gives an idea about the economic importance of a species.

The organized tree planting first started in the Malla Era was continued up to the Rana Era (Poudel, 2010). New species like *Araucaria araucana*, other imported species from Europe along with pines were planted to beautify Kathmandu Valley urban areas and palaces. Later with the introduction of modern urban-environmental planning in the 1960s and 1970s, the Government renovated roads and trails throughout Kathmandu. Again in the 1980s, urban environmental planners introduced a three-line green belt. Trees were also planted along either side of other roads (Poudel, 2010), roadside gardens and traffic islands (Baral and Kurmi, 2005). Many parks were also built during different historical eras. A botanical garden and zoo were also built. Thus, many native as well as exotic tree species were planted.

Kathmandu valley with the rapid urban population growth rate of 3.9 % is one of the fastest growing urban agglomerations in South Asia (Muzzini & Aparicio, 2013). It is characterized not only by the rapid population growth rate in the urban core but also by the rapid expansion of urban sprawl in the periphery. Plant communities are sensitive to urban expansion and therefore may serve as indicators for human-induced land use change (Vakhlamova *et al*., 2014). The rural system usually is rich in natural vegetation (Xiao *et al.*, 2017) with more timber production whereas due to rapid urbanization, TOF formations have increased with less timber production in urban area. Thus tree species selection for afforestation in TOF will help to minimize the demand-supply gap of timber (Shrivastav *et al*., 2012).

TOF are little recognized in forest resources assessments, and it is only recently that TOF started receiving attention from the research community and the general public (Kleinn, 2000). Nepal's annual import of wood and wooden materials exceeds NPR 6 billion (RSS, 2019.). In this context, the study of TOF in terms of timber production would be important (Oli, 2002). Since FY 2004/05, the Department of Forests Research and Survey (now the Forest Research and Training Center), Government of Nepal has started the assessment of TOF at national level (FAO, 2009). But it is limited only to volume assessment by diameter class. The assessments of TOF in terms of timber and firewood production along the urban-rural gradient are lacking. In this background, this study aims to analyze diameter class, quality class, wood production potential and timber and firewood values of TOF along the urban-rural gradient in Kathmandu valley of central Nepal.

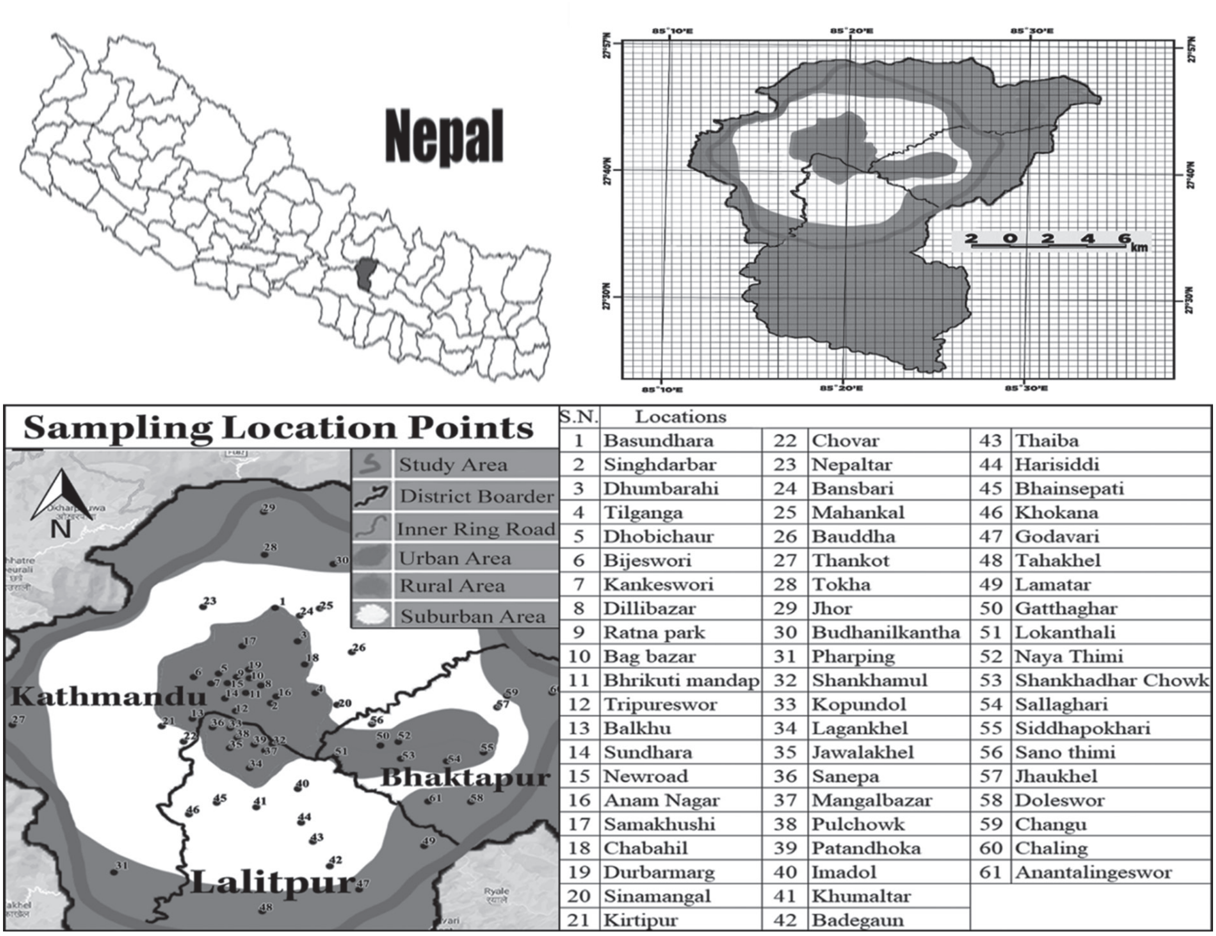
Materials and methods

Study area

The study was carried out in Kathmandu valley (ca. 66,500 ha in area), which includes three districts namely, Kathmandu, Lalitpur and Bhaktapur of Bagmati Province in the middle hill region of central Nepal (ICIMOD, 2007; Figure 1). This bowl-shaped valley extends between 27°32’13” N to 27°49’10” N latitude and 85°11’31” E to 85°31’38” E longitude. It’s elevation ranges between 1,100–2,700 m a.s.l. (Mishra *et al*., 2019). It is characterized by sub-tropical vegetation and has a distinct monsoon climate with hot and wet summers and cold and dry winters. The average annual minimum and maximum temperature are 1.6°C in January and 31.9°C in April respectively and the average annual rainfall is 1,509 mm (based on DHM data between 2000-2018).

Sampling and data collection

A two-phase sampling method was applied (Lister *et al*., 2011). In first phase, the study area was divided into 500 m x 500 m grids (n = 2800) (Figure 1). A total of 1,046 sites with TOF were identified under urban, suburban and rural stratum categorized on the basis of population and urban development (GoN, 2014). Google Earth image interpretation showed that more sites with TOF were found in urban (440) stratum than in suburban (366) and rural (240) strata. Twenty percent of sites with TOF from three strata [urban



S.N.	Locations	S.N.	Locations	S.N.	Locations
1	Basundhara	22	Chovar	43	Thaiba
2	Singhdarbar	23	Nepaltar	44	Harisiddi
3	Dhumbarahi	24	Bansbari	45	Bhainsepati
4	Tilganga	25	Mahankal	46	Khokana
5	Dhobichaur	26	Bauddha	47	Godavari
6	Bijeswori	27	Thankot	48	Tahakhel
7	Kankeswori	28	Tokha	49	Lamatar
8	Dillibazar	29	Jhor	50	Gatthaghar
9	Ratna park	30	Budhanilkantha	51	Lokanthali
10	Bag bazar	31	Pharping	52	Naya Thimi
11	Bhrikuti mandap	32	Shankhamul	53	Shankhadhar Chowk
12	Tripureswor	33	Kopundol	54	Sallaghari
13	Balkhu	34	Lagankhel	55	Siddhapokhari
14	Sundhara	35	Jawalakhel	56	Sano thimi
15	Newroad	36	Sanepa	57	Jhaukhel
16	Anam Nagar	37	Mangalbazar	58	Doleswor
17	Samakhushi	38	Pulchowk	59	Changu
18	Chabahil	39	Patandhoka	60	Chaling
19	Durbarmarg	40	Imadol	61	Anantalingeswor
20	Sinamangal	41	Khumaltar		
21	Kirtipur	42	Badegaun		

Figure 1: Map of the study area. The distribution of the sample points in urban, suburban and rural strata

(88), suburban (73) and rural (48) strata] were selected randomly for the field survey (Figure 1). In second phase field survey was done. Circular sample plots with 20 m radii (area = 0.13 ha) were used for the survey (FRA/DFRS, 2011). Plant characteristics (height, DBH and quality class) of woody plants (trees and shrubs) 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 measured using Suunto clinometer (PM-5/360 PC). Tree quality class was also noted for individual trees. Plants were identified to species level based on herbarium specimen prepared following standard procedure (Bridson & Forman, 1998). The vernacular names of the plant species were also recorded with the help of local people and verified with Sharma (2014). Identification was done by using literatures such as Flora of Kathmandu Valley (Malla *et al*., 1986), followed by comparison with identified specimens previously deposited at Tribhuvan University Central Herbarium (TUCH), Nepal, scientific names were determined. Press *et al*. (2000) and Plants of the World Online (https://powo.science.kew.org/) were followed for plant nomenclature.

Species richness of the study area and across the strata were estimated with respect to the area sampled at the study area and each stratum. Average species richness was calculated as the total number of species recorded per plot (Dorji *et al*., 2014). Growth forms of the plants were based on Sharma (2014). Frequency of the individual tree species were also calculated (Danekhu *et al*., 2016-18).

Data analysis

DBH and height of the recorded trees were used.

Estimation of above ground biomass of trees

The total above ground tree biomass was estimated using allometric equation developed by Petersson *et al.* (2012).

$$AGTB = 0.0509\ \rho\ D^2\ H$$

Where, AGTB = aboveground tree biomass (kg), ρ= wood specific gravity (g cm^{-3}), D = tree diameter at breast height (cm), H = tree height (m).

Sharma & Pukkala (1990) and Zanne *et al*. (2009) were used for wood specific gravities of tree species. For the tree/shrub species for which wood specific gravity data were not available, the arithmetic mean of all known tree/shrub species in the study area was used (Brown *et al*., 1989).

Estimation of biomass of merchantable timber and firewood

Merchantable weights of log of quality class A tree and quality class B tree were calculated only for trees with DBH ≥30 cm as such trees are regarded as mature trees (DoF, 2004 and Brown *et al.*, 2020). The biomass of merchantable timber of log of class A tree and class B tree were estimated using following allometric equations adapted from Petersson *et al.* (2012).

Merchantable weight of log of class A tree AGTB = $0.0509 * \rho * D^2 * 6$ (kg)

Merchantable weight of log of class B tree AGTB= $0.0509 * \rho * D^2 * 3$ (kg)

Where, AGTB = aboveground tree biomass (kg), ρ= wood specific gravity (g cm^{-3}), D = tree diameter at breast height (cm), 6 and 3 are the lengths (m) of merchantable logs of class A and class B trees respectively.

The biomass of firewood was calculated for timber yielding trees by subtracting the biomass of merchantable timber from the total AGTB of trees. The total AGTB of trees of class C were also accounted as fire wood biomass. These biomasses were converted into kg ha^{-1}.

Economic valuation of merchantable timber and firewood

As the merchantable timber are sold in cu ft measurement, biomass of merchantable timber of class A and class B trees in ton ha^{-1} were converted into volume (cubic feet) by multiplying with 40

(Wallis, 1970). Market value of merchantable timber of class A and B were calculated by multiplying the merchantable volumes by the per cu ft market price of timber. Unlike timber, the firewood is sold in per kg measurement. So, the market value of firewood was calculated by multiplying the firewood biomass by per kg market price of firewood. Retail market prices of class A, class B logs and firewood of tree species were collected from the retail depots (n = 4) (Ahmed, 2008). The average market prices were used for valuation. For the tree species for which market prices were not available (both timber and firewood), the average values of market prices of all tree species were used (Bembenek *et al*., 2014). Market values of timber of class A and class B were added to that of firewood to get the total economic value of individual tree species. All these values were then summed up to get the total economic value of all tree species except the bamboo. As bamboos are sold as culms (Bhusal & Bashyal, 2020), their merchantable values were calculated by multiplying the density per hectare by average market price. All these prices were then summed up to get the total merchantable value of wood in each stratum and the study area. Economic values in NPR were converted into US$ by multiplying with 129.8 (1 US$ = 129.8 NPR, accessed on 11/7/2022)

Statistical analysis

First the data were standardized. Standardized values are calculated by subtracting the sample mean of each variable from each observation and dividing this difference by the sample standard deviation (Gotelli & Ellison, 2013). Those values were then tested for normality. However, the data were not normal and their normality did not improve even after transformation so Kruskal-Wallis test with post-hoc Mann-Whitney test at $p \leq 0.05$ were used for comparison among groups. PAST (V 4.09; Hammer *et al*., 2001) was used for analysis.

Results

Plant species diversity

A total of 150 species of plants [trees (n=121) and shrubs (n=29)] belonging to 111 genera and 57 families were enumerated from the study area. Though the average species richness was found to be higher in urban stratum than in suburban and rural strata, Kruskal-Wallis test followed by Mann-Whitney test showed that there are no significant differences among the strata (Table 1 and Table 2).

Table 1: Species richness of trees outside forest along the urban-rural gradient in Kathmandu valley, Nepal. Number of plots, species richness (range), species richness ha^{-1} and average species richness (ha^{-1}) in three strata are shown. Different superscript letters indicate statistical significance at p<0.05 (Kruskal-Wallis test followed by Mann Whitney test)

Strata	Number of plots	Species richness (range)	Species richness (ha^{-1})	Average species richness (ha^{-1})
Urban	88	109 (1-21)	9.85	55.95±31.67^{a}
Suburban	73	89 (1-16)	9.7	46.31±26.99^{a}
Rural	48	85 (2-15)	14.09	45.74±23.35^{a}

Table 2: Scientific name, vernacular name, English name, family and frequency of species of trees outside forest species found in the study area

S.N.	Scientific name	Vernacular name	English name	Growth form	Family	Frequency (%)
1	*Acacia catechu* (L.F.) Willd.	Khayar	Cutch tree	Tree	Leguminosae	0.48
2	*Acacia nilotica* (L.) Willd. ex Del.	Babool	Gum arabic tree	Tree	Leguminosae	0.96
3	*Acer oblongum* Wall. ex DC.	Phirphire	Himalayan maple	Tree	Sapindaceae	0.48
4	*Agave cantula* Roxb.	Ketuke	Century plant	Shrub	Agavaceae	0.48
5	*Alangium chinense* (Lour.) Harms	Baman patti	Chinese alangium	Tree	Alangiaceae	0.48
6	*Albizia julibrissin* Durazz.	Rato siris	Mimosa tree	Tree	Leguminosae	9.09
7	*Albizia procera* (Roxb.) Benth.	Seto siris	White siris tree	Tree	Leguminosae	0.96
8	*Alnus nepalensis* D. Don	Uttis	Alder	Tree	Betulaceae	10.05
9	*Alstonia neriifolia* D. Don			Tree	Apocynaceae	1.91
10	*Alstonia scholaris* (L.) R. Br.	Chatiwan	Devil's tree	Tree	Apocynaceae	3.35
11	*Anthocephalus chinensis* (Lam.) A. Rich. ex Walp.	Kadamgachi	Kadam	Tree	Rubiaceae	0.48
12	*Araucaria bidwillii* Hook.	Dhengre sallo	Monkey puzzle	Tree	Araucariaceae	6.70
13	*Araucaria columnaris* J. R. Forst & Hook.		Coral reef araucaria	Tree	Araucariaceae	0.48
14	*Araucaria heterophylla* (Salisb.) Franco		Living Christmas tree	Tree	Araucariaceae	8.13
15	*Areca catechu* L.	Bhale supari	Betel nut	Tree	Palmae	1.44
16	*Artocarpus integra* (Thumb.) Merr.	Rookh katahar	Jack fruit	Tree	Moraceae	0.48
17	*Azadirachta indica* A. Juss.	Neem	Neem tree	Tree	Meliaceae	2.39
18	*Bambusa nepalensis* Stapleton	Bansa	Bamboo	Grass	Gramineae	3.83
19	*Bauhinia variegata* L.	Koiralo	Purple orchid tree	Tree	Leguminosae	2.87
20	*Berberis asiatica* Roxb. ex DC.	Chutro	Barberry	Shrub	Berberidaceae	0.96
21	*Borassus flabellifer* L.	Taad	Toddy palm	Tree	Palmae	5.74
22	*Bougainvillea glabra* Choisy	Kagaj phool	Paper flower	Shrub	Nyctaginaceae	2.39
23	*Brugmansia arborea* Pers.	Dhaturo	Angel's trumplet	Shrub	Solanaceae	1.91
24	*Buchanania latifolia* Roxb.	Chiraungi	Cuddaph almond	Tree	Anacardiaceae	0.48
25	*Buddleja asiatica* Lour.	Bhimsenpati	Butterfly bush	Shrub	Loganiaceae	8.61
26	*Burretiokentia vieillardii* Pic. Serm.	Taad	Tiger palm	Tree	Palmae	0.48
27	*Callistemon citrinus* (Curtis) Skeels	Kalki phool	Bottle brush	Tree	Myrtaceae	19.14
28	*Camellia japonica* L.	Chinia guransa	Garden camellia	Shrub	Theaceae	0.96

S.N.	Scientific name	Vernacular name	English name	Growth form	Family	Frequency (%)
29	*Carica papaya* L.	Mewa	Papaya	Tree	Caricaceae	2.39
30	*Carya illinoensis* (Wangenheim) K. Koch	Picanut	Pecan	Tree	Juglandaceae	0.48
31	*Caryota urens* L.	Jagar	Fish- tail palm	Tree	Palmae	0.96
32	*Cassia fistula* L.	Raj brichya	Cassia pods	Tree	Leguminosae	0.48
33	*Cassia mimosaides* L.	Amala jhar	Tooth cup	Shrub	Leguminosae	0.48
34	*Casuarina equisetifolia* L.	Jangali jhyau	Whistling pine	Tree	Casuarinaceae	0.48
35	*Cedrus deodara* (Roxb. ex D. Don) G. Don	Devdaru	Deodar	Tree	Pinaceae	0.96
36	*Celtis australis* L.	Khari	Europian nettle tree	Tree	Ulmaceae	29.67
37	*Cestrum nocturnum* L.	Rat ki rani	Night jasmine	Shrub	Solanaceae	0.48
38	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	Lapsi	Nepali hog plum	Tree	Anacardiaceae	11.96
39	*Cinnamomum camphora* (L.) J. Presl	Kapoor	Camphor	Tree	Lauraceae	41.15
40	*Cinnamomum tamala* (Buch-Ham) Nees & Eberm.	Tejpatta	Cinnamon leaf	Tree	Lauraceae	0.48
41	*Citrus aurantifolia* (Christm) Swingle	Kagati	Lemon	Tree	Rutaceae	5.74
42	*Citrus jambhiri* Lush.	Jyamir	Florida lemon	Tree	Rutaceae	0.96
43	*Citrus limon* (L.) Burn. F.	Nibuwa	Lime	Tree	Rutaceae	1.91
44	*Citrus maxima* (Burm.) Herr.	Bhogate	Pummelo	Tree	Rutaceae	18.18
45	*Citrus reticulata* Blanco.	Suntala	Mandarin orange	Tree	Rutaceae	0.48
46	*Cotinus coggygria* (Scop.)	Rato peepal	Smoke bush	Shrub	Anacardiaceae	0.48
47	*Croton roxburghii* Balakrishnan	Ach	Croton	Tree	Euphorbeaceae	0.48
48	*Cycus pectinata* Buch.-Ham.	Kalbal	Cycus	Tree	Cycadaceae	0.96
49	*Cyphomandra betaceae* (Cav.) Sendt	Tyamter	Tree tomato	Shrub	Solanaceae	0.96
50	*Dalbergia sissoo* Roxb.	Sisau	Indian rosewood	Tree	Leguminoceae	4.31
51	*Diospyros kaki* Thunb.	Haluwabed	Persimon	Tree	Ebenaceae	4.31
52	*Diploknema butyracea* (Roxb.) Lam.	Chiuri	Butter fruit	Tree	Sapotaceae	0.48
53	*Duranta erecta* L.	Nil kanda	Golden dewdrops	Shrub	Verbenaceae	0.96
54	*Elaeocarpus sphaericus* (Gaertn.) K. Schum.	Rudrakshya	Utrasum bead tree	Tree	Elaeocarpaceae	5.74
55	*Eriobotrya japonica* (Thumb.) Lindl.	Laukat	Loquat	Tree	Rosaceae	0.48
56	*Erythrina arborescens* Roxb.	Theki kath	Himlayan coral bean	Tree	Leguminosae	0.48
57	*Erythrina stricta* Roxb.	Phaledo	Indian coral tree	Tree	Leguminosae	1.91
58	*Eucalyptus camaldulensis* Dehn.	Masala	River red gum	Tree	Myrtaceae	4.78
59	*Euphorbia pulcherrima* Willd. Ex Klotzsch	Lalupate	Poinsettia	Shrub	Euphorbeaceae	1.91

S.N.	Scientific name	Vernacular name	English name	Growth form	Family	Frequency (%)
60	*Ficus auriculata* Lour.	Timilo	Roxburgh fig	Tree	Moraceae	2.39
61	*Ficus benghalensis* L.	Bar	Banyan fig	Tree	Moraceae	5.74
62	*Ficus benjamina* L.	Sami	Weeping fig	Tree	Moraceae	4.78
63	*Ficus elastica* Roxb.	Rubber plant	Rubber plant	Tree	Moraceae	7.18
64	*Ficus lacor* Buch.-Ham.	Kabhro	Java fig	Tree	Moraceae	5.26
65	*Ficus neriifolia* Sm.	Dudhilo	Willow leaf fig	Tree	Moraceae	0.48
66	*Ficus religiosa* L.	Pipal	Sacred fig	Tree	Moraceae	25.84
67	*Ficus semicordata* Buch-Ham ex Sm.	Khanayo	Drooping fig	Tree	Moraceae	0.48
68	*Fraxinus floribunda* Wall.	Lankure	Ash	Tree	Oleaceae	1.44
69	*Ginkgo biloba* L.		Maidenhair tree	Tree	Ginkgoiaceae	0.48
70	*Gossypium arborium* L.	Kapas	Cotton plant	Shrub	Malvaceae	0.48
71	*Grevillea robusta* A. Cunn. ex R. Br.	Kagiyo	Silky oak	Tree	Proteaceae	29.19
72	*Hibiscus brackenridgei* A. Gray		Rose mallow	Shrub	Malvaceae	0.48
73	*Hibiscus rosa-sinensis* L.	Ghanti phool	China rose	Shrub	Malvaceae	1.44
74	*Homalium napaulense* (DC.) Benth.	Falame kanda		Tree	Flacourtiaceae	0.48
75	*Ilex excelsa* (Wall.) Hook. Fil.	Pwanle		Tree	Aquifoliaceae	1.44
76	*Jacaranda mimosifolia* D.Don	Nilo phool	Jacaranda	Tree	Bignoniaceae	19.14
77	*Jasminum mesnyi* Hance	Double jai	Primrose jasmine	Shrub	Oleaceae	0.48
78	*Juglans nigra* L.	Hade okhar	Black walnut	Tree	Juglandaceae	4.31
79	*Juglans regia* L.	Dante okhar	English walnut	Tree	Juglandaceae	2.87
80	*Juniperus chinensis* L.	Dhupi	Chinese juniper	Shrub	Cupressaceae	0.96
81	*Juniperus communis* L.	Dhupi	Pencil cedar	Shrub	Cupressaceae	0.48
82	*Juniperus indica* Bertol.	Dhupi	Black juniper	Shrub	Cupressaceae	6.22
83	*Juniperus recurva* Buch.-Ham. ex D. Don	Dhupi	Himalayan juniper	Tree	Cupressaceae	3.35
84	*Lagerstroemia indica* L.	Asare phool	Crape myrtle	Tree	Lythraceae	12.44
85	*Lagerstroemia parviflora* Roxb.	Bot dhairo	Crepe flower	Tree	Lythraceae	0.48
86	*Lagerstroemia reginae* Roxb.	Thulo asare	Queen's crape myrtle	Shrub	Lythraceae	0.48
87	*Leucaena leucocephala* (Lam.) De Wit	Epil	Ipil ipil	Tree	Leguminoseae	0.96
88	*Ligustrum confusum* Decne.	Kanike rookh	Privet	Tree	Oleaceae	0.48
89	*Lindera pulcherrima* (Nees) Benth. ex Hook. F.	Shyal phusre	Wild privet	Tree	Lauraceae	0.96
90	*Litchi chinensis* Sonner	Lichi	Lychee	Tree	Santalaceae	0.96
91	*Litsea monopetala* (Roxb.) Pers.	Kutmiro	Many-flowered litsea	Tree	Lauraceae	3.83
92	*Macadamia integrifolia* Maiden & Betche		Queensland nut	Tree	Proteaceae	0.48

S.N.	Scientific name	Vernacular name	English name	Growth form	Family	Frequency (%)
93	*Madhuca longofolia* (Koeing)	Chiuri	Macbride	Tree	Sapotaceae	0.48
94	*Magnolia soulangeana* Soul.	Neel kamal	Saucer magnolia	Tree	Magnoliaceae	0.48
95	*Mahonia nepaulensis* DC.	Jamanemandro	Mahonia	Tree	Berberidaceae	0.48
96	*Malvaviscus arboreus* Cav.	Khursani phool	Turkcap	Shrub	Malvaceae	0.96
97	*Mangifera indica* L.	Aap	Mango	Tree	Anacardiaceae	7.18
98	*Manglietia insignis* (Wall.) Blume	Rookh kamal		Tree	Magnoliaceae	5.74
99	*Melia azedarach* L.	Bakaino	China berry	Tree	Meliaceae	14.35
100	*Michelia champaka* L.	Champ	Champaca	Tree	Magnoliaceae	4.78
101	*Michelia fuscata* Bl.	Kankakchampa	Banana shrub	Shrub	Magnoliaceae	0.48
102	*Miliusa velutina* (Dunal) Hook. f. & Thombs	Kali kath	Velveti miliusa	Tree	Annonaceae	0.48
103	*Morus alba L.*	Kimbu	Common mulberry	Tree	Moraceae	5.74
104	*Murraya koenigii* (L.) Sprengel	Kadi patta	Curry tree	Tree	Rutaceae	0.48
105	*Musa paradisiaca* L.	Kera	Banana	Shrub	Musaceae	0.96
106	*Myrica esculenta* Buch-Ham. ex D. Don	Kafal	Box myrtale	Tree	Myricaceae	0.96
107	*Myrsine capitellata* Wall.	Seti kath		Tree	Myrsinaceae	0.48
108	*Nerium indicum* Miller	Karbir	Indian oleander	Tree	Apocynaceae	1.44
109	*Nerium oleander* variegatum	Kannel	Kaner	Tree	Apocynaceae	2.39
110	*Nyctanthes arbor-tristis* L.	Parijat	Coral jasmine	Tree	Oleaceae	7.66
111	*Persea americana* Mill.	Ghiu phal	Avocado	Tree	Lauraceae	8.61
112	*Persea duthiei* (King ex Hook. F.) Kosterm.	Kaulo	Duthiei bay tree	Tree	Lauraceae	2.87
113	*Phoenix humilis* Royle.	Khajur	Dwarf date palm	Tree	Palmae	0.96
114	*Phoenix sylvestris* Roxb.	Taadi	Wild date palm	Tree	Palmae	0.48
115	*Phyllanths emblica* L.	Amala	Emblic	Tree	Euphorbeaceae	2.87
116	*Pinus roxburghii* Sarg.	Khote salla	Chir pine	Tree	Pinaceae	14.35
117	*Platanus orientalis* L.	Chinar	Oriental plane	Tree	Platanaceae	0.48
118	*Podocarpus neriifolius* D. Don	Gunsi	Oleander Podocarp	Tree	Podocarpaceae	0.48
119	*Populus jacquemontiana* Dode.	Lahare pipal	Poplar	Tree	Salicaceae	11.96
120	*Prunus avium* L.	Cherry	Sweet cherry	Tree	Rosaceae	0.48
121	*Prunus cerasoides* D. Don	Paiyun	Himalayan cherry	Tree	Rosaceae	9.57
122	*Prunus domestica* L.	Aaloo bokhada	Europian plum	Shrub	Rosaceae	7.18
123	*Prunus persica* (L.) Batsch	Aaroo	Peach	Tree	Rosaceae	8.61
124	*Psidium guajava* L.	Amba	Guava	Tree	Myrtaceae	17.22
125	*Punica granatum* L.	Anar	Pomegranate	Tree	Punicaceae	4.78
126	*Pyrus communis* L.	Naspati	Europian pear	Tree	Rosaceae	0.48

S.N.	Scientific name	Vernacular name	English name	Growth form	Family	Frequency (%)
127	*Pyrus crenata* Buch.-Ham. ex D. Don.	Naspati	Wild pear	Tree	Rosaceae	0.96
128	*Pyrus malus* L.	Syau	Apple	Tree	Rosaceae	0.96
129	*Pyrus pashia* Buch.-Ham. ex D. Don.	Mayal	Wild Himalayan pear	Tree	Rosaceae	5.74
130	*Pyrus pyrifolia* (Burn.) Nak.	Naspati	Asian pear	Tree	Rosaceae	9.57
131	*Quercus glauca* Thumb.	Falant	Ring-cupped oak	Tree	Fagaceae	0.48
132	*Rhododendron arboreum* Smith	Lali guransa	Tree rhododendron	Tree	Ericaceae	0.96
133	*Ricinus communis* L.	Andir	Castor bean	Shrub	Euphorbiaceae	0.48
134	*Salix tetrasperma* Roxb.	Bainsa	Indian willow	Tree	Salicaceae	11.00
135	*Sambucus hookeri* Rehder	Galeni	Elder	Tree	Sambucaceae	6.70
136	*Sapindus mukorossi* Gaertn.	Rittha	Soap berry	Tree	Sapindaceae	0.96
137	*Schefflera impressa* (C. B. Clarke) Harms	Simaal	Schefflera vine	Tree	Araliaceae	1.44
138	*Schima wallichii* (DC.) Korth.	Chilaune	Needlewood tree	Tree	Theaceae	6.22
139	*Spathodea campanulata* P. Beauv		African tulip tree	Tree	Bignoniaceae	0.48
140	*Syzygium cumini* (L) Skeels	Jamuna	Malabar plum	Tree	Myrtaceae	8.61
141	*Syzygium jambos* (L.) Alston	Gulab jamun	Rose apple	Tree	Myrtaceae	2.87
142	*Tecoma stans* (L.) H. B. K.	Ghata pushpi	Yellow bell	Shrub	Bignoniaceae	0.96
143	*Thespesia lampas* (Cav.) Dalz. & Gibs.	Ban kapas	Common mallow	Shrub	Malvaceae	1.91
144	*Thuja orientalis* L.	Mayur Pankhi	Cedar	Tree	Cupressaceae	29.19
145	*Toona ciliata* M. Roem.	Tooni	Indian cedar	Tree	Meliaceae	0.48
146	*Trachycarpus* sp. H. Wendl.	Taad	Fan palm	Tree	Palmae	0.96
147	*Vitex negundo* L.	Simali	Five-leaved chaste tree	Shrub	Verbenaceae	0.96
148	*Woodfordia fruticosa* (L.) Kurz	Dhangero	Fire flame bush	Shrub	Lythraceae	0.48
149	*Zanthoxylum armatum* DC.	Timur	Prickly ash	Tree	Rutaceae	0.48
150	*Ziziphus incurva* Roxb.	Hade bayar	Bead plum	Tree	Rhamnaceae	1.44

Tree density, tree height and stem DBH

The average tree density in the study area was 236.35±173.12 ha^{-1}. Maximum height of the tree was 31.50 m with an average of 6.83±3.77 m. Similarly, maximum DBH of the stem was 203 cm with an average of 21.44±19.49 cm. The average tree density was higher in suburban stratum (248.44±198.56 ha^{-1}) than in urban (232.58±155.08 ha^{-1}) and rural (224.88±165.31 ha^{-1}) strata (Table 3). However, the difference was not significant. The tallest tree (31.50 m) and widest tree (203 cm) were found in urban stratum. The urban stratum was found to have significantly taller and wider trees than suburban and rural strata (Table 3).

Table 3: Average tree density (±SD), maximum and average (±SD), tree height and maximum and average (±SD) stem DBH of trees outside forest along the urban-rural gradient in Kathmandu valley, Nepal. Different superscript letters indicate statistical significance at p<0.05.

Strata	Average Tree Density (Number of stem ha^{-1})	Tree Height (m)		Stem DBH (cm)	
		Maximum	Average	Maximum	Average
Urban	232.58±155.08 [a]	31.5	7.64±4.63[a]	203	22.80±19.85[a]
Suburban	248.44±198.56 [a]	20.3	6.43±2.97[bc]	157.3	20.36±16.80[b]
Rural	224.88±165.31 [a]	23	5.92±2.68[c]	187	20.62±22.59[b]

Tree density by quality class and stem diameter class

The average density of merchantable trees of quality class A, quality class B and quality class C in the study are were 20.90±37.01 ha^{-1}, 13.09±22.16 ha^{-1} and 202.37±178.53 ha^{-1} respectively. The average density of merchantable trees of quality class A was found to be significantly higher ($p<0.05$) in urban stratum than in rural stratum but that did not differ significantly from that in suburban stratum (Table 4). Moreover, the differences in average densities of merchantable trees of quality class B and C were not significant among three strata ($p<0.05$).

Similarly, the average stem densities of diameter classes 5-9.90 cm, 10-19.90 cm, 20-29.90 cm and ≥ 30 cm in the study area were found to be 79.51±107.30 ha^{-1}, 64.28±77.09 ha^{-1}, 34.94±36.62 ha^{-1} and 57.24±60.92 ha^{-1} respectively (Table 4). There were no significant differences in the average stem densities across different strata except for the diameter class 20-29.90 cm. Urban and suburban strata were found to have significant stem density of diameter class 20-29.90 cm than the rural stratum (Table 4).

Table 4: Average densities (±SD) of trees by tree quality classes and stem diameter classes of trees outside forest along the urban-rural gradient in Kathmandu valley, Nepal. Different superscript letters indicate statistical significance at p<0.05.

Strata	Average density of trees by quality class (ha^{-1})			Average stem density by diameter class (ha^{-1}) (cm)			
	A	B	C	5-9.90	10-19.90	20-29.90	≥30
Urban	28.20±45.50[a]	15.37±23.57 [a]	189.02±160.72 [a]	66.26±93.69 [a]	68.97±71.06 [a]	37.06±35.84[a]	60.29±60.12 [a]
Suburban	18.85±29.60[ab]	11.77±21.87 [a]	217.83±207.20 [a]	87.83±119.45 [a]	61.35±83.17 [a]	40.10±43.78[a]	59.17±67.38 [a]
Rural	10.61±25.96[b]	10.94±19.87 [a]	203.35±163.62 [a]	92.80±111.09 [a]	60.16±79.29 [a]	23.20±20.75[b]	48.72±51.80 [a]

Volume and biomass of merchantable timber and firewood

Out of 53 tree species with merchantable timber recorded in the study area, 13 species could yield timber of quality class A, 13 could yield timber of quality class B, while 27 could yield timber of both quality class A and B (Appendix I).

The total volume of merchantable timber in the study area was 625.51 cu ft ha $^{-1}$ with 549.33 cu ft ha $^{-1}$ and 76.18 cu ft ha $^{-1}$ as volumes of merchantable timber class A and class B. Total biomass of firewood was 50840.85 kg ha^{-1}. The volume of merchantable timber was highest in the urban stratum followed by rural and suburban strata while biomass of firewood was highest in urban stratum followed by suburban and rural strata (Table 5).

Table 5: Volume of merchantable timber and biomass of firewood from trees outside forest along the urban-rural gradient in Kathmandu valley, Nepal. Volume ha^{-1} by quality class and total volume ha^{-1} of merchantable timber and total biomass ha^{-1} of firewood

Strata	Class A timber (cu ft ha^{-1})	Class B timber (cu ft ha^{-1})	Total timber (cu ft ha^{-1})	Firewood (kg ha^{-1})
Urban	537.08	84.88	621.96	55835.49
Suburban	250.04	47.31	297.35	39410.01
Rural	442.94	66.82	509.76	39032.12

Market value of merchantable wood

The total market values were calculated based on the per unit market price of the timber and firewood in the study area (Appendix II). Based upon the market values of individual tree species. (Appendix III), the total market values of timber class A, timber class B, total timber, firewood and total wood from the TOF were found to be NPR. 746,613 (US$ 5,752), NPR. 96,358 (US$ 742), NPR. 842,971 (US$ 6,494), NPR. 516,612 (US$ 3,980) and NPR. 1362,880 (US$ 10,500) ha^{-1}. The market value of total merchantable timber was highest in the rural stratum followed by urban and suburban strata while that of firewood was highest in urban stratum followed by suburban and rural strata (Appendix IV, Appendix V, Appendix VI and Table 6).

Cinnamomum camphora was the tree species with highest market value of timber class A, timber class B, total timber and total wood value ha^{-1} as (NPR. 229,851) (US$ 1,771), (NPR. 17,399) (US$ 134), (NPR. 247,250) (US$ 1,905) and (NPR. 2,96,101) (US$ 2,281) in the study area (Table 7). *Pinus roxburghii* was the tree species with highest market value of firewood as (NPR. 63,793) (US$ 491) here. Rural stratum had the highest merchantable values for timber class A in *C. camphora*, for total timber in *C. camphora*, for firewood in *Eucalyptus camaldulensis* and for total wood in *C. camphora* while the urban stratum had the highest merchantable value for timber class B in *C. camphora*.

Economically, *C. camphora*, recorded from 86 plots and *P. roxburghii* recorded from 30 plots showed the highest merchantable timber and firewood values respectively in the study area. 32 timber class A and 49 timber class B logs of *C. camphora* were estimated from the study sites. *C. camphora* was second highest expensive species, the retail market prices of which varied from NPR 2200 to 3200. *E. camaldulensis*, *S. cumini* and *F. floribunda* were other tree species with more economic valuations. Local merchantable market prices matter during valuation because they vary for a single species.

Table 6: Market values (MV) of merchantable wood i.e., timber plus firewood from trees outside forest along the urban-rural gradient in Kathmandu valley, Nepal. Market values of timber of class A and B, total timber, firewood and total wood in NPR and US$

Strata	MV of timber class A (NPR ha^{-1})	US$	MV of timber class B (NPR ha^{-1})	US$	MV of total timber (NPR ha^{-1})	US$	MV of firewood (NPR ha^{-1})	US$	MV of total wood (NPR ha^{-1})	US$
Urban	698,567	5,382	108,255	834	806,821	6,216	488,709	3,765	1,295,531	9,981
Suburban	383,485	2,954	60,759	468	444,244	3,423	444,104	3,421	888,828	6,848
Rural	789,871	6,085	80,539	620	870,410	6,706	380,303	2,930	1,250,713	9,636

Table 7: Tree species and their market values (MV) of timber class A, timber class B, total timber, fire wood and the total wood in different strata of the study area

Strata	Species	MV of timber class A (NPR ha^{-1})	US$	Species	MV of timber class B (NPR ha^{-1})	US$	Species	MV of total timber (NPR ha^{-1})	US$	Species	MV of firewood (NPR ha^{-1})	US$	Species	MV of total wood (NPR ha^{-1})	US$
Urban	*Cinnamomum camphora*	218,142	1,681	*Cinnamomum camphora*	31,077	239	*Cinnamomum camphora*	249,219	1,920	*Pinus roxburghii*	86,736	668	*Cinnamomum camphora*	315,156	2,428
Suburban	*Eucalyptus camaldulensis*	116,498	898	*Syzigium cumini*	16,069	124	*Eucalyptus camaldulensis*	120,125	925	*Pinus roxburghii*	91,760	707	*Syzigium cumini*	175,826	1,355
Rural	*Cinnamomum camphora*	530,006	4,083	*Fraxinus floribunda*	15,196	117	*Cinnamomum camphora*	543,055	4,184	*Eucalyptus camaldulensis*	92,461	712	*Cinnamomum camphora*	591,656	4,558

Discussion

A total of 150 plant species were reported from the study area (Table 2). Vakhlamova *et al.* (2014) found slightly high species richness (160) in urban–rural gradient in Kazakhstan. It might be due to enumeration of all vascular plants regardless of DBH in the study. Moreover, Thompson (2010) found comparatively less species diversity (22) from in Khartoum, Sudan. It is possibly due to enumeration of only the living fences in the urban and suburban gardens where homogeneity of species occurs. Species richness in terms of stratum area (ha^{-1}) was higher in rural stratum than in urban and suburban strata (Table 1). Vakhlamova *et al*. (2014) also found an increasing trend of species richness from urban to rural in urban–rural gradient in Kazakhstan, Western Siberia. This pattern can be explained by the fact that plant life forms and evolutionary strategies do not follow any urban-rural gradient, rather are affected by varied habitat and landscape features. In addition, reduced suitable habitats for plants in densely built-up urban areas and excessive trampling of vegetated patches might cause decrease in plant diversity (Aronson *et al*., 2014). Average species richness (ha^{-1}) was higher in urban stratum than in suburban and rural strata which are due to trees were planted types in the urban stratum while majority of them were natural woodlots in remaining strata.

Tree density in the present study area was found higher than that in TOF in Morang (15 ha^{-1}) (DFRS, 2007) and Nawalparasi (10 ha^{-1}) districts (Kharal *et al*., 2008) which might be due to dominance of agricultural lands and less tree plantation culture in Terai area. The average tree density was found more in suburban stratum than in urban and rural strata which is due to abundance of trees with 20-29.9 stem diameter class indicating more branched trees here.

The higher average tree density in urban stratum than in rural in this study (Table 3) showed the similar patterns in Morang and Nawalparasi districts (DFRS, 2007; Kharal *et al*., 2008) This pattern could be due to plantation drives (also includes exotic species) during Panchayat regime in the urban areas in Kathmandu valley and major other urban areas (Goutam, 2018). Moreover, rural people cut down the trees for domestic use. The average trees heights and average DBH also followed the same distribution pattern (DFRS, 2007 and Kharal *et al.*, 2008).

Average density of tree quality class A and B were found more in urban stratum than in suburban and rural strata whereas that of tree quality class C was found more in rural stratum than in suburban and urban strata (Table 4). This is supported by the occurrence of more average stem density and distribution of mature trees (≥30) in the urban stratum. This is due to more abundance of such mature trees *Eucalyptus camaldulensis, Ficus elastica, Jacaranda mimosifolia* etc.) in the parks, roads, river and stream lines etc. whereas due to less dominance of such sized trees, rural stratum had less average tree density with dominance of smaller stem diameter class. Furthermore, both tallest tree and widest tree were also recorded in urban stratum.

Out of four stem diameter classes, dominance of smaller diameter class (5-9.90 cm and 10-19.90 cm) in the urban stratum in the study area (Table 4) is similar as Morgenroth *et al*. (2020) reported in America's urban forests as > 40% of trees in the smallest DBH class (< 15 cm) which could be attributed to preference for smaller ornamental trees as Bottle brush, Albizia, Junipers etc. in urban areas or a recent increase in tree planting efforts. A greater proportion of stem diameter classes of 10-19.9 cm and ≥ 30 cm in urban stratum were also same as Morgenroth *et al*. (2020) found the dominance of 16–45 cm DBH class in urban forests. This may be due to existence of youthful trees. As regards the stem densities of diameter classes 5-9.90 cm, 10-19.90 cm, 20-29.90 cm and ≥ 30 cm in Kathmandu valley, values are higher than those reported from Morang (DFRS, 2007) and Nawalparasi (Kharal *et al.*, 2008); that could be attributed to less planted trees in both Morang district and Nawalparasi district. Further, stem density of lower diameter class (5-9.90 cm) was higher in rural stratum than that in suburban and urban strata whereas stem densities of higher diameters were higher in urban and suburban strata except for trees of diameter 20-29.9 cm which showed uneven distribution. This result is consistent with the findings reported from Morang district (DFRS, 2007), but different from that reported from Nawalparasi district (Kharal *et al*., 2008). This could be due to more naturally regenerated trees in rural stratum in both Morang and the study area. Also, tree plantation drive earlier during Rana regime and Panchayat regime would have contributed to this pattern of tree size class distribution (Goutam, 2018).

TOF are important in terms of wood production. DFRS (2015), on the basis of FAO recommendation, has stated that 13.29% of middle mountains forests have the potential of timber production. This study shows slightly higher value (14.38%) of timber production by TOF. Similar results are found in India (FSI, 2011; Ghosh & Sinha, 2018) as well as in Kerala, India (Krishnankutty *et al*., 2008). But Yadav *et al*. (2020) reported higher percentage of timber production (25.17%) from TOF in Dhangadhi Municipality, Siraha district, Nepal which is due to more distribution of planted tree species with wider DBH there.

In a study by Bembenek *et al*. (2014), high mean tree height, mean DBH and high mean volume of merchantable timber with low mean tree density of Scots pine were reported. The higher volumes of merchantable timbers of class A and class B in the urban stratum than in rural and suburban strata in the study area could be due to distribution of more mature and taller trees. It might be due to conservation of the old trees in the parks, road sides, river lines, pond lines, etc. Similarly, lower volumes of merchantable timbers of class A and class B in the rural stratum might be due to lesser tree density as well as less dominance of stem density of ≥ 30 diameter class.

Conclusions

Urban TOF are important in terms of species diversity whereas suburban TOF are richer in terms of density. Due to the presence of large sized tree species planted during Rana regime, urban TOF have taller and wider trees. Due to more tree density of timber class A and class B in urban stratum, volumes of total merchantable timber along with timber class A and class B and biomass of merchantable firewood were also found higher here. Rural TOF are economically more important. Due to high market prices of the wood of tree species recorded in rural stratum, market value of timber class A and total timber were found higher in rural stratum than the others. Urban TOF are also economically important because it showed high market value for B class timber, firewood and total wood. In terms of TOF species, *C. camphora* and *P. roxburghii* were found to be economically more important as they showed the highest merchantable timber and firewood values. People should be encouraged for afforestation in TOF areas with these species which offers opportunity of timber availability and could help in local livelihood. On the other hand, import of wood and wooden materials could be minimized as well as urban greenery would be enhanced.

Acknowledgements

Mr. Mahendra Shrestha, Mr. Mayukh Shrestha, Mrs. Laxmi Joshi Shrestha, Mrs. Prativa Neupane and local people are acknowledged for their support during data collection. Mr. Mayukh Shrestha helped in developing sampling location points map of the study area.

References

Ahmed, P. (2008). Trees Outside Forests (TOF): A case study of wood production and consumption in Haryana. *International Forestry, 10*(2), 165–172.

Aronson, M. F., La Sorte, F. A., Nilon, C. H., Katti, M., Goddard, M. A., Lepczyk, C. A., *et al.* (2014). A global analysis of the impact of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society,* Series B.*281,* 1–8.

Asanzi, P., Putzel, L., Gumbo, D., & Mupeta, M. (2014). Rural livelihoods and the Chinese timber trade in Zambia's western province. *International Forestry Review,16*(4), 447-458. URL: https://doi.org/10.1505/146554814813484095.

Baffetta, F., Corona, P., & Fattorini, L. (2010). Assessing the attributes of scattered trees outside the forest by a multi-phase sampling strategy. *Oxford Journals, Life Sciences, Forestry, 84*(3), 315–325.

Baral, R., B., & Kurmi P., P. (2005). Assessing city beutification with plants: The Kathmandu perspective. *Banko Jankari*, *15*(1), 49–57.

Bembenek, M., Karaszewski, Z., Kondracki, K., Lacka, A., Mederski, P. S., Skorupski, M., Strzelinski, P., Sulkowski, S., &Wegiel· A. (2014). Value of merchantable timber in Scots pine stands of different densities. *Drewno*, 57(192), 133–142. DOI: 10.12841/wood.1644–3985.S14.09.

Bhusal, S., & Bashyal, S. (2020). Assessing the status, utilization and market value chain of Bamboo species (Case study from Chure area of Arghakhanchi District, Nepal). *Global Scientific Journals*,*8*(7), 2254–2275. ISSN 2320–9186. www.globalscientificjournal.com

Bridson, D., & Forman, L. (1998). *The Herberium Hand Book*, 3rd Edition, Royal Botanical Garden, UK.

Brown, S., Gillespie, A. J. R., & Lugo, A., E. (1989). Biomass estimation for tropical forests with applications to forest inventory data. *Forest Science*, *35*(4)**,** 881–902.

Brown, H. C. A., Berninger, F. A., Larjavaara, M., & Appiah, M. (2020). Above-ground carbon stocks and timber value of old timber plantations, secondary and primary forests in Southern Ghana. *Forest Ecology and Management, 472*,1-11. 118236.https://doi.org/10.1016/j.foreco.2020.118236

Crecente-Campo, F., Alboreca, A. R. & Di-eguez-Aranda, U. (2009). A merchantable volume system for *Pinus sylvestris* L. in the major mountain ranges of Spain. *Ann. For. Sci.*, *66*(8), 808-808. c_ INRA, EDP Sciences, DOI: 10.1051/forest/2009078. www.afs-journal.org.

Danekhu, U., Shrestha, R., & Maharjan, S., R. (2016-18). Assessment of non timber forest products in Baghmara Buffer Zone Community Forest, Chitwan, Nepal. *Journal of Natural History Museum*, *30*, 209–220

DFRS (2007). *Tree Outside Forests (Morang and Dhanusa)*. Government of Nepal.

DFRS (2011). *Field manual for Assessment of Trees outside Forests (TOF)*. FRA-Nepal.

DFRS (2015). *Nepal State of Nepal's forests*. ISBN: 978-9937-8896-3-6 www.dfrs.gov.npDFRS (2015). *Middle Mountains Forests of Nepal*. FRA-Nepal. ISBN:978-9937-8896-2-9. http://frtc.gov.np

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. ISSN 2012–3612.

DoF (2004). *Community Forestry Inventory Guidelines*. (in Nepali) Department of Forests, Babarmahal, Kathmandu, Nepal.

Dorji, T., Moe, S. R., Klein, J. A., & Totland, O. (2014). Plant Species Richness, Evenness, and Composition along Environmental Gradients in an Alpine Meadow Grazing Ecosystem in Central Tibet, China. *Arctic, Antarctic and Alpine Research, 46*(2), 308–326.

FAO (1998). *Trees Outside the Forests (TOF)*. Conservation, Research and Education Service (FORC), FAO, Rome. Retrieved from www.fao.org/docrep/003/X6685E/X6685E07.htm. FAO. (1999a). *State of the World's Forests*. Rome, 154 pp.

FAO (2009). Asia-Pacific Forestry Sector Outlook Study II. Working Paper No. APFSOS II/WP/2009/05

Foresta, H. d., Somarriba, E., Temu, A., Gauthier, Boulanger. D., Feuilly, H., & Gauthier, M. (2013). *Towards the Assessment of Trees Outside Forests.* FRA working Paper 183. FAO. Rome.

FSI (2003). *State of forest report 2003*, Forest Survey of India, Ministry of Environment and Forests, Dehradun, India.

FSI (2011). *India State of Forest Report*. https://www.fsi.nic.in/forest-report-2011 Accessed on 12/27/2020

Ghosh, M., & Sinha, B. (2018). Policy analysis for realizing the potential of timber production from trees outside forests (TOF) in India. *International Forestry Review*, *20*(1), 89-103.https://doi.org/10.1505/146554818822824255.

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

GoN. (2014). *Population Monograph of Nepal*. National Planning Commission Secretariat. Central Bureau of Statistics, Kathmandu, Nepal. 1. ISBN: 978-9937-2-8971-9.

Gotelli, N.J., & Ellison, A.M. (2013). A Primer of Ecological Statistics. Sinauer Associates, Inc.

Goutam, K. R. (2018). Urban forestry in the federal context of Nepal. *Banko Janakari*, *28*(1), 1–2.

Hammer Ø, Harper DAT, & Ryan PD. (2001). PAST: Paleontological Statistics Software Packagefor Education and Data Analysis. *Palaeontol Electron*, *4*(1), 9 pp.

ICIMOD (2007). *Kathmandu Valley Environment Outlook*. ISBN 978 92 9115 019 9. 978 92 9115 020 5 (electronic).

Kharal, D. K., Giri, R. K., & Karna, D. L. (2008). *Assessment of Trees Outside Forests Nawalparasi District, Nepal*. Department of Forest Research and Survey, Kathmandu, Nepal.

Kleinn, C. (2000). On Large-area inventory and assessment of trees outside forests. *Unasylva*, *51*(200), 3–10.

Klimas, C. A., Kainer, K. A., & Wadt, L. H. de O. (2012). The economic value of sustainable seed and timber harvests of multi-use species: An example using *Carapa guianensis*. *Forest Ecology and Management, 268*, 81–91. www.elsevier.com/locate/foreco

Krishnankutty, C. N., Thampi, K. B., & Chundamannil, M. (2008). Trees Outside Forests (TOF): A case study of the wood production and consumption situation in Kerala. *International Forestry Review*,*10*(2), 156–64. doi:10.1505/ifor.10.2.156.

Malla, S. B., Rajbhandari, S. B., Shrestha, T. B., Adhikari, P. M. and Adhikari, S. R. (ed.). 1986. *Flora of Kathmandu Valley*. Ministry of Forests and Soil Conservation. Department of Medicinal Plants, Kathmandu, Nepal.

Mejia, E., Pacheco, P., Muzo, A., & Torres, B.

(2015). Smallholders and timber extraction in the Ecuadorian Amazon: Amidst market opportunities and regulatory constraints. I*nternational Forestry Review*, *17*(1). URL: https://doi.org/10.1505/1465548.15814668954.

Mishra, B., Sandifer, J., & Gyawali, B. R. (2019). Urban heat island in Kathmandu, Nepal: Evaluating relationship between NDVI and LST from 2000 to 2018. *International Journal of Environment*, *8*(1), 17–27. *ISSN 2091-2854*. DOI: http://dx.doi.org/10.3126/ije.v8i1.22546

Morgenroth, J., Nowak, D. J., & Koeser, A. K. (2020). DBH distributions in America's urban forests-An overview of structural diversity. *Forests*, *11*(135). doi:10.3390/f11020135. www.mdpi.com/journal/forests.

Muzzini, E., & Aparicio, G. (2013). *Urban Growth and Spatial Transition in Nepal-An Initial Assessment*. The World Bank. ISBN 978-0-8213-9659-9 — ISBN 978-0-8213-9661-2 (electronic). DOI: 10.1596/978-0-8213-9659-9

Oli, B. N. 2002. Trees outside forests: An ignored dimension of forest resource assessment. *Banko Janakari*, *12* (1), 79–81.

Oduro, K.A., Arts, B., Hoogstra-Klein, M.A., Kyereh, B. & Mohren, G.M.J. (2014). Exploring the Future of Timber Resources in the High Forest Zone of Ghana. *International Forestry Review*, *16*(6), 573-585. URL: https://doi.org/10.1505/146554814814095320.

Ouattara, A., N'Da, H. D., Hervé, M., A., B., & Fernand, K. (2014). Assessment of the Merchantable Timber Volume of the Savannah Woodlands on the Communal Lands in Northeastern Côte d'Ivoire. *International Journal of Scientific & Engineering Research*, *5* (12), ISSN 2229–5518

Petersson, H., Holm, S., Stahl, G., Alger, D., Fridman, J., Lehtonen, A., Lundstrom, A., & Makippa, R. (2012). Individual tree biomass equations or biomass expansion factors for assessment of carbon stock changes in living biomass- A comparative study. *Forest Ecology and Management*, *270*, 78–84.

Pompa-García, M. J., Corral-Rivas, J., Hernández-Díaz, J. C., & Alvarez-González, J. G. (2009) A system for calculating the merchantable volume of oak trees in the northwest of the state of Chihuahua, Mexico. *Journal of Forestry Research*, *20*(4), 293–300. DOI 10.1007/s11676-009-0051-x

Poudel, K. (2010). Green streets: the trees of Kathmandu. http://ecs.com.np/features/green-streets-the-trees-of-kathmandu. Assessed on 8/24/2019

Press, J. R., Shrestha, K. K., Sutton, D.A. (2000). *Annotated Checklist of the Flowering Plants of Nepal*. The Natural History Museum, London.

RSS (2019). Country's dependency on wood increasing, timber import exceeds Rs 6 billion. My Republica. [accessed 2022 Dec 24]. http://myrepublica.nagariknetwork.com/news/70395/.

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

Sharma, E. R., & Pukkala, T. (1990). Volume equations and biomass prediction of forest trees of Nepal. Forest Survey and Statistics Division, Ministry of Forest and Soil Conservation. Kathmandu, Nepal. 47.

Shrivastav, A., Pandey, A. K., & Dubey R. (2012) Assessment of important trees outside forests (TOF) in Gorakhpur District of Uttar Pradesh. *The Indian Forester*, *138*(3),252-256. DOI: 10.36808/if/2012/v138i3/4622

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. doi: 10.3389/fevo.2016.00053

Thompson, J. L., Gebauer, J., & Buerkert, A. (2010). Fences in urban and peri-urban gardens of Khartoum, Sudan. *Forests, Trees and Livelihoods, 19*, 379-391. DOI: 10.1080/14728028.2010.9752679

Vakhlamova, T., Rusterholz, H. P., Kanibolotskaya, Y.,& Baur, B. (2014). Changes in plant diversity along an urban–rural gradient in an expanding city in Kazakhstan, Western Siberia. *Landscape and Urban Planning,132*, 111-120. www.elsevier.com/locate/landurbplan

Wallis, N. K. (1970). *Australian Timber Handbook*.Angus & Robertson Ltd., 221 George Street, Sydney

Xiao, L., He, Z., Wang, Y. & Guo, Q. (2017) Understanding urban–rural linkages from an ecological perspective *Sustainable Development & World Ecology*, *24*(1), 37–43. DOI: 10.1080/13504509.2016.1157105

Yadav, Y., Chhetri, B. B. K., Raymajhi, S., Tiwari, K. R., & Sitaula, B. K. (2020). Evaluating contribution of trees outside forests for income of rural livelihoods of Terai region of Nepal. *Open Journal of Forestry,10*(4), 388-400. https://doi.org/10.4236/ojf.2020.104024

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Jansen, I. J., Jansen, S., Lewis, S. L., Miller, R. B., Swenson, N. G., Wiemann, M. C., & Chave, J. (2009). Global wood density database. Dryad. Identifier: http://hdl.handle.net/10255/dryad.235.