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ASSESSMENT OF ENVIRONMENTAL VALUES PROVIDED BY TREES LOCATED IN LIEN CHIEU INDUSTRIAL PARK, DA NANG CITY, VIETNAM

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Abstract. Trees have a vital role in boosting human well-being by bringing nature into cities and providing habitat for wildlife. The i-Tree Eco model was used on 1,189 trees from 21 identified species to assess the eco-benefits of trees in Lien Chieu Industrial Park (LCIP) in Da Nang, Vietnam. The most predominant species were discovered to be *Dipterocarpus alatus*, *Hopea odorata*, *Alstonia scholaris*, *Peltophorum pterocarpum*, and *Terminalia catappa*. The leaf area benefit of trees at the Lien Chieu Industrial Park has been assessed to be 79,800 m^2, with a leaf biomass of 7,187 kg. Furthermore, by storing 59,530 kg of carbon and sequestering 8,430 kg of this molecule every year, these trees produced environmental benefits. Other ecosystem services provided include oxygen production (22.46 tons per year), water overflow control (369.03 m^3 per year), and PM2.5 dust reduction (15,767.20 g per year). These findings can assist urban planners and policymakers in optimizing the structure and composition of urban trees in order to increase ecosystem service delivery.

Keywords: Carbon storage and sequestration, Da Nang, ecosystem, i-Tree Eco, tree's value.

1. INTRODUCTION

Vietnam is undergoing tremendous industrialization and modernization. As a consequence, various factories, workshops, enterprises, industrial parks, and export processing zones have been established and are in operation. These industrial zones have offered various economic advantages to the country, including job creation and increased output. They have, however, had a negative influence on the environment, resulting in air pollution, water pollution, and land degradation (Quỳnh, 2020).

Trees are an important component of industrial parks (Selmi et al., 2016). They conserve energy, remove pollutants from the air, filter rainwater, cool high temperatures, and reduce noise and odors. They also help to reduce the negative impacts of pollution on the community, as well as to improve the living environment and eliminate pollutants generated by O_3, SO_2, NO_x, CO, and particulate matter (PM1.0, PM2.5, and PM10) (Nowak et al., 2018).

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Lien Chieu Industrial Park during operation has generated large amounts of CO, CO_2, SO_2, NO_2, causing a significant impact on the air environment in Da Nang (Da Nang city electronic information portal, 2017). Along with minimizing sources of pollution, planting trees is one of the most effective solutions for protecting the environment. However, previous studies have mainly focused on the current status of species composition and the maintenance of tree systems, compared to a few research investigating trees' ecological benefits and environmental protection values.

The i-Tree Eco model was developed in collaboration with the Forest Service, the United States Department of Agriculture (USDA), and the Davey Research Institute (www.itreetools.org). The i-Tree Eco model was used to evaluate vegetation composition, structure, and potential for air pollution mitigation (Nowak, 2021). In addition, this model was used in the study Above Ground Biomass and Carbon Sequestration of Urban Green Spaces in Da Nang City, Vietnam (Tran & Doan, 2024). The goal of this study was to assess the status of tree structures in LCIP and estimate ecosystem services such as carbon storage and accumulation, stormwater runoff reduction, and air pollution removal on key LCIP road networks as a foundation for management.

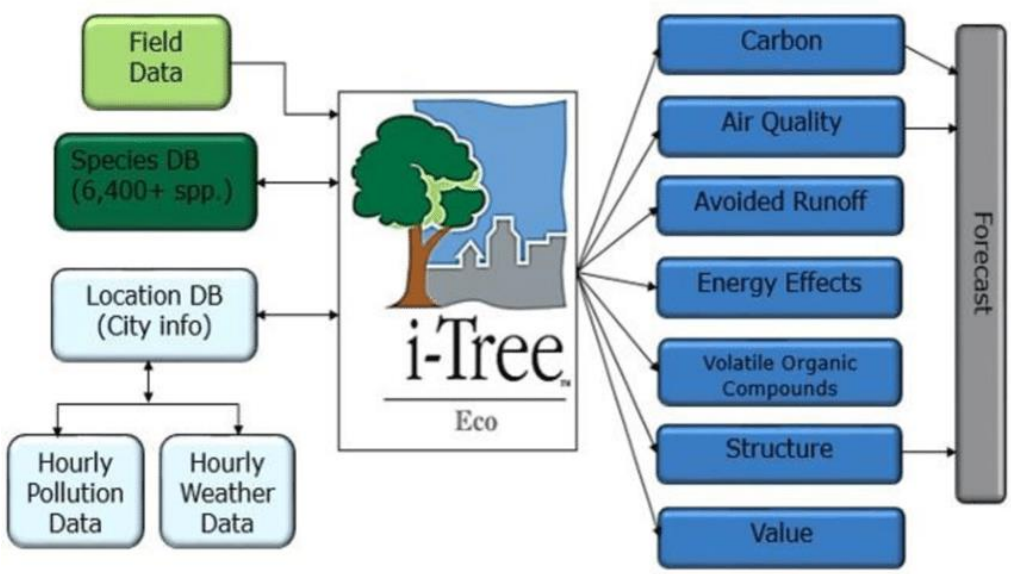

Figure 1. *Input data and functions by the i-Tree Eco model*
Source: (Pace, 2020)

2. MATERIALS AND METHODS

2.1. Study Area

The research was conducted at LCIP, Lien Chieu district, Da Nang city, located at coordinates 16°07'26"N 108°07'4"E" (Figure 2). LCIP has an area of 289.35 hectares and has been placed to nearly 100 companies in the area. LCIP with six streets (street 3, street 4, street 4A, street 7, street 9, and Ta Quang Buu Street) were investigated.

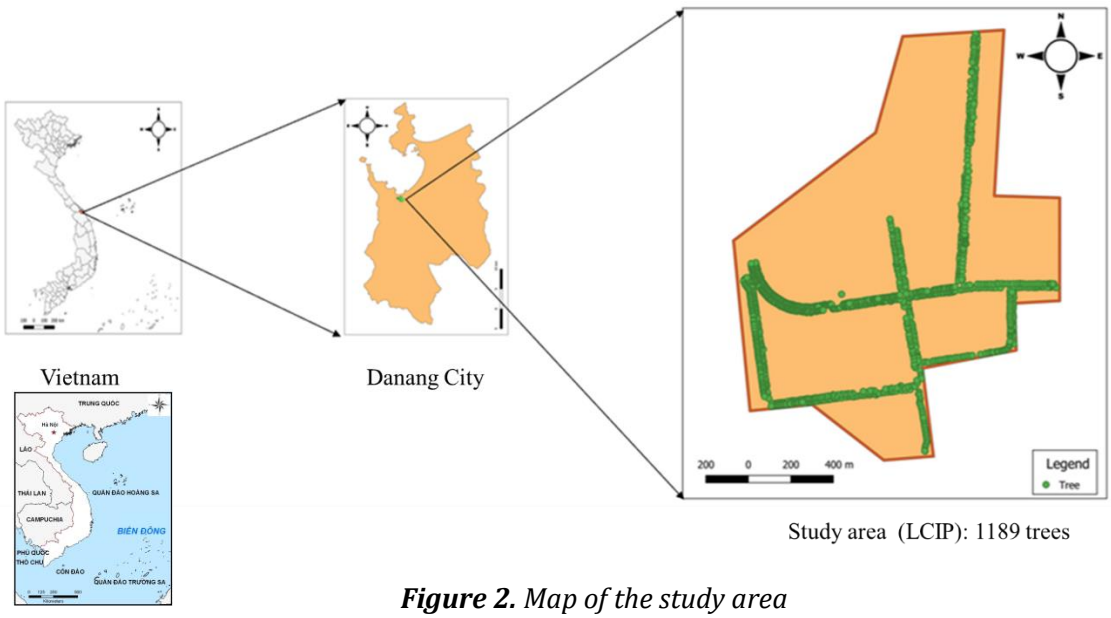

Figure 2. *Map of the study area*

2.2. Data Collection

Field sampling of all street trees was measured according to the inventory method with 1,189 trees between January and April 2023 at LCIP. Field measurements were obtained using the i-Tree Eco field manual (www.itreetools.org), including: i) tree species were identified in the field, ii) Tree locations were located using Gaia-GPS navigation software, iii) diameter at breast height (DBH) and crown width were measured by using a tape measure, iv) total tree height and crown height (height to living top, height to crown base) were recorded using the Sndway Sw-600A laser rangefinder, v) percent crown missing, crown health (dieback), and crown light exposure were all recorded using visual inspection (Nowak et al., 2003).

2.3. Estimating the value of trees by i-Tree Eco

The United States Department of Agriculture (USDA) created i-Tree Eco to assist managers and scientists in evaluating the ecological structure and function of urban forests. The i-Tree Eco is developed in this study to evaluate data obtained in the field from single trees, a comprehensive inventory of the study region, as well as meteorological and air quality data from local hours (Pace et al., 2018). This data is used to assess the structure, environmental effect, and ecological worth of trees (Hirabayashi et al., 2022).

3. RESULTS AND DISCUSSION

3.1. Species Composition and Structure

According to the survey data, there were 1,189 trees of 21 species. We discovered a significant difference in species contribution between two groups, as indicated in Table 1. The top five most prevalent species comprised 111-423 trees (equal to 9.34-35.35%) of

the total. The most prevalent tree, *Dipterocarpus alatus*, accounts for more than one-third of the total area. Meanwhile, the other species has less than 50 trees, and overall contributions are less than 4%.

Table 1. *Species composition and leaf area value of trees in LCIP*

Scientific names	Vietnamese names	Numbers of trees	Percentage (%)	Leaf Area (m^2)		Leaf biomass (kg)	
				Total	Average	Total	Average
Dipterocarpus alatus	Dầu rái	423	35.58	15,200	35.93	865	2.04
Hopea odorata	Sao đen	211	17.75	11,490	54.45	654	3.10
Peltophorum pterocarpum	Lim xẹt	194	16.32	26,320	135.67	2,275	11.73
Terminalia catappa	Bàng	124	10.43	10,300	83.06	1,334	10.76
Alstonia scholaris	Hoa sữa	111	9.34	7,850	70.72	1,167	10.51
Terminalia mantaly	Bàng Đài Loan	45	3.78	830	18.44	108	2.40
Khaya senegalensis	Xà cừ	25	2.10	4,460	178.40	331	13.24
Dalbergia tonkinensis	Sưa	19	1.60	260	13.68	22	1.16
Delonix regia	Phượng vĩ	8	0.67	1,430	178.75	124	15.50
Cassia fistula	Muồng hoàng yến	6	0.50	200	33.33	51	8.50
Roystonea regia	Cau bụng	4	0.34	140	35.00	24	6.00
Acacia spp.	Keo lá tràm	3	0.25	580	193.33	139	46.33
Other species		16	1.30	740	388.33	93	42.33
Total		1,189		79,800		7,187	

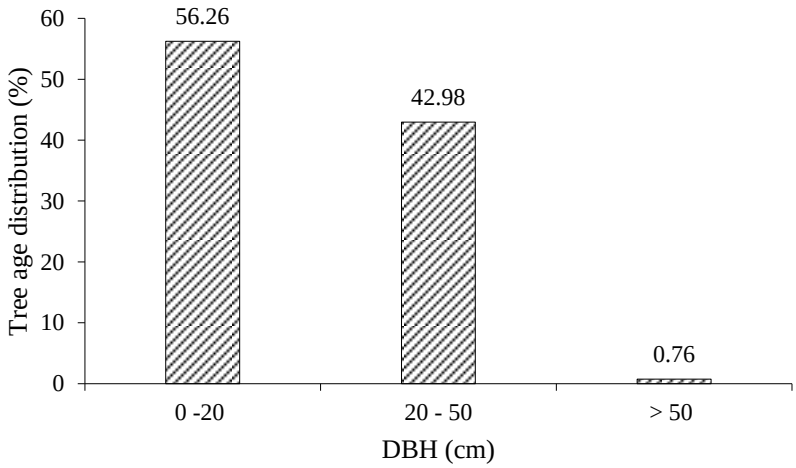

Figure 3. *The age structure of trees in LCIP*

The total leaf biomass for the research region was similarly determined to be 7,187 kg, according to the study findings. *Peltophorum pterocarpum* had the greatest value in leaf biomass at 2,275 kg, followed by *Alstonia scholaris* (1,167 kg) and *Terminalia*

catappa (1,334 kg). The average weight of the tallest tree was *Acacia spp*., 46.33 kg (Table 1). The DBH distributions were the significant criteria varied between diameter ranges. Young trees (56.26%) had the largest proportion, followed by developing trees (42.98%) and elderly trees (0.76%) (Figure 3).

3.2. Oxygen production

The overall oxygen generation value for the study area was 22.46 tons/year. *Peltophorum pterocarpum* produced the most oxygen, 6.13 tons/year. *Dipterocarpus alatus* was the second largest producer, producing 5.32 tons/year. *Hopea odorata*, *Terminalia catappa*, and *Alstonia scholaris* produced 3.55, 2.7, and 2.18 tons/year, respectively. The top five species contributed 19.88 tons/year of the overall oxygen production value, whereas the other species contributed just 2.58 tons/year (Figure 4).

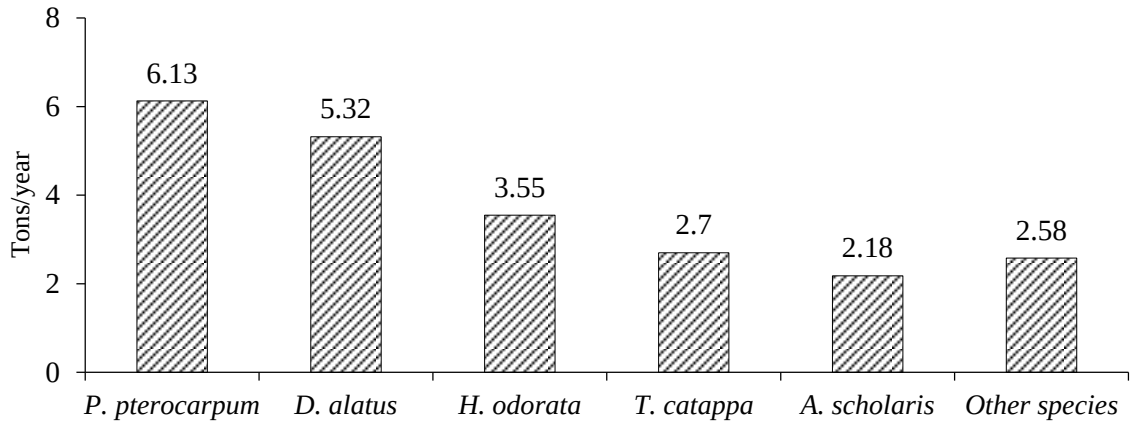

Figure 4. *Annual oxygen produced by predominant trees*

3.3. Carbon storage and sequestration

Trees in the LCIP are predicted to store 59,530 kg of carbon, worth $11,189.033, and add 8,430 kg/year, worth $1,589.498. Findings revealed that the species with the highest carbon storage and accumulation capacity was *Peltophorum pterocarpum*, with values of 14,450 kg ($2,728,293) and 2,300 kg/year ($434.429/year), respectively, followed by *Dipterocarpus alatus* with 12,860 kg ($2,429.251) and 2,000 kg/year ($377.082/year), *Hopea odorata* with 9,030 kg ($1,706.069) and 1,330 kg/year ($251.314/year), *Terminalia catappa* with 7,240 kg ($1,368.022) and 1,010 kg/year ($191.494/year), and *Alstonia scholaris* with values of 5,480 kg ($1,034.159) and 820 kg/year ($154.620/year) (Table 2).

With a total value of 369.03 m^3/year equivalent to $875.077/year, the species with the highest value of preventing overflow water was *Peltophorum pterocarpum*, with 121.82 m^3/year equivalent to $288.899/year, followed by *Dipterocarpus alatus*, with 70.35 m^3/year equivalent to $166.824/year. *Hopea odorata* reached 53.19 m^3/year, or

$126.139/year, *Terminalia catappa* reached 47.68 m^3/year, or $113.080/year, and *Alstonia scholaris* reached 36.32 m^3/year, or $86.141/year (Table 2).

Table 2. *Annual carbon storage and sequestration values*

Scientific names	Number of trees	Carbon storage (kg)		Carbon sequestered (kg/year)		Avoided runoff	
		Total	Value ($)	Total (kg)	Value ($)	Total (m^3)	Value ($)
Dipterocarpus alatus	423	12860	2429.251	2000	377.082	70.35	166.824
Hopea odorata	211	9030	1706.069	1330	251.314	53.19	126.139
Peltophorum pterocarpum	194	14450	2728.293	2300	434.429	121.82	288.899
Terminalia catappa	124	7240	1368.022	1010	191.494	47.68	113.08
Alstonia scholaris	111	5480	1034.159	820	154.62	36.32	86.141
Terminalia mantaly	45	590	110.765	140	26.202	3.86	9.16
Khaya senegalensis	25	3970	749.347	280	52.654	20.65	48.961
Dalbergia tonkinensis	19	1270	240.517	110	19.948	1.18	2.802
Delonix regia	8	2240	423.533	180	34.824	6.64	15.737
Cassia fistula	6	370	70.136	60	10.622	0.9	2.145
Roystonea regia	4	630	118.275	80	15.579	0.66	1.568
Acacia spp.	3	810	153.871	20	4.184	2.66	6.316
Other species	16	590	56.795	100	16.546	3.12	7.305
Total	1,189	59,530	11,189.033	8,430	1,589.498	369.03	875.077

3.4. PM2.5 removal

Table 3. *Annual PM2.5 removed by trees in LICP*

Scientific names	Number of trees	Percentage (%)	PM 2.5 removal (g)	Average (g)	Total value ($)
Dipterocarpus alatus	423	35.58	3,001.30	7.1	2,147.31
Hopea odorata	211	17.75	2,269.30	10.75	1,623.54
Peltophorum pterocarpum	194	16.32	5,196.60	26.79	3,718.45
Alstonia scholaris	111	9.34	1,550.20	13.97	1,108.73
Terminalia catappa	124	10.43	2,034	16.4	1,455.47
Terminalia Mantaly	45	3.78	164.9	3.66	117.894
Khaya senegalensis	25	2.1	880.8	35.23	630.188
Dalbergia tonkinensis	19	1.6	50.5	2.66	3.607
Delonix regia	8	0.67	283	35.38	202.547
Cassia fistula	6	0.5	38.6	6.43	2.76
Roystonea regia	4	0.34	28.2	7.05	20.182
Acacia spp	3	0.25	113.6	37.87	8.13
Other species	16	1.34	156.2	77.07	111.867
Total	1,189		15,767.20		11,150.68

The total amount of PM2.5 dust removed was estimated to be 15,767.20 g/year, which is worth $11,150.68/year. *Peltophorum pterocarpum* had the highest PM2.5

removal value, with 5,196.6 g/year corresponding to $3,718.45/year, followed by *Dipterocarpus alatus* with 3,001.3 g/year corresponding to $2,147.31/year, and *Hopea odorata* with 2,269.3 g/year equivalent to $1,623.54/year. *Acacia spp* had the highest average PM2.5 dust removal value of 37.87 g/year, followed by *Delonix regia* with 35.38 g/year, *Khaya senegalensis* with 35.23 g/year, and *Peltophorum pterocarpum* with 26.79 g/year (Table 3).

4. CONCLUSIONS

Dipterocarpus alatus, *Hopea odorata*, *Alstonia scholaris*, *Peltophorum pterocarpum*, and *Terminalia catappa* were found to be the most common species among the 1,189 surveyed trees. Concerning tree age distribution, the percentage of young trees was the highest (56.26%), followed by maturing trees (42.98%), and old trees (0.76%). The benefits of leaf shading and biomass were 79,800 m^2 and 7,187 kg, respectively. Furthermore, at 59,530 kg carbon, the value of environmental benefits from carbon storage was $11,189.033, and an accumulation of 8,430 kg per year corresponds to US$1,589.498 per year. There was also a value for oxygen production of 22.46 tons/year, overflow prevention of 369.03 m^3 per year (equivalent to $875.077 per year), and removal of PM2.5 dust of 15,767.20 g per year (equivalent to $11,150.68 per year).

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REFERENCES

Da Nang city electronic information portal, 2017. Retrieved from Air pollution in Lien Chieu industrial park. Accessed 9 April 2024, https://www.danang.gov.vn/web/guest/tich-hop/gop-y-chi tiet?

Hirabayashi, S., Kroll, C. N., Nowak, D. J., & Endreny, T. A., 2022. i-Tree Eco Dry Deposition Model Descriptions. https://www.itreetools.org/documents/60/i-Tree_Eco_Dry_Deposition_Model_Descriptions_V1.5.pdf

Nowak, D. J., 2021. Understanding i-Tree: 2021 summary of programs and methods. *USDA Forest Service One Gifford Pinchot Drive Madison, 200-2021* (December), 1-100. https://www.nrs.fs.fed.us/pubs/

Nowak, D. J., Crane, D. E., Stevens, J. C., & Hoehn, R. E., 2003. The urban forest effects (UFORE) model: Field data collection manual. 13210 (315): 31.

Nowak, D. J., Maco, S., & Binkley, M., 2018. i-Tree: Global Tools to Assess Tree Benefits and Risks to Improve Forest Management. *Arboricultural Consultant*, *51*(4): 10-13.

Pace, R., 2020. Modeling ecosystem services of urban trees to improve air quality and microclimate. *TUM School of Life Sciences*, 137.

Pace, R., Biber, P., Pretzsch, H., & Grote, R., 2018. Modeling ecosystem services for park trees: Sensitivity of i-tree eco simulations to light exposure and tree species classification. *Forests*, 9(2): 1-18.

Quỳnh, C. T., 2020. Đánh giá hiện trạng và ứng dụng mô hình Meti-lis để kiểm soát ô nhiễm môi trường không khí khu công nghiệp Liên Chiểu, Thành phố Đà Nẵng. Luận văn Thạc sĩ kỹ thuật - Trường Đại học Bách Khoa - Đại học Đà Nẵng.

Selmi, W., Weber, C., Rivière, E., Blond, N., Mehdi, L., & Nowak, D., 2016. Air pollution removal by trees in public green spaces in Strasbourg city, France. *Urban Forestry and Urban Greening*, *17*(2): 192-201.

Tran, N.-S, & Doan, C. C., 2024. Above Ground Biomass and Carbon Sequestration of Urban Green Spaces in Danang City, Vietnam. *Asian Journal of Biology*, *20*(6): 1-8.

ĐÁNH GIÁ GIÁ TRỊ MÔI TRƯỜNG CỦA CÂY XANH TẠI KHU CÔNG NGHIỆP LIÊN CHIỂU, THÀNH PHỐ ĐÀ NẴNG, VIỆT NAM

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Tóm tắt: Cây xanh có vai trò quan trọng trong việc bảo vệ và nâng cao sức khỏe con người trong các đô thị và cung cấp môi trường sống cho động vật hoang dã. Trong nghiên cứu này, mô hình i-Tree Eco phân tích 1.189 cây xanh thuộc 21 loài đã được xác định để đánh giá lợi ích sinh thái của cây xanh tại Khu công nghiệp Liên Chiểu (LCIP) ở Đà Nẵng, Việt Nam. Các loài chiếm ưu thế nhất là *Dipterocarpus alatus, Hopea odorata*, *Alstonia Scholaris*, *Peltophorum pterocarpum* và *Terminalia catappa*. Diện tích và sinh khối lá của cây xanh tại Khu công nghiệp Liên Chiểu được ước tính là 79.800 m^2 và 7.187 kg. Hơn nữa, với lượng carbon lưu trữ là 59.530 kg và tích lũy 8.430 kg mỗi năm, những cây xanh tại khu vực nghiên cứu đã mang lại lợi ích cho môi trường. Các giá trị môi trường khác được cung cấp bao gồm sản xuất oxy (22,46 tấn mỗi năm), kiểm soát nước tràn (369,03 m^3 mỗi năm) và giảm bụi PM2.5 (15.767,20 g mỗi năm). Những kết quả nghiên cứu này có thể là thông tin cơ sở cho các nhà quy hoạch đô thị và các nhà hoạch định chính sách trong việc tối ưu hóa cấu trúc và thành phần của cây xanh đô thị nhằm tăng cường giá bảo vệ môi trường của cây xanh.

Từ khoá: Carbon lưu trữ, Carbon tích lũy, Đà Nẵng, hệ sinh thái, i-Tree Eco, giá trị cây xanh.

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