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# Assessment of species diversity and its management challenges in avenue plantation (study of Shankhamul and Balkumari road)

## Abstract

Greenery is importantly significant in city to maintain the fresh air and recreation. Hence roadside plantations have been done here, but study regarding the species diversity is very limited. Therefore, this study was conducted to explore species diversity in roadside plantations and assess the factor affecting the management on it. Sankhamul and Balkumari areas in the Kathmandu city were selected as the study sites. The observation was done from 25th February to 1st March 2021 to collect field data. A total of thirty 5mx5m samples were collected particularly species were counted and their diameter at breast height and heights were recorded. Similarly, their photographs were also taken so that the unknown species could later be identified. Total 26 local people were asked to find the factors affecting the management of roadside plantation. The Likert scale was used to categorize the factors. The collected data were analyzed using Shannon diversity index, Simpson's index, and species richness. The factors affecting the roadside plantation were calculated applying principle component analysis. A total of 30 plant species were planted in the roadside plantation. The highest value of Shannon diversity index was 2.53 in Janata Road, Balkumari, and Simpson's index was also the highest at same road section with 0.96 while species richness was the highest around 2.40 at Satya Sai Udhan, Shankhamul Road. The Sorenson index was the highest among Janata Road and Chhitijnagar, Balkumari with 0.38. One-way ANOVA and post-hoc test Turkey's b showed that there was a significant difference in Shannon -Wiener index between tree species of the study sites at a 5% significance level. Lack of fencing and solid waste disposal near trees were the main factors affecting the Janata Road Balkumari with scoring 5 and principal component analysis showed Vandalism by People and Animals (VPA), lack of irrigation, and Low Maintenance and Care of Species were positively correlated. The research will be useful to understand the biodiversity of plantation areas on the roadside.

**Keywords:** biodiversity index, road side plantation, urban forest

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## Introduction

Globally, the urban plantation is considered as one of the important component to maintain sustainability in the city. This is an important asset of towns or cities because urban plantations supply the fresh air and serve as a recreation place. The urban plantation is serving to minimize the adverse environmental problems caused by overwhelming population and their luxurious life, increasing infrastructures, vehicles and exploiting natural resource.[1] Therefore, the urban forests are also known as the backbone of green infrastructures because they help to improve the environmental and ecological footprint in the city.[2] FAO defines Urban Forestry as " A network or system comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas."[2] There are many environmental and ecological functions of roadside trees. Roadside trees function to filter the air through reducing air pollution, lessens the effect of wind and urban heat island. More importantly, it helps to control noise pollution as well. Formation of soil, maintaining soil fertility, purifying and regulating the water quality, reducing the soil erosion, serving as a wind break are some of the valuable function of roadside plantation.[3] Increasing tree cover by 10% in urban areas is capable to minimize almost 6% surface water runoff.[4] The roadside avenue plantations are also the part of biological diversity.[5] The diverse species of plants in the city perform a variety of functions.[6,7] There are several functions of roadside plantation, there it is becoming an attractive programme in city. These days, Kathmandu Metropolitan and other Kathmandu Valley Municipalities, MOFE (Ministry of Forest and Environment), Department of Forest and Soil Conservation, DOA (Department of Agriculture), and other several INGOs and NGOs are active to increase the greenery in the city.[8] Nepal Clean Environment Grand Expedition 2075' and 'Forest Decade Program (2014-2023)' are playing important role to promote the plantation in city as well.[1,9,10] Then, the questions come in our mind as city dweller that how the diversity is maintained in the city.[11] At the same time is avenue plantation managed and what are factors affecting to manage the plantation.

## Materials and methods

**Study area:** Sankhamul lies at the northeast edge of Patan. The area is geographically placed at 27.6853° N and 85.3317° E. It is situated at the junction where Manohara and Dhobikhola River meet Bagmati and is also a border between Kathmandu and Lalitpur Districts. It is an open space for the city to breath with some greenery. Hence, people come here for jogging and exercising. The restoration of the cremation ghats, a flower garden and a paint job on the various structures along the Bagmati has made the place aesthetically pleasing. Similarly, Balkumari lies in Kathmandu, Ward No. 32 of Kathmandu Metropolitan City. The area is geographically placed at 27.6742° N, 85.3408° E.[12]

Figure 1 The annual average mean temperature is 18.1 °C | 64.5 °F. It experiences generally warm, mild, and temperate climate. The summers are much wet and rainier than the winter. About 1505 mm | 59.3 inch of precipitation falls per annum. June is the hottest month of the year, with an average temperature of 23.6 °C | 74.5 °F. The lowest average temperature occurs within the year in January when it is around 10.1 °C | 50.2 °F.[13] Variety of plant and flower species can be seen in the park and roadside areas. Flowering plants and some fruit species can be seen around these areas. The preliminary field

visit was done in 19th February 2021, to observe the plant species. Three sections on road were selected for the study. The data collection was done from 25th February to 1st March, 2021. Total of 30 sample plots sections with an area of 5mx5m was established to collect field data. Counting and recording of species was done, photographs were taken. The diameter of species at eye level was measured, height, of the species was also recorded. The data collection sheet was prepared to collect the above data. Local people were asked to find the factors affecting the protection of plantation. The Likert scale was used for categorization of the factors.

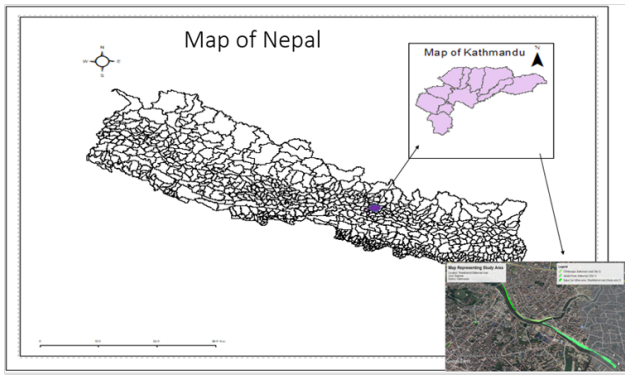


**Figure 1** Map of study area.

The highest value was recorded with 5 and least value with 1. The collected data were analyzed using

a. biodiversity indexes

b. similarity index and

c. principal component analysis.

### Biodiversity index of plant species

Diversity Index was assessed to determine and compare the biological diversity of the species across the sample sites.

### Shannon-Wiener index (Ma and Liu, 1994)

The Shannon diversity index (H) is an index that is commonly used to characterize species diversity in a community. The value of Shannon Wiener index ranges from 1.5 to 3.5.The higher the index, the more likely it is to indicate a diverse group. It was calculated as

$$H = \sum_{i=1}^{s} - \left( P_i \mathrm{X} 1 n P_i \right)$$

where H= Shannon Wiener Diversity index

$P_i$ = fraction of the entire population made up of species I (total number of species / no. of individual of species)

S= number of species encountered

### Simpson's index of diversity (E.H Simpson, 1949)

Simpson's index of diversity is the compliment of Simpson index where the value ranges from 0 to 1, and calculated as 1-D. In Simpson's index of diversity higher the value of the index higher is the diversity of the sample. Simpson's index of diversity is calculated as:

$$D = 1 - \frac{\sum n\left( n-1 \right)}{N\left( N-1 \right)}$$

where, n = the number of individuals displaying one sample

$N$ = the total number of all individuals

### Species richness

Species richness was also be calculated as follow:

Species richness = $S/\sqrt{N}$

where S= Number of species in a community

N= Number of individuals of all species in a community

### Similarity index of plant species Sorensen Index (Thorvald Sorensen, 1948)

To know the similarity between the tree species of sample sites Sorensen Index was used. The Sorensen Index compares the similarity between plant communities in their species composition and species contribution.

It was calculated as

$$Ss = \frac{2a}{2a + b + c}$$

where, a = Number of species in sample A and sample B

b = Number of species in sample B but not in sample A

c = Number of species in sample A but not in sample B

### Analysis of management factors (Principal component analysis)

Principal Component Analysis as done to analyze the management factor affecting tree species which was ranked according to Likert Scale. The results showed that there were list of 10 management factors affecting the tree plantation of sample sites along Shankhamul and Balkumari road. These factors were ranked on the value based on Likert scale from 1 to 5. The number indicated the local people's opinion on management factors. 1 denoted strongly disagree, 2 denoted disagree, 3 denoted neutral, 4 denoted agree and similarly, 5 denoted strongly agree.

## Result

### Plant species in different sites of Shankhamul and Balkumari road

#### List of tree species planted along Shankhamul and Balkumari Road

The result showed that sample sites along Balkumari and Shankhamul road recorded 30 plant species belonging to 13 families with total tree count of 57. There were 12, 9, and 9 plant species with total tree count of 28, 15, 14 trees recorded in Janata Road, Chhitijnagar, and Satya Sai Udhan area respectively. Myrtaceae and Solanaceae were recorded as the family with highest species richness with 14, and 10 species respectively. Similarly, Pinaceae, Magnoliaceae, and Scrophulariaceae were recorded as the family with lowest species richness with 1 species each Table 1, Figure 2.

#### Species diversity in Shankhamul and Balkumari road

The diversity index was calculated with number of species, Shannon – Wiener index, Simpson's index of diversity and species richness to determine the species diversity in different sample sites along Shankhamul and Balkumari road. The value of Shannon – Wiener index was highest in Janata Road, Balkumari comparison to Chhitijnagar and Satya Sai Udhan area, Shankhamul. Similarly, the Simpson's index of diversity was highest in Janata Road to

Chhitijnagar and Satya Sai Udhan area, Shankhamul compared. However, species richness was obtained highest in Satya Sai Udhan area, Shankhamul compared to Janata Road and Chhitijnagar Table 2.

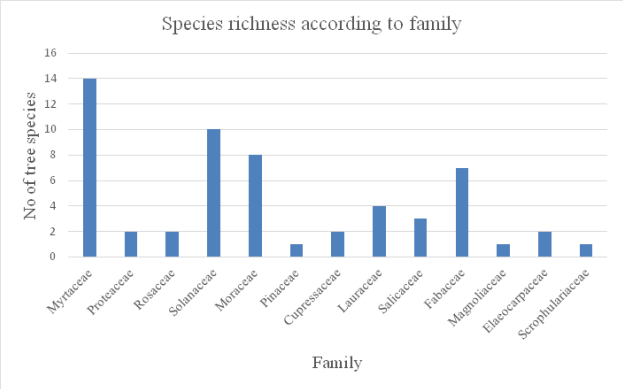


**Figure 2** Species richness on tree species planted along Shankhamul and Balkumari road.

## Comparing species diversity in different sample sites along Shankhamul and Balkumari road

### Comparing species diversity with sorensen index

The tree species on three sample sites were compared with Sorensen's Index (Ss). Results showed that with a value of 0.38 Janata Road and Chhitijnagar shared more common species compared to other sample sites. Similarly, Chhitijnagar and Satya Sai Udhan with a value of 0.22 and Janata Road and Satya Sai Udhan with a value of 0.28 shared less common species among them Table 3.

### Common tree species in different sample sites along Shankhamul and Balkumari road

According to the results of the species comparison among the sample sites, there were 4 species common to both Janata Road and Chhitijnagar. Similarly, only 2 species were common to Chhitijnagar, Balkumari, and Shankhamul's Satya Sai Udhan area. In Janata road, Balkumari, and Satya Sai Udhan area, Shankhamul, 3 species were found to be common. However, only 1 species was found to be common in all three sample sites Table 4.

### Comparison of species diversity in Shankhamul and Balkumari road

Statistically, One Way ANOVA and post-hoc test Turkey's b were applied to compare the diversity indices of tree species of the sample sites. It was applied to find the overall difference among the variety of groups or groups that were significantly different. Specifically, one-way ANOVA showed that there was a significant difference in Shannon -Wiener index between tree species of three sample sites at a 5% significance level since the p-value was less than 0.05, where p was 0.00. The post-hoc test Turkey's b also showed a significant difference in the mean value of Shannon -Wiener index at Janata Road, Chhitijnagar, and Satya Sai Udhan since it falls under a different subset at a 95% confidence level. Similarly, Simpson's index of diversity was tested with one-way ANOVA which also showed a significant difference in tree species of three sample sites at a 5% significance level since the p-value was less than 0.05, where p was 0.00. The post-hoc test Turkey's b showed a significant difference in the mean value of Simpson's index of diversity at Janata Road, Chhitijnagar, and Satya Sai Udhan since it falls under a different subset at a 95% confidence level. Likewise, species richness of tree species was also tested with one-way ANOVA which showed a significant difference in tree species of three sample sites at a 5% significance level since the p-value was less than 0.05, where p was 0.00. The post-hoc test Turkey's b showed a significant difference in the mean value of species richness in Janata Road, Chhitijnagar, and Satya Sai Udhan since it falls under a different subset at a 95% confidence level Tables 5 & 6.

**Table 1** List of tree species planted along Shankhamul and Balkumari road

| S.N. | Scientific Name | Local Name | Janata Road, Balkumari | Chhitijnagar, Balkumari Road | Satya Sai Udhan, Shankhamul Road |
|---|---|---|---|---|---|
| 1 | Buddleja asiatica | Bhimsen pati | ✗ | ✗ | ✓ |
| 2 | Calliandra spp | Kyaliyandra | ✗ | ✓ | ✗ |
| 3 | Callistemon lanceolatus | Kalki Phool | ✓ | ✓ | ✓ |
| 4 | Cassia fistula | Rajbriksha | ✗ | ✓ | ✓ |
| 5 | Cinnamomum camphora | Kapoor | ✓ | ✓ | ✗ |
| 6 | Datura stramonium | Dhaturo, | ✓ | ✗ | ✗ |
| 7 | Deodar cedar | Devdar, | ✓ | ✗ | ✗ |
| 8 | Elaeocarpus ganitrus | Rudrakshya | ✗ | ✓ | ✗ |
| 9 | Eucalyptus camaldulensis | Masala Tree | ✓ | ✗ | ✗ |
| 10 | Ficus bengalensis | Barh | ✓ | ✓ | ✗ |
| 11 | Ficus benjamina | Sami | ✗ | ✓ | ✗ |
| 12 | Ficus elastic | Rubber | ✓ | ✗ | ✗ |
| 13 | Ficus religiosa | Peepal | ✓ | ✗ | ✓ |
| 14 | Grevillea Robusta | Kaaiyo | ✓ | ✗ | ✗ |
| 15 | Juniperus chinensis | Chinese Dhupi | ✓ | ✓ | ✗ |
| 16 | Magnolia champaca | Chanp, Champ | ✗ | ✓ | ✗ |
| 17 | Prunus cerasoides | Painyu | ✓ | ✗ | ✓ |
| 18 | Prunus persica | Aaru | ✗ | ✗ | ✓ |
| 19 | Salix babylonica | Bains, Banis | ✓ | ✗ | ✓ |
| 20 | Senna siamea | Cassod | ✗ | ✗ | ✓ |
| 21 | Solandra maxima | - | ✗ | ✗ | ✓ |
| 22 | Syzygium jambos | Jamun, Gulaf Jamun, Rose apple | ✗ | ✗ | ✓ |

✓= present ✗= absent

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**Table 2** Diversity index of tree planted along Shankhamul and Balkumari road

| Sample Site | No of Species | Shannon Winner Index (H) | Simpsons Diversity Index (SDI) | Species Richness |
|---|---|---|---|---|
| Janata Road, Balkumari | 28 | 2.53 | 0.96 | 2.26 |
| Chhitijnagar, Balkumari Road | 15 | 2.25 | 0.95 | 2.32 |
| Satya Sai Udhan, Shankhamul Road | 14 | 2.24 | 0.93 | 2.4 |

**Table 3** Sorrenson Index to compare the similarity of species between sample sites

| Sample Site | Sorensen Index |
|---|---|
| Janata Road and Chhitijnagar, Balkumari | 0.38 |
| Chhitijnagar, Balkumari and Satya Sai Udhan, Shankhamul Road | 0.22 |
| Janata Road and Satya Sai Udhan, Shankhamul Road | 0.28 |

**Table 4** Common tree species among three sample sites

| Sites | Common tree species |
|---|---|
| Janata Road and Chhitijnagar, Balkumari | Callistemon lanceolatus, Cinnamomum camphora<br>Ficus bengalensis & Juniperus chinensis 'Stricta' |
| Chhitijnagar, Balkumari and Satya Sai Udhan, Shankhamul Road | Callistemon lanceolatus & Cassia fistula |
| Janata Road and Satya Sai Udhan, Shankhamul Road | Callistemon lanceolatus,<br>Ficus religiosa&<br>Salix babylonica |
| Janata Road, Chhitijnagar, Balkumari and Satya Sai Udhan, Shankhamul Road | Callistemon lanceolatus |

**Table 5** Statistical comparison of biodiversity with one way ANOVA

| Site | Comparison of biodiversity by p value (one way ANOVA) | | | | | |
|---|---|---|---|---|---|---|
| | Shannon – Wiener index | | Simpson's index of diversity | | Species richness | |
| Janata Road, Balkumari | P value | 0 | P value | 0 | P value | 0 |
| | Decision | Significant | Decision | Significant | Decision | Significant |
| Chhitijnagar, Balkumari | P value | 0 | P value | 0 | P value | 0 |
| | Decision | Significant | Decision | Significant | Decision | Significant |
| SatyaSai Udhan, Shankhamul | P value | 0 | P value | 0 | P value | 0 |
| | Decision | Significant | Decision | Significant | Decision | Significant |

**Table 6** Post-hoc test to compare the biodiversity of tree species

| Post-hoc test to Compare biodiversity (Turkey's b) | | | |
|---|---|---|---|
| **Site** | **Shannon – Wiener index alpha subset = 0.05** | **Simpson's index of diversity alpha subset = 0.05** | **Species richness alpha subset = 0.05** |
| Janata Road, Balkumari | 2.53 | 0.93 | 2.26 |
| Chhitijnagar, Balkumari | 2.25 | 0.95 | 2.32 |
| Satya Sai Udhan, Shankhamul | 2.24 | 0.96 | 2.4 |
| Remarks | Significant difference | Significant difference | Significant difference |

**Factors affecting the plantation on Shankhamul and Balkumari road**

Principle Component Analysis (PCA) of the management factors affecting the tree species in Janata Road, Balkumari showed that Vandalism by People and Animals (VPA), No Availability of Water except Rain (NAWER), and Low Maintenance and Care of Species (LMCS) were positively correlated with each other as they fell in same quadrant. Whereas, Termites and Insects (TAI), Absence of Weed Control (AWC), Absence of Fences (AOF), Exposure to Dust (ETD), Solid Waste Discarded around Trees (SWDAT), and Tree Disturbing Power Supply Poles (TDPSP) were positively correlated with each other as they fell in same quadrant Figure 3.

Similarly, Principle Component Analysis (PCA) of the management factors affecting the tree species in Chhitijnagar, Balkumari showed that Absence of Fences (AOF), Termites and Insects (TAI), and Absence of Weed Control (AWC) were positively correlated with each other as they fell in same quadrant. Whereas, Low Maintenance and Care of Species (LMCS), Tree Disturbing Power Supply Poles (TDPSP), and Vandalism by People and Animals (VPA) were positively correlated with each other as they fell in same quadrant. Moreover, Worn out Fences (WOF), and Exposure to Dust (ETD) were positively correlated with each other as they fell in same quadrant. Figure 4 Likewise, Principle Component Analysis (PCA) of the management factors affecting the tree species in Satya Sai Udhan, Shankhamul showed that Vandalism by People and Animals (VPA), Absence of Weed Control (AWC), Solid Waste Discarded around Trees (SWDAT), and Worn out Fences (WOF) were positively correlated with each other as they fell in same quadrant. Similarly, Termites and Insects (TAI), and Absence of Fences (AOF) were positively correlated with each other as they fell in same quadrant. Moreover, Low Maintenance and Care of Species (LMCS), Tree

Disturbing Power Supply Poles (TDPSP), and No Availability of Water except Rain (NAWER) were positively correlated with each other as they fell in same quadrant Figure 5.

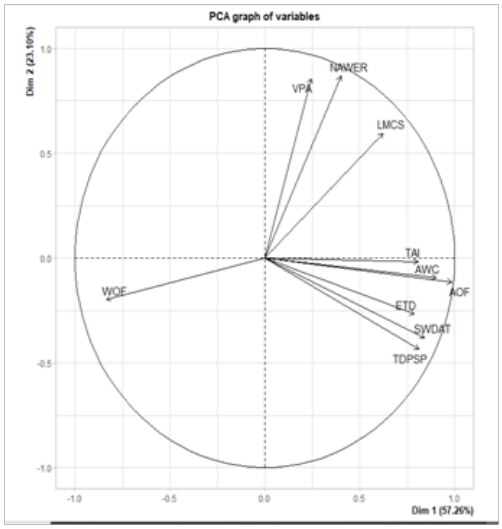


**Figure 3** PCA of factors affecting tree species in Janata Road, Balkumari species in Chhitijnagar, Balkumari.

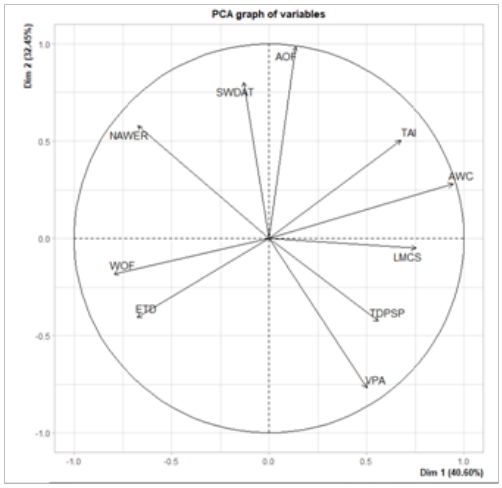


**Figure 4** PCA of factors affecting tree Janata Road, Balkumari species in Chhitijnagar, Balkumari.

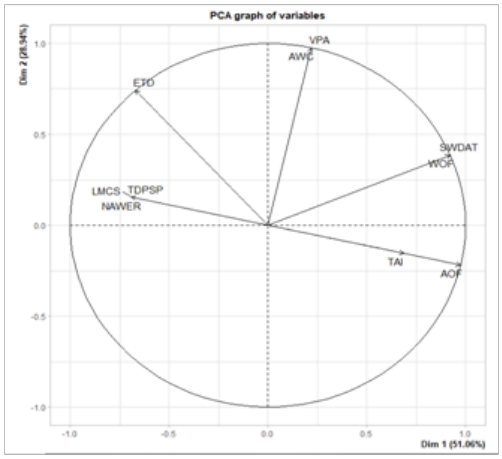


**Figure 5** PCA of factors affecting tree species in Satya Sai Udhan, Shankhamul.

## Discussion

Roadside plantation in the present context has been a subject of interest for the sustainable development and beautification of towns and cities in the urban forestry sector. Urban forests including community forests, trees along roadsides, riversides, parks, gardens, street trees, and residential areas can be seen throughout the cities of Nepal. The study conducted on a roadside plantation along Shankhamul and Balkumari area identified 30 plant species belonging to 13 families. Flowering species and species like *Eucalyptus camaldulensis* dominated the roadside plantation whereas trees with the least number of fruit species were found. Eucalyptus, *Salix babylonica*, *jacaranda*, and the fast-growing, imported *Populus* trees were common among the roadsides in Kathmandu valley from the past.[10,14] Our results are similar to this. The reason behind this, the nursery owner produces only these species in their forest nursery so only these tree species are planted. The species diversity of a community determines the biological diversity of an ecological community.[7] Among species diversity indices Shannon-Winner index, Simpson's index of diversity, and species richness were chosen. The Shannon-Winner index was obtained highest with 2.53 in Janata Road, Balkumari followed by Chhitijnagar with a value of 2.25 and Satya Sai Udhan area, Shankhamul closely following with a value of 2.24. According to Nagendra and Gopal, the higher index value indicate a good diversity of a community.[15] Similarly, Simpson's index of diversity was highest with 0.96 in Janata Road compared to Chhitijnagar with 0.95 and Satya Sai Udhan area, Shankhamul with 0.93. High scores (near 1) indicate a high level of diversity, whereas low scores (near 0) indicate a low level of diversity.[7]

However, species richness was obtained highest with 2.40 in Satya Sai Udhan area, Shankhamul compared to Janata Road with 2.32 and Chhitijnagar with 2.26. Janata Road and Chhitijnagar shared more common planted tree species with a value of 0.38. Similarly, Chhitijnagar and Satya Sai Udhan with a value of 0.22 and Janata Road and Satya Sai Udhan with a value of 0.28 shared less common species among them. The Sorensen Index compares the similarity between plant communities in their species composition and species contribution.[16] The statistical comparison using One Way ANOVA and post-hoc tests Turkey's b also showed there were significant differences in plantation of species. The planted tree species were diverse in the city because nursery owner grow that species which are more profitable.[17] Similar results were seen in these sites as well. Principle Component Analysis showed that solid waste disposal around trees, unmanaged waste dumping, vandalism by people and animals, lack of weeding, disturbing the fences, air pollution, no irrigation, attack of termites and insects were the important factors to manage the roadside plantation of the study site. The study done by[18,19] showed that urban waste disposal and improper care were the important factor to manage the urban forest Our results are quite similar to these studies because these studies were also done in city plantations.

## Conclusion and recommendation

The roadside plantation was inhabited by different flowering plants, with the least number of fruit species. Some of the species that dominated the sample sites along Shankhamul and Balkumari road were *Eucalyptus camaldulensis, Callistemon lanceolatus,* and *Cinnamomum camphora.* The majority of the plants were from the Myrtaceae and Solanaceae families. The diversity indices of sample sites were significant and relatively high, indicating that species are diverse in three different sample sites, with 2 or 3 common species

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between them. However, in the plantation section no systematic selections of species were found. Roadside plantation plays an important role in beautifying the aesthetic value of a city. Regardless of their beneficiary value, several management factors are affecting them. So, it is crucial to control or access the factors that can directly or indirectly influence or affect these species. This research would help to further study spacing, choices, and preferences of the roadside species for effective road safety. It is recommended that intensive and conscious research in terms of economic, environmental, and aesthetic aspects should be done before roadside plantations in urban areas.

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## Conflicts of interest

The author declares that there is no conflict of inertest.

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