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Environmental Assessment of Plant Species Using APTI and API along NH-07 in Himachal Pradesh, India

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Abstract

The assessment of Air pollution tolerance index and anticipated performance index of most occurring plants along National Highway-07 (Nahan – Paonta Sahib), Himachal Pradesh. The investigation has been done along NH-07 from December 2023 to January 2024. There were four 10-km segments of the 40-km NH-07 route between Nahan and Paonta Sahib were separated for analysis. The vehicle activity's effect on vegetation was evaluated by measuring plants at D1 (0–5 m), D2 (5–10 m), and D3 (>10 m) distances from the NH-07 on both sides. Based on the estimated APTI and the socioeconomic traits of most occurring plant species found along the roadside at various locations, the expected performance index (API) was evaluated. The findings revealed that, all the four dominant species scored less APTI score (< 11) and categorised as sensitive plant species. There is no discernible variance in APTI across all sites, according to the two-way ANOVA. The APTI and socioeconomic factors are used in the novel ecological process known as the Anticipated Performance Index (API) to choose plant species that will reduce air pollution. The findings, as reported by API, indicated that among the four most dominant plant species, Shorea robusta (API = 4) considered as "good" performance, Eucalyptus globulus (API = 3) is a moderate performer whereas Ficus roxburghii and Mallotus phillippenis (API = 2) are poor performers. Therefore, it is recommended that a green belt be created for the top performer i.e. Shorea robusta in a particular study area.

Keywords: APTI; API; Green Belt; Environmental assessment; Plant species; Himachal

Introduction

The increase in vehicular movement, the burning of fossil fuels in industry, coal mining operations, and deforestation have all contributed to a major decline in air quality in India's urban areas in recent years (Molnar et al. 2020). Harmful gaseous pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matter pose risks to human health and serve as precursors to vehicular emissions (Muthu et al., 2021). Motor cars in India account for 60–70% of the burden of urban air pollution (Ghafari et al., 2020), and living things are harmed or uncomfortable by rising concentrations of these pollutants in the environment. The increase in greenhouse gases emitted by vehicular and industrial emissions also causes meteorological changes such as a rise in temperature in urban areas (Isinkaralar 2023; Supriya et al., 2018). According to Smith and Staskawicz (2020), plants are important because they provide food and habitat to a variety of organisms, as well as aesthetic value, and they also intercept air pollutants. According to Kaur and Nagpal (2017), plants also have a considerable deal of potential for the absorption, adsorption, and storage of contaminants on their leaf surfaces. The three mechanisms exist in plants that help them eliminate pollution: particulate deposition, leaf absorption, and particulate accumulation on the protected side of the leaf surface due to the large surface area of the leaves, which functions as a sink (Roy et al. 2020 and Javanmard et al., 2020). Air pollution, on the other hand, may have a negative impact on plant growth by altering morphological traits, photosynthetic activity, biochemical parameters, and seed germination (Kaur and Nagpal,

2017). A number of plants will modify their biochemical characteristics to adapt to the constantly shifting conditions; these modifications will mostly affect chlorophyll, ascorbic acid, leaf pH, and relative water content. To identify plant species as sensitive, intermediate, or tolerant to air pollutants, changes in parameters other than biochemical ones will be taken into account when measuring the Air Pollution Tolerance Index (APTI) of those species (Molnar et al., 2020). Environmental activists and policymakers stress the significance of a permanent green belt in and near urban areas and on highways to decrease the result of toxic fine particulates and to use as a bioindicator of pollution. Green belts are an effective way to mitigate air emissions by trapping particulate matter and capturing gaseous pollutants (Alotaibi et al. 2020). Air pollution tolerance index (APTI), which is useful in assessing the impact of pollutants solely on biochemical parameters, is one of the frequently used indices for plant selection (Chaudhary and Rathore, 2019; Molnar et al., 2020; Roy et al., 2020). The expected performance index (API) for the green belt air pollution mitigation strategy takes into account certain biological and socioeconomic factors (Kaur and Nagpal, 2017; Sahu et al., 2020; Javanmard et al., 2020). This API is a better tool than the APTI, which has been used to gauge how well dominant species can remove contaminants from the atmosphere (Karmakar and Padhy, 2019; Sharma et al., 2020). The present study aims to evaluate the APTI and API of most occurring plant species along the roadside in the study area, identifying species adapted to unique environmental conditions and assessing their impact on air quality improvement and landscape aesthetics. It will provide insights into selecting resilient species for sustainable landscaping practices in challenging terrain.

Material and Methods

Site description

Nahan is located in Himachal Pradesh, India's southeast in the Sirmaur district. It is situated at an average elevation of 932.2 meters. 30.55°N 77.3°E is the location of Nahan. The industrial town of Paonta Sahib is located in the state of Himachal Pradesh in India. It is located south of the Sirmaur district on National Highway 72, also known as New NH 7. The river separates the states of Himachal Pradesh and Uttarakhand. Paonta Sahib is located at 30.438°N 77.624°E in coordinates. At an average elevation of 1,276 feet, or 389 meters, it is situated. located on the Yamuna River's bank, which acts as a boundary between the states of Himachal Pradesh and Uttarakhand. It lies near the towns of Dehradun in Uttarakhand, Nahan in Himachal Pradesh, Saharanpur in Western Uttar Pradesh, and Yamunanagar in Haryana. It is located in the westernmost region of the Doon Valley, about 44 kilometers from Dehradun. The distance between Paonta Sahib and Kaleshwar National Park is 19 kilometers [Figure 1 (A, B)].

Experimental details

The study was conducted from December, 2023 to June, 2024 under the Department of Environmental Science, Himachal Pradesh University Summerhill Shimla (Himachal Pradesh). A preliminary survey of the National Highway 7 (Nahan to Paonta Sahib) was directed from December 2023 to January 2024. The 40 km stretch of NH-07 from Nahan to Paonta Sahib was divided into four 10 km sections for analysis. To evaluate the impact of vehicular activity on vegetation, plants were assessed at distances of D1 (0-5 m), D2 (5-10 m), and D3 (>10 m) from the NH-07 on both sides [Figure 1(B)]. The study revealed four dominant species included *Ficus roxburghii*, *Mallotus philippensis*, *Shorea robusta*, and *Eucalyptus globulus in study area*. The data collection and laboratory examination performed from March to June, 2024, focused on these species across the specified distances. In each 10 km stretch, three composite samples of each species were randomly gathered to ensure uniformity in plant age, size, and ecological conditions. The Air Pollution Tolerance Index (APTI) is determined by estimating four biochemical parameters: ascorbic acid, total chlorophyll, leaf extract pH, and relative water content. The index is calculated using the formula provided by Singh and Rao (1983).

$$APTI=([A(T+P)] +R)/10$$

Where,
A- Ascorbic acid (mg g^{-1}),
T- Total chlorophyll (mg g^{-1}),
P- Leaf extract pH,
R- relative water content (%)

Through local interviews and research of the literature, the socioeconomic value of roadside plants was evaluated in order to generate the Air Pollution Index (API). Following Kaur and Nagpal (2017), the plants were ranked both negatively and positively by integrating biological factors (such as habit, canopy, and economic worth) with APTI values.

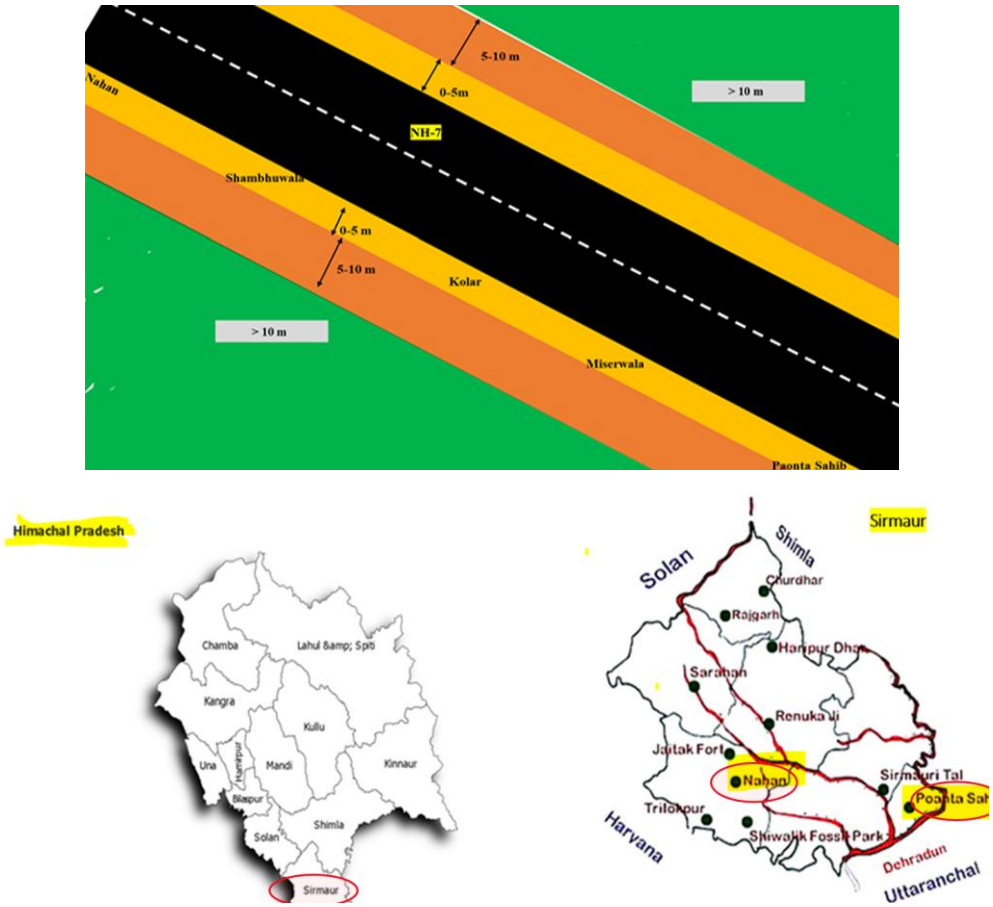

Fig. 1a. Layout design of study area

Fig. 1b. Map of the study area (Source: Google Earth)

Results and Discussion

The current study unambiguously demonstrates how the four plant species exposed to traffic areas changed in terms of their pH, total chlorophyll content, relative water content, and ascorbic acid content.

Table 1. Categorization of plant species based on APTI score (Singh et al., 1991)

Category of plant species	APTI score
Sensitive	Less than 11
Intermediate	Between 12 and 16
Tolerant	Above 17

Ascorbic Acid Content (AAC)

Natural antioxidant ascorbic acid strengthens plants' defences against air pollution. For the creation of cell walls, defense, and cell division, ascorbic acid is essential. The dominant plant species of the selected study area varied significantly in their ascorbic acid content that ranged from 0.717 to 0.734 mg g^{-1} (Figure 2). The findings revealed that among the four species, maximum ascorbic acid content was recorded in *Ficus roxburghii* (0.734 mg g^{-1}) and minimum ascorbic acid content was recorded in *Eucalyptus globulus* (0.717mg g^{-1}) at par with *Shorea robusta and Mallotus philipensis* (0.729 mg g^{-1}).The order of ascorbic acid in the leaves of selected species was *Ficus roxburghii* (0.734mg g^{-1}) > *Mallotus philipensis* (0.729 mg g^{-1}) *Shorea robusta* (0.729mg g^{-1}) > *Eucalyptus globulus* (0.717mg/g - 1). The maximum ascorbic acid content in the leaves of *Ficus roxburghii* may probably be due to genetic variation as well as due to its higher adaptive capacity to tolerate stresses of the environment including air pollution. The maximum amount of ascorbic acid of (0.901 mg g^{-1}) recorded at a horizontal distance of 0-5m from the National Highway whereas, lowest amount (0.417 mg/g^{-1}) was recorded in plants growing at a horizontal distance of >10 m (control site) from the National highway [Figure 2 (A)]. It demonstrates how raising AA under environmental stress strengthens a species' antioxidant capacity (Karmakar et al., 2021).

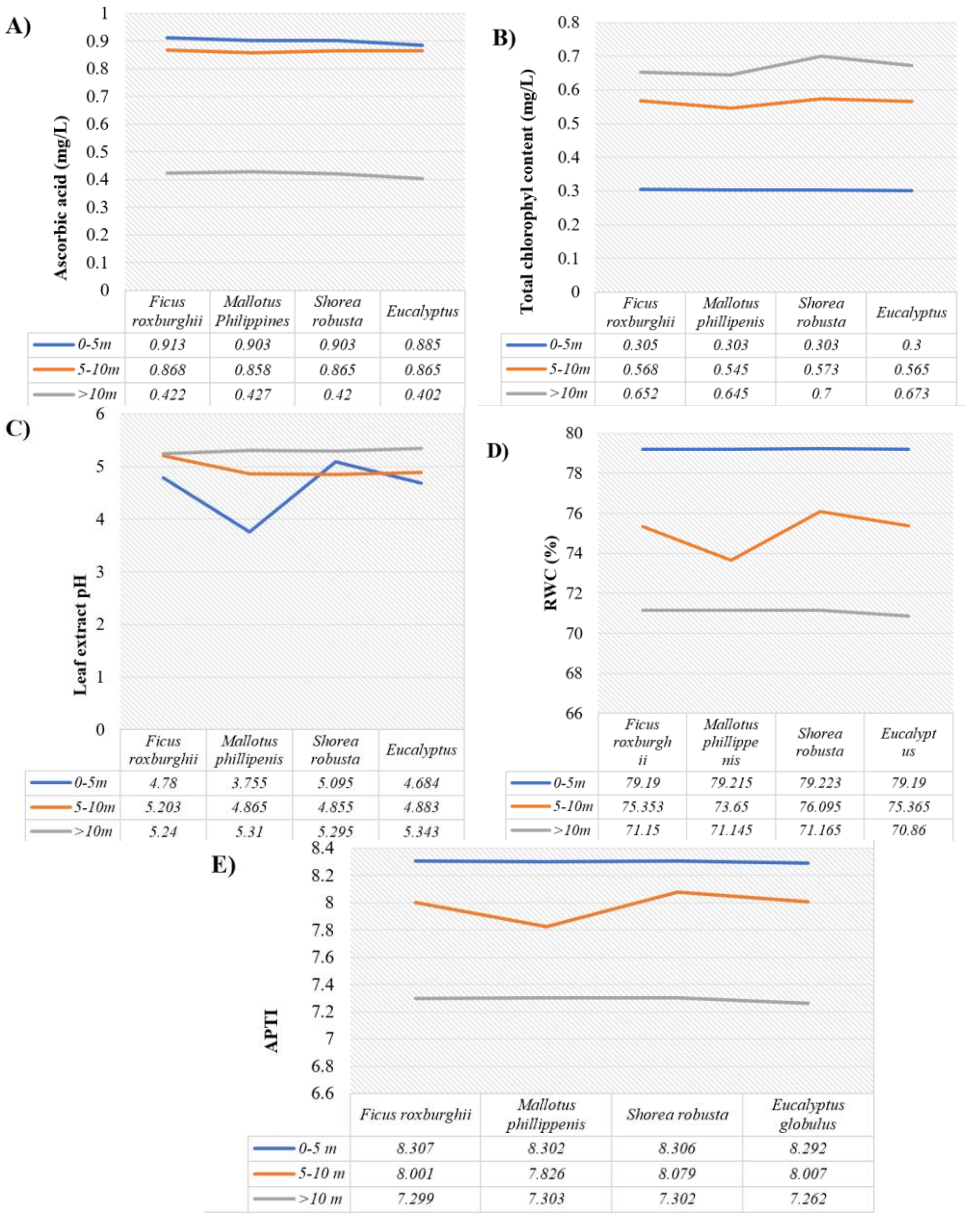

Fig. 2 (A, B, C, D). Variation in bio-chemical parameters **E)** Variation in the tolerance level of selected plant species in different horizontal distances along NH-7

Total chlorophyll content (Tchl)

The chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. The common plant species growing alongside Nahan to Paonta Sahib

National Highway were found to exhibit significant variation in their leaf chlorophyll content. It was found that the leaf chlorophyll content of the selected plant species varied from 0.498 to 0.525 mg g^{-1} [Figure 2 (B)]. Among the four plant species, *Shorea robusta* was noticed to have maximum chlorophyll content of 0.525 mg g^{-1} in their leaves followed by *Eucalyptus globulus*, *Ficus roxburghui*, *Mallotus philippensis*, with respective values of 0.513, 0.508 and 0.498 mg g^{-1}. The variation in the chlorophyll content in the leaves of selected plant species may be attributed to the genetic variations of the plant species. Further, the variations in leaf chlorophyll content of plant species may vary with the pollution status of the area as well as the tolerance and sensitivity of the plant species. Among the specified horizontal distance, *Shorea robusta* was found to register maximum leaf chlorophyll content (0.668 mg/g^{-1}) at a distance of >10 m (D3 = control site). The lowest chlorophyll content of 0.303 mg/g^{-1} was recorded at a distance of D1 (0-5 m). The poor air quality, which includes particulate matter, SO_2, and NO_2, settles on leaves and clogs stomata, reducing the amount of chlorophyll in the leaf by decreasing the transpiration rate, which is the primary cause of the decline in Tch in urban and semi-urban areas (Bharti et al., 2018). The Lowest Tch value was also caused by other causes, such as high temperature, soil pollution, and salt stress conditions (Gopamma et al., 2022; Karmakar et al., 2021; Zhang et al., 2020).

Table 2. Anticipated Performance Index of plant species (Sharma, 2020)

Grade	Score (%)	Assessment Category
0	Up to 30	Not Recommended
1	31 – 40	Very Poor
2	41 – 50	Poor
3	51 – 60	Moderate
4	61 – 70	Good
5	71 – 80	Very Good
6	81 – 90	Excellent
7	91- 100	Best

Table 3. Grading of plant species based on Air Pollution Tolerance Index (APTI) as well as biological parameters and socio – economic parameters.

Grading character	Pattern of Assessment	Grade allotted
Air Pollution Tolerance Index	8.5- 9.0	+
	9.1-9.5	++
	9.6-10	+++
	10.1-10.5	++++
	10.6-11	+++++
Plant habit	Small	-
	Medium	+
	Large	++
Canopy structure	Sparse / irregular / globular spreading	-
	Crown open / semi-dense	+
	Spreading dense	++
Type of plant	Deciduous	-
	Evergreen	+
Laminar characteristics	Small	-
1. Size	Medium	+
2. Texture	Large	++
	Smooth	-
	Coriaceous	+
Hardiness	Delineate	-
	Hardy	+
Economic value	Less than three uses	-
	Three or four uses	+
	Five or more uses	++

Maximum score a plant can attain = 16

Leaf Extract pH

The leaf extract pH is a biochemical parameter that serves as a sensitivity indicator of air pollution pH of the leaf extract signifies the tolerant capacity of the leaf species. The maximum level of pH in leaf extract indicates that the plants are tolerant under polluted conditions. In the present investigation, the plant species growing along the Nahan to Paonta Sahib National Highway exhibited statistically significant variation in the leaf extract pH. The range of the leaf extract pH among selected plant species was from 4.643 to 5.11 [Figure 2 (C)]. The maximum leaf extract pH was recorded in *Eucalyptus globus* (5.11) whereas, the minimum leaf extract pH was noticed in *Mallotus philipensis* (4.643). The order of the leaf extract pH in plant species was *Eucalyptus globulus* (5.11) > *Shorea robusta* (5.082) which is at par to *Ficus roxburghii* (5.074) and is followed by *Mallotus philipensis* (4.643). The trend of leaf extract pH is similar to chlorophyll content with respect to different horizontal distances of plant species from the National Highway. The leaf extract pH

increased with the increase in horizontal distance which was recorded maximum 5.297 of at the distance of D3 = >10 m (control site) from the road, whereas the minimum leaf extract pH of 4.684 was recorded at a distance of D1= 0-5 m from the roadside. The lowest value of pH in the case of plants growing near the National Highway may be attributed to a high level of vehicular pollution at this site. According to Roy et al. (2020) and Singh et al. (2020), there was a variance in the pH of the leaf extract of the tree species. This fluctuation may have been caused by air pollutants (SO_2 and NO_2) present in the atmosphere, which reduce the pH when absorbed by the tree leaves. This is because of disruptions in stomatal exchange, pollutants lower photosynthetic efficiency, which causes sensitive species to become more acidic (Bandara & Dissanayake, 2021; Bharti et al., 2018).

Table 4. Evaluation of plant species based on APTI value and some biological and socio-economic characteristics

Plant species	Assessment parameters				Laminar structure				Grade allotted	
	APTI	PLANT HABIT	CANOPY STRUCTURE	TREE TYPE	SIZE	TEXTURE	HARDNESS	ECONOMIC IMPORTANCE	TOTAL PLUS	%SCORING
Ficus roxburghii	+	-	+	+	++	+	+	+	8	50
Mallotus philippenesis	+	++	+	-	+	-	+	++	8	50
Shorea robusta	+	++	++	-	++	+	+	++	11	69
Eucalyptus globulus	+	++	-	+	++	-	+	++	9	56

Table 5. Anticipated performance index (API) of selected plant species

Sr. No.	Plant species	Total grade Allotted	%Score	API Grade	Assessment category
1.	*Ficus roxburghii*	8	50	2	Poor
2.	*Mallotus philippenesis*	8	50	2	Poor
3.	*Shorea robusta*	11	69	4	Good
4.	*Eucalyptus globulus*	9	56	3	Moderate

Relative water content (RWC)

The amount of water in the leaf tissues of trees is essential to their physiological and metabolic functions. It is a direct measure of deficit in leaves. It is evident from the data presented in [Figure 2(D)] that the relative water content of the dominant plant species growing alongside Nahan to Paonta Sahib National Highway varies significantly at particular horizontal distances. The range of the RWC among selected plant species was from 4.64 to 5.11% [Figure 2(D)]. It was revealed that the RWC among the dominant plant species was showed with a maximum in *Shorea robusta* (75.494%) which was at par with *Eucalyptus globulus* and *Ficus roxburghii* (75.138%) and (75.231%) and minimum RWC was recorded in *Mallotus philippensis* (74.67%). The order of the plant species based on the leaf RWC was *Shorea robusta* (75.494%) > *Eucalyptus globulus* (75.138%) > *Ficus roxburghii* (75.231%) > *Mallotus philippensis* (74.67%). The variation in the relative water content among the plant species may be due to the difference in the genetic makeup. The relative water content of the most occurring plant species was found to exhibit a significant variation while increasing the distance from National Highway, maximum relative water content was recorded at a distance of D1 = 0-5 m (79.204%) whereas minimum (71.08%) at a horizontal distance of D3 = >10 m (control site). There were no statistically significant differences ($p<0.05$) between the control site and the other polluted locations. High RWC trees that are close to contaminated areas have a greater capacity for tolerance, which aids in preserving physiological balance and life processes under trying circumstances (Bandara & Dissanayake, 2021; Roy et al., 2020). This is because of their innate ability to withstand stress and stop water loss, tree leaves were revealed to have a greater RWC (Singh et al., 2020). The findings of Lakshmi Kanta Panda & Aggarwal (2018) are consistent with the results.

APTI and API

The plant or tree species have a great capacity to withstand pollution, as seen by their high APTI values. The current study used APTI as a technique to determine how differently roadside plant species respond to air pollution. According to Singh et al. (1991), the APTI score was used to categorize the species' tolerance levels into four categories: sensitivity, intermediate tolerance, moderate tolerance, and tolerance. According to the results of the two-way ANOVA, there was no significant difference between the polluted and control sites (Figure 2). The results showed that APTI of selected plant species varied from 7.811 to 7.869 [figure 2 (E)]. The results showed that among plant species, *Shorea robusta* (7.896) has the highest APTI which is *at par to the Ficus*

roxburghii (7.869), *Eucalyptus globulus* (7.854) followed by *Mallotus philippensis* (7.811). The APTI of the most occurring plant species varied with different horizontal distances from the National Highway. The highest APTI of 8.302 was recorded adjacent to the National Highway at a distance of D1(0-5 m), whereas the lowest APTI of 7.291 was recorded at a distance of D3 = >10 m (control site). The highest APTI of the plants growing at the horizontal distance of 0-5 m from the Highway may be attributed to capacity of plants to adapt to stress conditions created by vehicular pollution. The lowest APTI of the plants growing at the distance of D1 = >10 m (control site) may be attributed to its lower pollution level. The findings showed that *Shorea robusta* has the highest APTI value throughout all the sites and can be considered a tolerant species in comparison to other dominant species along the NH-07. Although these four dominant species are scored less than 11 which categorized as sensitive according to Singh et al. (1991).

Nonetheless, in a small number of cases where the highest APTI was discovered, it was believed to be the result of the high concentration of pollutants in the region, showing that, in line with previous studies, APTI values increase as pollution concentration rises (Bharti et al., 2018; Sahu et al., 2020; Shrestha et al., 2021). In contrast, other research revealed that pollutant concentration increased when APTI decreased (Bandara & Dissanayake, 2021; Rai & Panda, 2014).

The APTI of each plant species and other ecological and socioeconomic factors were taken into consideration when evaluating them for the creation of a green belt alongside the roadway. According to Mondal et al. (2011) and Prajapati & Tripathi (2008), the characteristics include leaf size, canopy structure, plant habit, size, texture, and the economic value of specific trees. API is used as an indicator to assess the capability of predominant species in the cleanup of atmospheric pollutants. The findings shown in Table no. 4 revealed that among four dominant plant species, *Shorea robusta* exhibited the highest grading (69%) followed by *Eucalyptus globulus* (56%), *Ficus roxburghii* and *Mallotus philippensis* (50%). The plant species *Shorea robusta* among all four plant species that performed as well as or good across all study sites, the rest of the three species *Eucalyptus globulus, Ficus roxburghii* and *Mallotus philippensis* performed from moderately to poorly were evaluated at all sites. Based on the species' APTI value, which varies at each site, the API grade changed. *Shorea robusta* was the best tree for plantations alongside selected National Highway-07 (Table 5).

Conclusion

The present investigation shows the variation in the API and APTI of the common plant species next to the NH-07. The results showed that all four species were categorized as sensitive, but the tree's susceptibility to air pollution was examined based on APTI score where *Shorea robusta* has found the highest API among the four most occurring plant species. Therefore, to endure the effects of pollution in the study area, this plant species can be recommended for cultivation.

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Author Contributions

KS provided the technical assistance, analysed, hypothesized, supervised and finalized the data and its manuscript; RC has collected samples and dealing out of samples. RKA reviewed the results and approved the final version of manuscript.

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