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Quarrying Impact on the Leaf Length, Leaf Breadth, and Leaf Area of Selected Edible Tree Plants in Areas around Selected Quarries of Federal Capital Territory (FCT), Abuja, Nigeria

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Abstract
The research work assessed the impact of quarrying activities on eight (8) selected edible tree plants in terms of leaf length, leaf breadth, and leaf area, in areas around selected quarries in the Federal Capital Territory, Abuja. Direct measurement and geometrical approximation methods were among the methodologies employed to conduct the research, and this shows reductions in the leaf lengths, leaf breadths, and leaf areas at the quarry sites, compared to the control site. ANOVA and T-test at a 0.05 level of Probability were the statistical tools employed. The tests show no significant statistical differences, but findings reveal that quarrying negatively impacts the leaf length, leaf breadth, and leaf area. Dust control policies and public awareness of the negative effects of quarrying are some of the recommendations to mitigate the effects of quarrying activities on these morphological features.

Keywords: Quarrying Activities, Morphology, Leaf Length, Leaf Breadth, Leaf Area

Introduction

Rock quarrying and stone crushing are global phenomena and have been a cause of concern everywhere, including in advanced countries (Okafor, 2006). Quarrying activity is a necessity that provides much of the materials used in traditional hard floorings, such as granite, limestone, marble, sandstone, slate, and even clay to make ceramic tiles. However, like many other man-made activities, quarrying activities significantly impact the environment (Okafor, 2006). In particular, it is often necessary to blast rocks with explosives to extract material for processing. Still, this extraction method gives rise to noise pollution, air pollution, damage to biodiversity, and habitat destruction (Okafor, 2006). Dust from quarry sites is a major source of air pollution. For example, limestone quarries produce highly alkaline (and reactive) dust, whereas coal mines produce acidic dust (Lameed & Ayodele, 2010). Air pollution is not only a nuisance (in terms of deposition on surfaces), and possible effects on health, in particular for those with respiratory problems, but dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, as well as chemical effects which may affect long-term survival (Gauch, 2001; Lameed & Ayodele, 2010). Vegetation, which refers to the plant cover of the earth, displays patterns that reflect a wide variety of environmental characteristics as well as temporal aspects operating on it (Kumi-Boateng et al., 2012). This is because it supports critical functions in the biosphere by regulating the flow of numerous biogeochemical cycles, like that of water, carbon, and nitrogen; it is also of great importance in local and global energy balance (Kumi-Boateng et al., 2012). The removal of vegetation cover significantly impacts soil characteristics, including soil fertility, chemistry, and texture (David & Mark, 2005). Although vegetation is of high environmental and biological importance, it is often under intense human pressure in mining areas, especially where surface mining and illegal small-scale mining activities are prevalent, resulting in changes in land-use/land cover of mine areas (Adewoye, 2005; David & Mark, 2005). Directly or indirectly, mining has been seen to be a major factor responsible for vegetation loss in mining areas worldwide (David & Mark, 2005). Directly, it is caused by vegetation clearance for various mining activities, and indirectly, by dust pollution as the volume of dust is discharged into the air during quarrying (Adewoye, 2005). This eventually gets deposited on the leaves of plants and flowers and the soil supporting the plants (David & Mark, 2005). The overall effect of this is that the photosynthetic and fruiting ability of the plants is impaired (David & Mark, 2005). When calcium, sulfur dioxide, among other chemical constituents enter the plants through the stomata pores, it leads to the destruction of chlorophyll and disruption of photosynthesis in plants, subsequently leading to stunted growth or death (Ujoh & Alhassan, 2014; Unanaonwi & Amonum, 2017).

Edible plants are major components of the ecosystem, which is a complex interaction between the biotic and abiotic entities of the environment (Osha, 2006). Unfortunately, land, plants, trees, and surface waters used for drinking and other domestic chores by the community absorb dust discharged from the quarry industry (Osha, 2006). Green plants, including edible trees especially, by their photosynthetic activities occupy an important position in the existence of life because of their ability to maintain a balance in the volume of Oxygen and Carbon dioxide, which leads to the purification of the environment (Lameed & Ayodele, 2010). They supply man with food, drugs, fibres, fuel, building materials, and other raw materials and serve as ornamentals. The plants, including edible tree plants, by their activities, influence and determine, to a large extent, the type of fauna to be expected, and any change or tilt in their composition affects the animal life in terms of food, shelter, security, and comfort (Wang, 2007). Such vegetation changes are the main concern of environmental botanists and ecologists in recent years, who have advocated a careful and cautious approach to activities promoting such changes (Wang, 2007). Air pollution, generally and especially dust from quarry sites, is known to be responsible for vegetation injury and crop yield loss and thus threatens the survival of plants in industrial areas (Iqbal & Shafig, 2001). Such dusts reduce plant cover, height, and number of leaves. Several studies (Anand, 2006; Aigbedion & Iyayi, 2007; Adekoya, 2003) have shown the negative impact associated with the environmental effects of quarrying activities. The damage caused to plants by air pollution includes necrosis (dead areas on leaf structure), chlorosis (loss or reduction of chlorophyll leading to yellowing of leaf), epinasty (downward curvature of the leaf due to higher rate of growth on the upper surface), and abscission of leaves (premature fall) (Anand, 2006). Adekoya (2003), Aigbedion and Iyayi (2007) discovered a trend of declining crop output on farms within a close radius of quarries. They concluded that the phenomenon is most probably associated with dust pollution on crop leaves and flowers, disrupting photosynthesis and reducing yield (Lameed & Ayodele, 2010). Quarrying is a mix of important issues. On the one hand, it supplies raw materials to meet society's needs, creates employment, and contributes to the local economy. On the other hand, it can significantly negatively impact the environment and local communities (Odunnaike et al., 2008), including edible trees. Many of the negative effects can be minimised or controlled if the operators and community strictly adhere to the policy and regulations governing the location of a structure in an environment, with the right planning and management (Oyinloye & Olofinyo, 2017). This paper, therefore, aims to investigate the impact of quarrying on some of the morphological features of selected edible tree plants in areas around quarries, in terms of leaf length, leaf breadth, and leaf area.

Materials and Methods

Study Area

The study was carried out in areas around some selected quarry sites within the Federal Capital Territory (FCT), Abuja, Nigeria. The FCT is made up of six (6) area councils, namely AMAC (Abuja Municipal Area Council), Bwari, Kuje, Gwagwalada, Kwali, and Abaji. The territory is located just north of the confluence of the Niger River and Benue River, lying between latitudes 8.25 and 9.20 north of the equator and longitude 6.45 and 7.39 east of Greenwich Meridian. Abuja is geographically located in the centre of the country (Federal_Capital_Territory_Nigeria, 2020).

Study Site/Site Selection

The study was carried out in areas around two selected quarry sites: CCECC quarry located at the Idu industrial area of Abuja Municipal Area Council, and Zeberced quarry located along the Kubwa/Bwari area of the Federal Capital Territory (FCT), Abuja, Nigeria.

Table 1: GPS of sampling points

Sampling locations	Latitude	Longitude
1. CCECC quarry	$9^{o.}$ 0048’	7^{o} .4109’
2. Zeberced quarry	$9^{o.}$ 1631’	7^{o} ·3093’
3. Control site	9^{o}. 0108’	7^{o}. 4134’

The CCECC (China Civil Engineering Construction Corporation) and Zeberced quarries are two major stone functional quarries in the Federal Capital Territory (FCT), Abuja, Nigeria. The location of both quarries has a predominant vegetation which includes economic/edible tree plant species, hence being selected for the study. The distance between both quarries is about twenty (20) to twenty-five (25) kilometres by road, depending on the route taken. These quarries supply granite and other construction materials for the city's infrastructure development, including roads, bridges, and buildings.

The climate of the FCT, Abuja, is a tropical savanna, with two distinct seasons: the rainy season (wet) and the dry season. These seasons affect both quarries similarly.

The Rainy Season (April to October): During this period, the region experiences heavy rainfall, which can affect quarry operations due to soil erosion, flooding in lower areas, and reduced visibility. The average annual rainfall is between 1,100 mm and 1,600 mm. Most quarry operations are slowed down due to waterlogging and slippery conditions caused by frequent rainfall.

The Dry Season (November to March): The dry season is characterized by Harmattan winds, which blow dust from the Sahara Desert into the region, resulting in low humidity and hazy conditions. The dry conditions make quarry operations easier, though dust can be an issue. Temperatures during the dry season can range from 28°C to 38°C during the day, while at night, temperatures can drop to 18°C or lower, especially during the Harmattan months of December and January.

The Vegetation of the area surrounding the quarries in Abuja primarily features savanna vegetation with scattered trees and shrubs due to the climatic conditions. The vegetation is predominantly grassland, interspersed with trees like acacia, baobab, and various types of palm trees, mangoes, shea butter, locust bean trees, etc.

The soil composition in and around the CCECC and Zeberced quarries is important for understanding the conditions under which quarry operations occur. The soil in Abuja and the surrounding regions is typically ferruginous tropical soils that are red or reddish-brown due to the high iron content. The soil is generally loamy-sandy, with a good level of permeability, which can be a disadvantage during the rainy season as the water washes away the soil layers, causing erosion.

The topography of the areas where the CCECC and Zeberced quarries are located is defined by a mix of rocky outcrops, undulating plains, and hills. The quarries are situated near granite hills, which are typical of the geology of Abuja. The region is known for its abundance of granite rock formations, which are quarried for construction materials. The surrounding landscape features rolling hills and plateaus that give way to steep drops in some places, particularly around the quarry sites where excavation has significantly altered the natural landscape (Federal_Capital_Territory_Nigeria, 2020).

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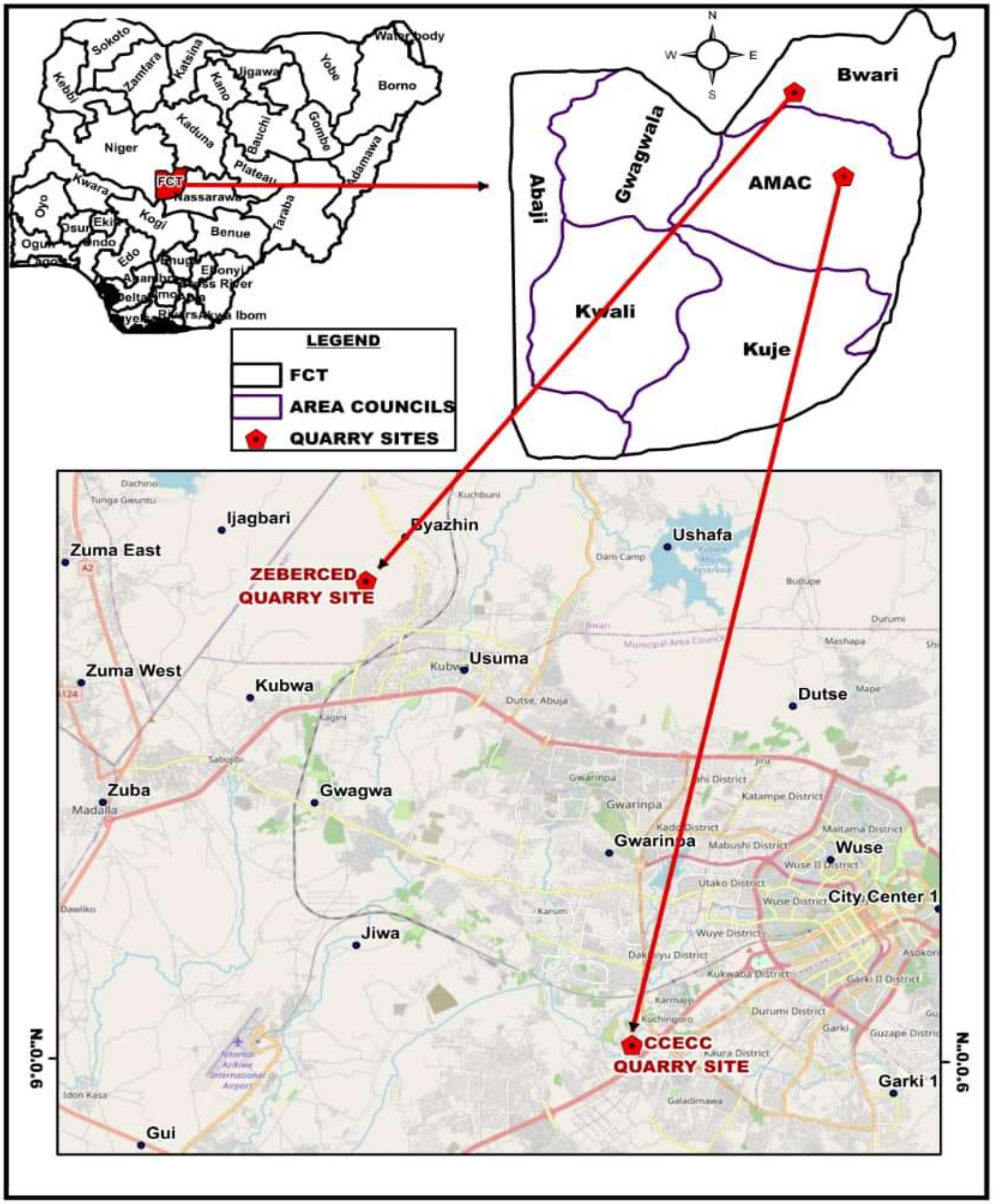

Plate 1. Map of Nigeria showing the location of the Federal Capital Territory (FCT), and the Quarry Areas (**Source**: Nassarawa state Geographical Information System, NAGIS. ArcGIS software, ArcMap online; Coordinate system: WGS84

Plant Selection

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The study plant selection consists of eight edible tree plants that grow in areas around the quarry sites. Eight edible tree plants within the quarry sites were identified and enumerated at intervals of a hundred (100) metres away from the quarry plant. These edible plants were also identified and enumerated at the control site.

Measurement of Plant Morphological Features (Leaf Length, Leaf Breadth, and Leaf Area)

The effect of quarrying activities on morphological features of edible tree plants: the leaf length, leaf breadth, and leaf area were determined. Eight edible tree plants around the selected quarries were selected for the study. These edible tree plants include: *Mangifera indica* (Mango), *Anacardium occidentales* (Cashew), *Citrus sinesis* (Cashew), *Carica papaya* (Pawpaw), *Psidium guajava* (Guava), *Parkia biglobosa* (Locust bean), *Vitellaria paradoxa* (Sheabutter), and *Cocos nucifera* (Coconut). The length, breadth, and area of the leaf samples from the identified and selected edible tree plants around the areas of the selected quarry sites and the control site were measured. Measurement of leaf length (in centimetres, cm) and leaf breadth (in centimetres, cm) was taken using direct measurement via linear rule, and the leaf area was calculated (in centimetres squared, cm^2) (Shradhanjali, et al., 2016). The geometrical approximation method was used to calculate the leaf area using the formula:

Leaf Area = Π x Length/2 x Width/2

Where Π = 3.142

Results

Table 2: Morphological Changes in Selected Edible Tree Plants

		LEAF LENGTH (CM)			**LEAF BREADTH (CM)**			**LEAF AREA (CM^2)**		
S/N	Edible Plant	Site A	Site B	Control	Site A	Site B	Control	Site A	Site B	Control
1	*Mangifera indica*	12.5	13.0	27.5	3.5	3.0	6.5	34.36	30.68	140.3
2	*Anacardium occidentales*	11.5	10.5	20.0	5.5	5.0	13.5	49.70	41.19	211.5
3	*Citrus sinensis*	6.0	5.8	11.5	3.0	4.5	6.5	14.14	20.51	58.56
4	*Carica papaya*	30.0	32	60.0	25.0	27.5	50	589.05	691.15	2356.19
5	*Psidium guajava*	8.0	8.7	12.50	4.0	4.2	13.5	25.13	28.71	132.73
6	*Vitellaria paradoxa*	9.5	9.0	22.0	4.5	4.7	8.0	33.57	33.24	125.66
7	*Parkia biglobosa*	6.5	7.2	20.0	3.0	2.5	6.5	15.32	14.13	102.4
8	*Cocos nucifera*	125	130	200	65	72	100	6385.04	7352.78	15707.96

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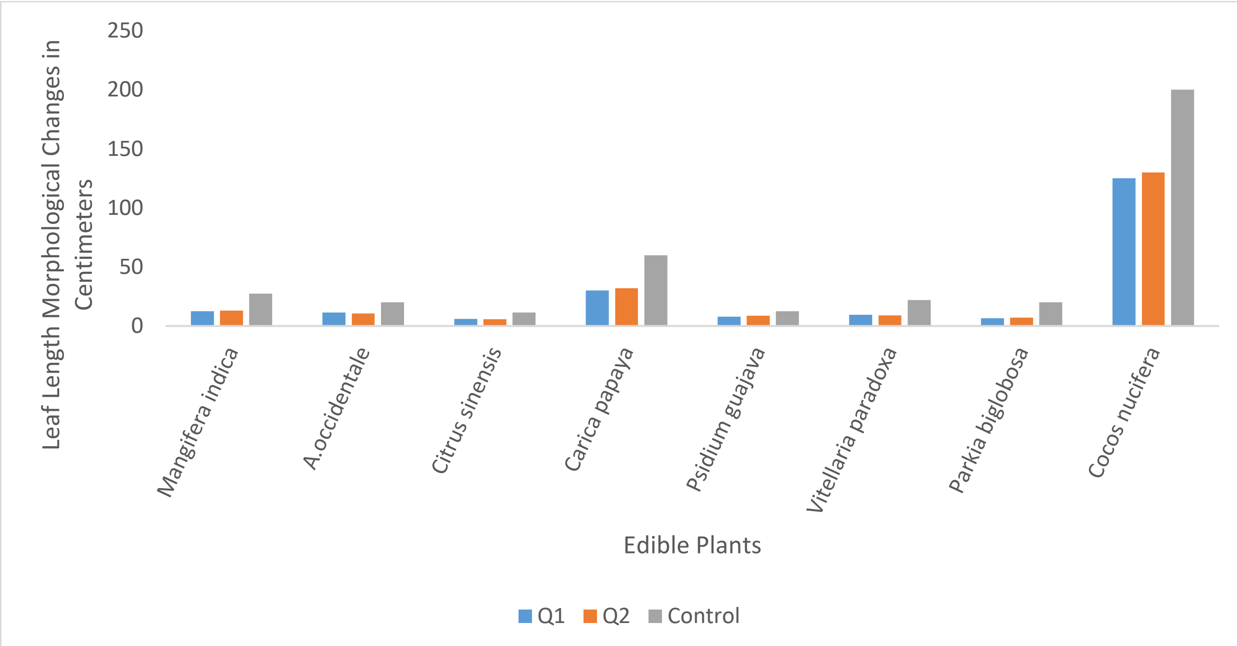

Fig. 1: Effect of Quarrying on Leaf Length

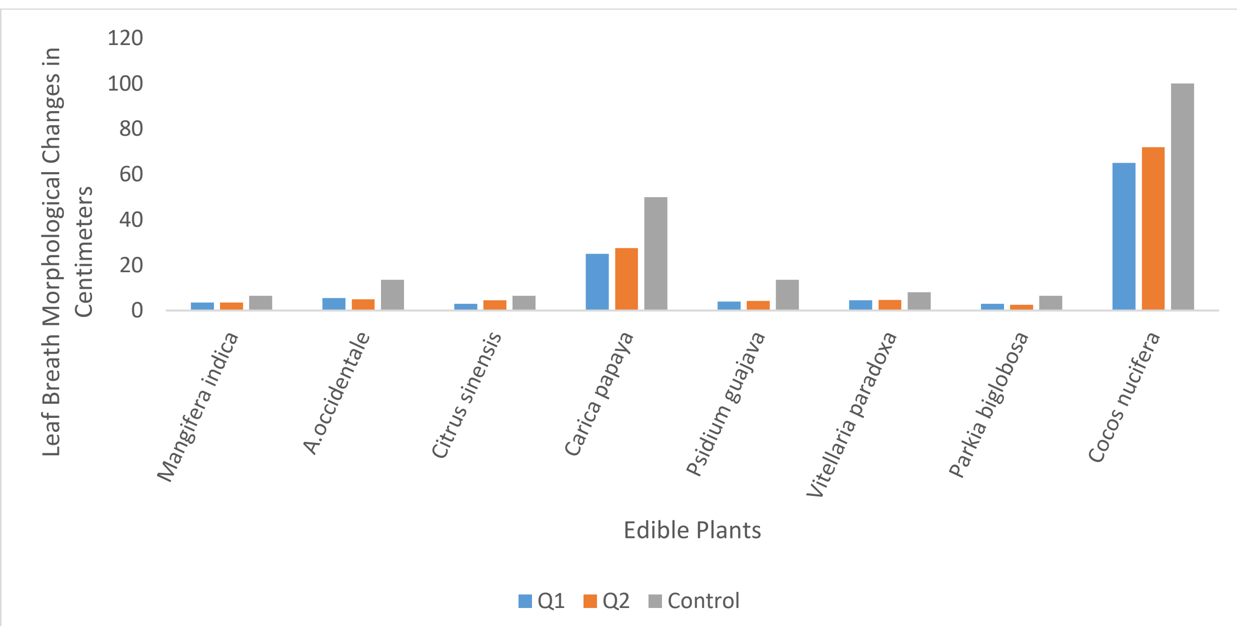

Fig. 2: Effect of Quarrying on Leaf Breadth

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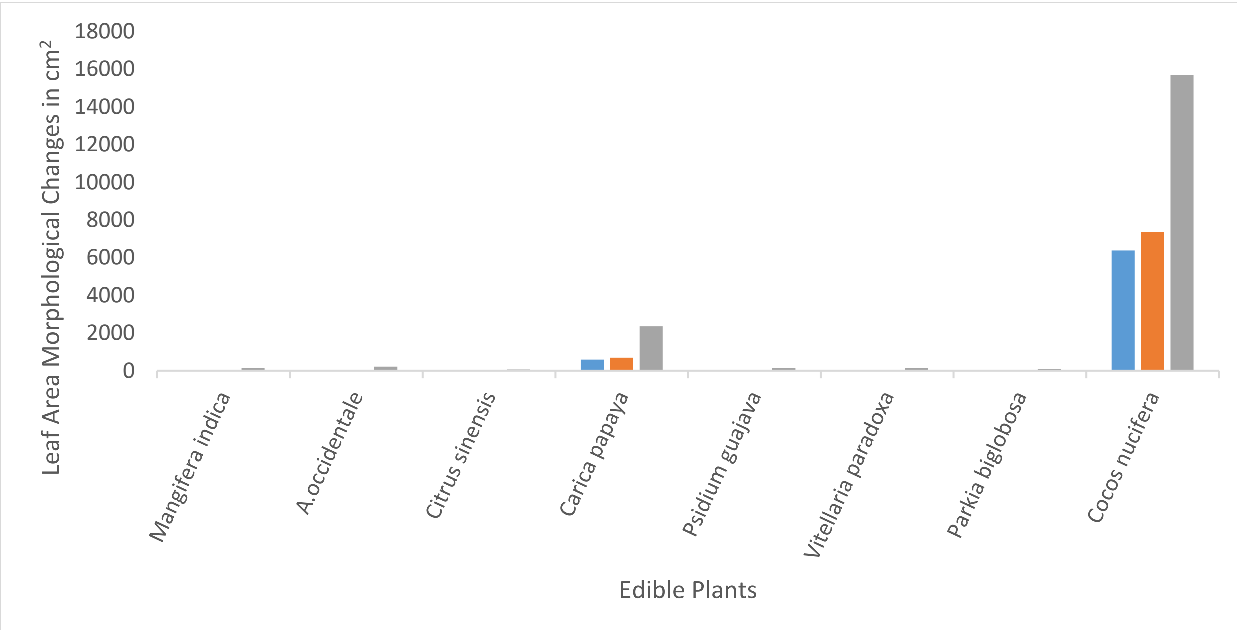

Fig. 3: Effect of Quarrying on Leaf Area

The result from Table 1 (Figures 1, 2, and 3) shows the measurement of some of the morphological features in terms of leaf length, leaf breadth, and leaf area. For all eight edible tree plants investigated, the highest leaf length, leaf breadth, and leaf area were recorded at the non-quarry (control) site. The edible tree plants in the areas around the two quarry sites, A and B (Q1 and Q2), have relatively slight differences in their leaf lengths, leaf breadth, and leaf areas. For *Mangifera indica*, the leaf length, leaf breadth, and leaf area were 12.5cm, 3.5cm, and 34.36 cm^2, respectively, for quarry site A. Quarry site B recorded 13.0cm, 3.0cm, and 30.68 $cm^{2,}$ respectively, while the control site recorded 27.5cm, 6.5cm, and 140.3 $cm^{2,}$ respectively. *Anacardium occidentales* recorded 11.5cm, 5.5cm, and 49.70 cm^2 at quarry site A, while quarry site B recorded 10.5cm, 5.0cm, and 41.19 $cm^{2,}$ respectively. The control site recorded 20.0cm, 13.5cm, and 211.5 $cm^{2,}$ respectively. *Citrus sinensis* recorded 6.0cm, 3.0cm, and 14.14 $cm^{2,}$ respectively, at quarry site A, while quarry site B recorded 5.8, 4.5, and 20.51 $cm^{2,}$ respectively. 11.5cm, 6.5cm, and 58.56 cm^2 were recorded for the control site. For *Carica papaya*, 30.0cm, 25.0cm, and 589.05 cm^2 were recorded respectively at quarry site A; 32.0cm, 27.5cm, and 691.15 cm^2 respectively at quarry site B, while the control site recorded 60.0cm, 50.0cm, and 2356. 19 cm^2 respectively. Psidium guajava recorded a leaf length, leaf breadth, and leaf area of 8.0cm, 4.0cm, and 25.13 $cm^{2,}$ respectively, at quarry site A, while quarry site B recorded 8.7cm, 4.2cm, and 28.71 $cm^{2,}$ respectively. The control site recorded 12.50cm, 13.5cm, and 132.73 $cm^{2,}$ respectively. For *Vitellaria paradoxa*, 9.5cm, 4.5cm, and 33.57 cm^2 were recorded respectively at quarry site A, and 9.0cm, 4.7cm, and 33.24 cm^2 were recorded at quarry site B. The control site recorded 20.0cm, 8.0cm, and 125.66 $cm^{2,}$ respectively. *Parkia biglobosa* 6.5cm, 3.0cm, and 15.32 $cm^{2,}$ respectively, at quarry site A; 7.2cm, 2.5cm, and 14.13 cm^2 at quarry site B, while the control site recorded 20.0cm, 6.5cm, and 102.4 $cm^{2,}$ respectively. For *Cocos nucifera*, quarry site A recorded 125.0cm, 65cm, and 6385.04 $cm^{2,}$ respectively, while quarry site B recorded 130cm, 72cm, and 7352.78 $cm^{2,}$ respectively. The control site recorded 200cm, 100cm, and 15707.96 cm^2 of leaf length, leaf breadth, and leaf area, respectively (Table 1) (Figures 2, 3, and 4).

Discussion

From the results shown in Table 1 (Figures 2,3, and 4), there are variations in the respective leaf length, leaf breadth, and leaf area of the edible plants investigated. The result has shown that the highest values of leaf length, leaf breadth, and leaf area were recorded at the control site. However, quarry sites show values that slightly vary. Morphological

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changes in leaf length, leaf breadth, and leaf area were observed in their values. The study shows that the values of the leaf length, leaf breadth, and leaf area in the control site are higher than in the quarry site, which is polluted. Shradhanjali, et al. (2016) reported that a reduction in leaf size and length could be due to dust deposition because of the plant's proximity to industrial areas. The study has shown that there is a negative impact of quarrying activities on the morphological features of tree plants, especially in terms of the length, breadth, and area of leaves. This is concisely expressed by the values recorded at the quarry sites and the control site. The result has shown that tree plants with no or less exposure to quarrying are better off, as expressed in the recorded leaf length, breadth, and leaf area at the quarry and control sites. The impact of quarrying activities on the selected edible plants, resulting in reduced leaf length, leaf breadth, and leaf area at the quarry sites, could be attributed to the stress encountered as a result of the quarry operations and activities. Stress from the quarry operations or activities may be in the form of dust deposition from quarrying, which can settle on leaves, reducing photosynthetic efficiency and leading to smaller, stunted leaf growth. Also, water and nutrient stress due to quarrying activities lead to disruption of soil and water availability, which can reduce the plant's ability to grow fully, limiting the leaf's length due to reduced nutrient uptake. Exposure of the tree plants to pollution such as heavy metals could inhibit normal leaf elongation, leading to shorter leaf length. Quarry dusts accumulate on leaves, reducing or hampering photosynthetic activities, leading to narrower leaves, as the plant allocates fewer resources to broaden them. The altered microclimate due to quarrying activities results in changes in temperature and wind conditions, which might influence the leaf's expansion, leading to smaller and narrower leaves. Quarrying activities lead to the overall reduction in leaf areas, as the tree plants experience stress from poor soil conditions, limited water, and reduced nutrient availability. Tree plants may also produce leaves with a smaller surface to minimize exposure to stressful conditions such as dust and pollutants.

The stress from quarrying might cause plants to adjust their leaf area as a survival mechanism, reducing the total leaf area to conserve energy and resources. The harsh conditions introduced by quarrying activities tend to reduce all three parameters of leaf length, leaf breadth, and leaf area, especially at the quarry sites, resulting in smaller and stunted leaves. These research findings are supported and corroborated by previous works of several researchers. Prusty et al. (2005) found that dust deposition on leaves reduced photosynthesis and chlorophyll content, affecting plant growth. This supports the idea that dust from quarrying can reduce leaf length, breadth, and area. Singh (2016), in his research study, showed that there is a significant dust deposition impact on the morphology of leaves, including reduced leaf length and area in plants near cement quarries and factories. Also, Larbi et al. (2010) reported how soil degradation and pollution affect water uptake, causing reduced leaf size (both length and breadth), particularly in trees in urban environments affected by quarrying. Bharose (2017) examined the impacts of stone quarrying and associated pollutants on nearby vegetation and found reduced leaf length and area due to exposure to quarry pollutants, heavy metals, and particulates. Mishram and Niyogi (2017) reported how pollutants from quarries, particularly heavy metals, led to stunted leaf growth and reduced leaf area in affected plants. Also, Sharma and Singh (2014) posited that open-pit mining alters microclimates, leading to water scarcity and stress on vegetation, which in turn results in smaller leaf size. Zheng et al. (2017) submitted that drought stress, which can be caused by quarrying activities, affects water tables, resulting in reduced leaf area, length, and breadth as plants adapt to conserve resources. Donisa (2005), in his study, highlighted the effects of stone quarrying on vegetation, particularly through dust and water stress, leading to stunted plant growth and reduced leaf area. Prajapati and Tripathi (2008) demonstrated the negative effects of dust from industrial and quarrying activities on leaf size and morphology. This research study and the various submissions from previous research studies collectively show that quarrying activities affect leaf length, breadth, and area through dust deposition, soil degradation, water stress, and exposure to pollutants. However, the result of the statistical analysis (Both ANOVA and T-Test) at a 0.05 level of probability shows no statistical difference in the relationship between the leaf length, leaf breadth, and leaf area of the quarry sites and the control site. This may be due to the tested distant range (100-400 metres) of the edible plants from the quarry site, which may reduce impact, apart from the fact that the research study was carried out in the rainy season. Water or high humidity may reduce the severe or significant effects of quarrying activities on the plants

Conclusion

The research study examined the impact of quarrying activities on edible tree plants, focusing on examining quarrying influences on edible tree plant morphology in terms of leaf length, leaf breadth, and leaf area, which are critical for photosynthesis, plant growth, and health. The main finding was that quarrying activities were found to negatively

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impact the morphology of edible tree plants in terms of their leaf length, leaf breadth, and leaf area, resulting in their decrease. This consequently reduces photosynthetic activities of the leaves, resulting in stunted growth and smaller leaves. The research findings reveal that leaf morphology was affected, showing reduced leaf length, leaf breadth, and leaf area, which may likely impair photosynthetic capacity.

Recommendations

1. There is a need for the establishment of buffer zones with vegetation barriers between quarry sites and nearby forested (tree plant) areas to minimize the spread of pollutants and to protect the remaining biodiversity, especially the edible and economic tree plants.
2. The government should formulate better dust control policies, and quarry operators should implement these policies and devise control measures such as water sprinkling systems or dust covers to reduce the amount of particulate matter released into the environment.
3. Cultivation of pollution-tolerant species of edible tree plants with very high APTI in areas near quarries should be encouraged and promoted to ensure the survival of vegetation and reduce air pollution.
4. Government agencies, including organized private agencies and organizations, should raise awareness about the ecological impact of quarrying, and enforce stricter environmental policies and penalties for non-compliance with environmental protection standards

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