Volume 15, Issue 4, 152537 (1-7)

Journal of Rangeland Science (JRS)

https://doi.org/10.57647/j.jrs.2025.1504.37

Role of woody plants in dust absorption and identifying dust centers in Ahvaz city, Iran

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Original Research

Received:
13 February 2024
Revised:
19 June 2024
Accepted:
2 March 2025
Published online:
20 October 2025

Abstract:

Dust is an atmospheric phenomenon that has a negative impact on the environment. Less noticed, the dust particles cause respiratory and cardiovascular health problems in the citizens of western and southern regions of Iran. One of the actions could be to plant trees that are compatible with the climate of these regions. To investigate the role of woody plants in identifying and controlling dust centers, the leaves of four tree species (*Albizia lebbeck*, *Eucalyptus camaldulensis*, *Conocarpus erectus* and *Cordia myxa*) were sampled in four regions representing 9 geographical directions (center, main and secondary regions) in Ahvaz city, Iran. Leaf area and dust concentration were spatially analyzed in the laboratory for three seasons, i.e., spring, summer and autumn 2021. The Inverse Distance Weighted (IDW) interpolation method was used to map pollution. The results showed that *C. erectus* and *C. myxa* had the highest dust binding efficiency with average values of 1.066 and 0.976 mg/cm^2, respectively, followed by *A. lebbeck* and *E. camaldulensis* with average values of 0.290 and 0.478 mg/cm^2, respectively. The results of dust distribution zones showed that domestic dust sources were significantly high in the southwestern and southeastern regions with average values of 1.880 and 0.869 mg/cm^2, respectively. Planting trees such as *C. erectus*, *A. lebbeck* and *C. myxa* in urban environments was suggested as an efficient method for dust control in the region.

Keywords: Dust pollution; Woody Plants; Bio detection; Interpolation; IDW method

Introduction

Biodetection is considered a cost-effective and straightforward method to measure environmental pollution (Long et al., 2013). For numerous years, biodetectors have been utilized to assess the gathering and spread of contaminants in the environment, such as heavy metals and particulate matter. Biodetectors encompass tree trunks, rings, leaves, mosses, plants native to rangelands, and lichens for this purpose (Mussali-Galante et al., 2019). Contaminants are deposited on the leaf surface can further penetrate into inner tissues. Leaves with different shapes and sizes have different particle retention capabilities (Smith, 2012) and pubescent leaves had greater scavenging efficiency than hairless ones both for inorganic and organic contaminants (Howsama et al., 2000). In addition, the roughness and integrity of the plant cuticle affect particle adhesion on the leaf surface, and cuticular and epicuticular waxes play an important role in the sorption of lipophilic compounds in leaves (Ziv et al., 2018). The capability of foliage to accumulate contaminants has been used for years to study pollution effects both in forests (Rautio and Huttunen, 2003) and in urban areas (Salemaa et al., 2001).

In a biomonitoring study using tree species in urban habitats of the cities of Edirne, European part of Turkey, the urban roadside, city center, and suburban sites were investigated. The leaves and bark samples of *Aesculus hippocastanum* L. were collected from 20 sites. The results showed that the concentration of heavy metals in *A. hippocastanum* did not exceed the upper limit. A high linear regression was obtained for Lead (Pb), Zinc (Zn), and Copper (Cu) within concentrations of the element in surface soil and in the washed plant leaves. However, the correlation in

the case of Cadmium (Cd) was insignificant (Yilmaz et al., 2006). Another study investigated the leaves of two common deciduous trees, namely horse chestnut (*Aesculus hippocastanum*) and linden (*Tilia spp*.), in three parks within the urban area of Belgrade as biomonitors focusing on the assessment of atmospheric pollution through trace elements [Arsenic (As), Vanadium (V), and Cd]. The results showed that as and V were higher in horse chestnut than in linden, although both species may be used as biomonitors for these elements, and optionally for Cd in conditions of its high atmospheric loadings (Sucur et al., 2010). Tomasevic et al. (2011) investigated the content of some trace elements [Aluminum (Al), As, Barium (Ba), V, Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Cu, Zn, Strontium (Sr), Cd, and Pb] in leaves of four tree species commonly found in the urban area of Belgrade, Serbia. It was found that washing the leaves proved effective in improving the representativeness of leaf samples. Serbula et al. (2012) evaluated the same species *Robinia pseudoacacia* L. as a possible bioindicator of airborne heavy metal pollution originating from mining and pyro-metallurgical copper production in Bor, Eastern Serbia. Although it was present in high concentrations in the air and topsoil of the examined area, results showed that *R. pseudoacacia* was not a suitable indicator of environmental pollution based on Arsenic. Kumar et al. (2016) used inverse distance weighting (IDW), Kriging (spherical and Gaussian), and spline techniques for spatial interpolation of air pollutants. The interpolated results of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and Suspended Particulate Matter (SPM) were compared with air quality data of Maharashtra Pollution Control Board (MPCB) in the same region. A comparison of results showed that values predicted by IDW and Kriging corresponded well to observational data. Taghizadeh and Kazemi (2013) used the average accumulated metal concentration based on the international standard limit (FAO and WHO). They found that the fruit of cultivated mulberry trees in Arak, Iran, was contaminated by elements aluminum (Al), nickel (Ni), arsenic (As), cadmium (Cd), and lead (Pb) which was related to dust absorption by the fruit of these trees. The concentrations of Al and Cd were $3-6$ times and Pb 4 times greater than the permissible limits, meaning that they were not safe for consumption.

About 9% of the Khuzestan plain in Iran contains dust sources with seven dust hot spots (Dinarvand et al., 2023). Ahvaz as the capital of Khuzestan province possesses significant development resources. However, the Ahvaz city is currently experiencing a severe environmental pollution crisis due to various factors, notably the lack of a cohesive and interconnected culture among ethnic groups and their constructive interaction with the environment. This crisis has escalated in recent decades, leading to Ahvaz being labeled as the most polluted city in the world by the international media last year (Velayatzadeh, 2020). This study was aimed to investigate the surface absorption of dust particles by native woody plants to determine which species are most effective at trapping air pollution.

Materials and methods

Study area

The research covers 9 regions within Ahvaz city, Iran, including the center, four main areas, and four secondary geographical directions. Ahvaz is the capital city of Khuzestan province and spans an area of approximately 209 km^2, located between latitude 31.50°N and longitude 49.11°E (figure 1).

Research method

The present study's methodology consists of four stages:

1) Data collection through a systematic random sampling of tree leaves and determination of the coordinates of the sampled points;

2) Laboratory analysis to quantify dust absorption in terms of weight per unit area of the leaf surface;

3) Statistical analysis to examine the mean of sampling regions; and

4) Identification of dust concentration zones across the city through interpolation (figure 2).

In each region, four common woody plant species (*Eucalyptus camaldulensis*, *Conocarpus erectus*, *Cordia myxa*, and *Albizia lebbeck*) were selected. Three replicates from each species and four leaves from each replicate were taken in each region. The harvested leaves were separately stored in sampling containers and transferred to the laboratory. All samples were washed with double distilled water and dried in an oven at 70 °C for 24 hours. Then, the precipitate was weighed by a digital balance and the sampling containers were washed and reweighed after drying. The area of washed leaves was recorded using graph paper (mm). Sampling was repeated in three replications with an interval of three months in early summer, autumn, and winter.

In leaves of each tree, the dust absorption was measured in mg/cm^2 of leaf area. Finally, the estimated values were tabulated according to dust absorption per unit area of the leaf surface and geographical coordinates of sampling points using Excel software. Analysis of variance and mean comparison (Duncan's test) was performed on the obtained data from the accumulated dust per leaf area. After comparing different interpolation techniques, the IDW method was employed within a GIS environment to map out the distribution of dust particles.

Results

The analysis of variance was performed to test the effect of plant species, geographical direction, and sampling sites using Duncan's test to compare the mean values of dust absorption by the leaves of different plant species in different sampling seasons (Table 1).

The means of dust absorption by each tree species in three seasons is presented in Table 2. In spring, there was no significant difference between *Eucalyptus camaldulensis*, *Conocarpus erectus*, and *Cordia myxa* plant species in dust

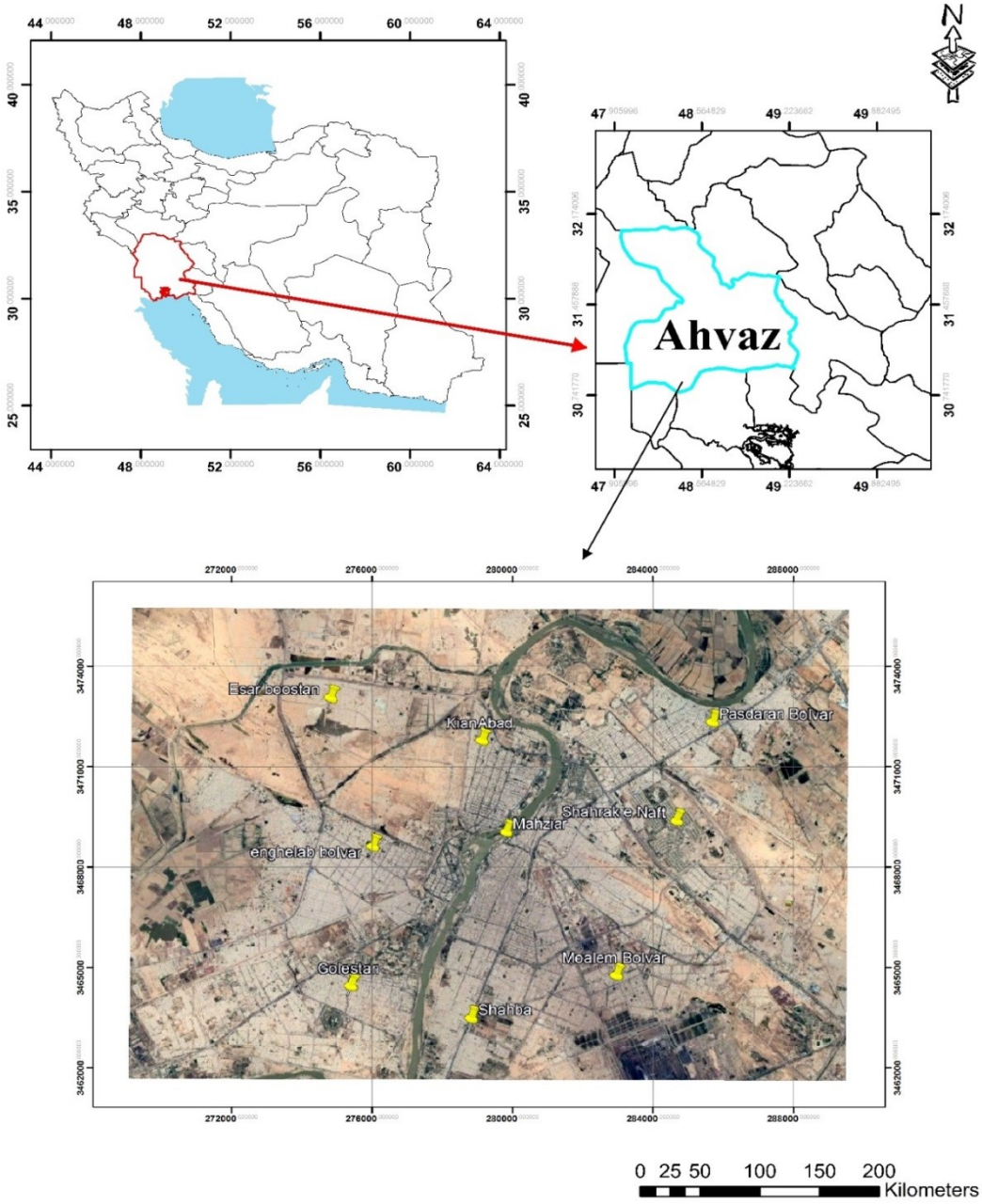


Figure 1. The location map of the study area, Ahvaz, Khuzestan province, Iran.

absorption. The highest and the lowest dust absorption, with values of 0.562 and 0.290 mg/cm^2, belonged to the *C. myxa* and *A. lebbeck* species, respectively. In summer, there was no significant difference between *E. camaldulensis* and *C. erectus*. The highest and the lowest dust absorption, with values of 1.157 and 0.976 mg/cm^2, belonged to *A. lebbeck* and *C. myxa* species, respectively. In autumn, there were significant differences between tree species. The highest and lowest dust, with values of 581 and 377 mg/cm^2, were absorbed by *C. erectus* and. *E. camaldulensis*, respectively. Meanwhile, there was no significant difference between *A. lebbeck* and *E. camaldulensis* species in the dust absorption rate.

In comparison among sampling sites, the highest dust, with values of 0.534 and 0.512 mg/cm^2 was absorbed by the plant species at Engelab and Esar Boostan regions (West and north-west of the city of Ahvaz), respectively. The lowest dust, with values of 0.349 and 0.368 mg/cm^2, was absorbed at Shahba and Sherkat Naft (East and South of the city of Ahvaz), respectively, on all tree species (Table 3).

The maps of dust pollution in Ahvaz city

Considering the amount of dust particles in the sampled sites in Ahvaz and comparing different interpolation techniques, the spatial distribution of dust pollution was mapped among the species for different seasons using the IDW method (figure 3).

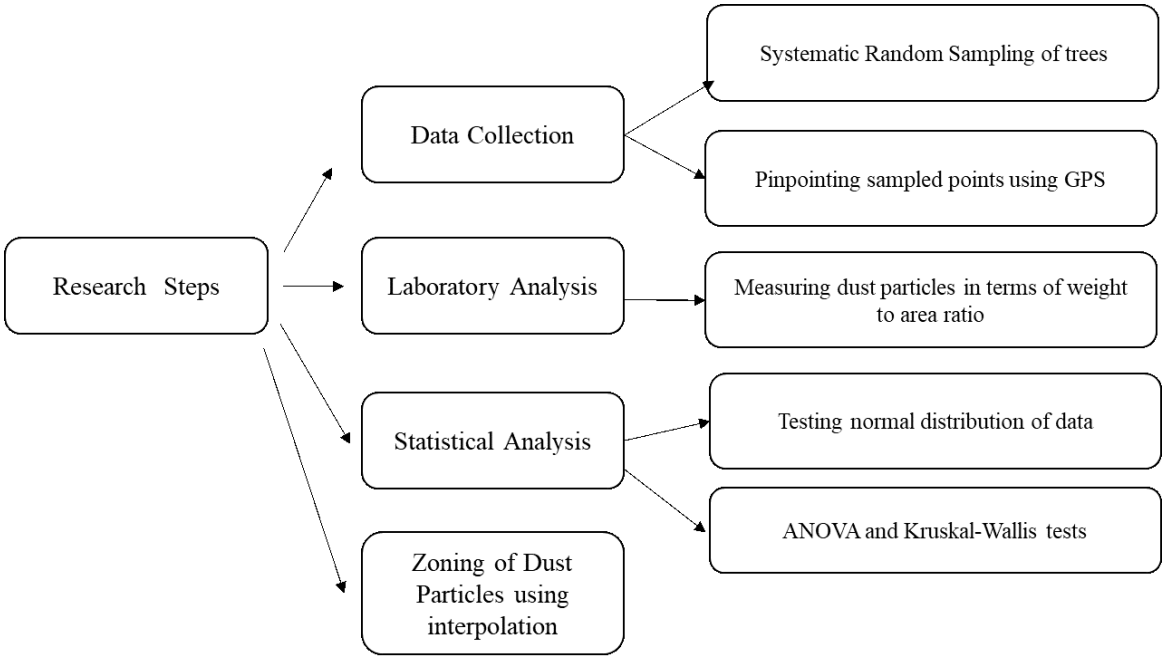


Figure 2. The implementation method.

Discussion

Recently, there is considerable interest in the physical and molecular basis of interactions between different plant species and their ecosystems. Abiotic stress factors such as oxidative pressure, temperature, toxicity, and salinity are major contributors to reducing crop yields and pose a significant threat to agricultural productivity (Raklami et al., 2021). Throughout their life cycle, plants are consistently exposed to adverse environmental conditions that have a detrimental

Table 1. Analysis of variance of the effect of plant species, geographical direction, and sampling site on the dust absorption by the tree leaves (Ahvaz, autumn).

Sources	DF	MS
Plant species (P)	3	0.227**
Sampling site (S)	8	0.044
Geographical direction (D)	9	0.087
P × D	9	0.004
P × S	24	0.027
D × S	24	0.006
P × D × S	72	0.006
Error	288	0.007
CV %		8.78

** = Significant at 1% probability level.

Table 2. Mean comparison of plant species in the dust absorption by the tree leaves in three seasons.

Plant Species	Dust Absorption (mg/cm^2)		
	Spring	Summer	Autmn
Eucalyptus camaldulensis	0.436^{ab}	1.066^{ab}	0.377^{c}
Cordia myxa	0.562^{a}	0.976^{b}	0.427^{b}
Albizia lebbeck	0.290^{b}	1.157^{a}	0.395^{bc}
Conocarpus erectus	0.478^{ab}	1.094^{a}	0.581^{a}

Means of column with the same letter are not significantly different using the Duncan 5% grouping method.

Table 3. The mean of dust absorption by the plant species in nine regions in autumn.

Ahvaz city	Geographical	Dust Absorption (mg/cm^2)				Region
Regions	Direction	*Eucalyptus camaldulensis*	*Cordia myxa*	*Albizia lebbeck*	*Conocarpus erectus*	Means #
Mahziar	Center of City (C)	0.342 b	0.400 b	0.467 b	0.617 a	**0.457 B**
Esar Boostan	North West (NW)	0.461 b	0.422 b	0.500 b	0.665 a	**0.512 A**
Enghelab	West (W)	0.491 b	0.559 b	0.339 c	0.746 a	**0.534 A**
Golestan	SouthWest (SW)	0.334 c	0.625 a	0.413 c	0.531 b	**0.476 B**
Shahba	South (S)	0.344 b	0.408 a	0.266 c	0.454 a	**0.368 C**
MoalemBolvar	South East (SE)	0.307 b	0.476 a	0.396 a	0.463 a	**0.410 B**
Sherkat Naft	East (E)	0.272 b	0.369 a	0.391 a	0.362 a	0.349 C
PasdaranBolvar	North East (NE)	0.423 b	0.430 b	0.386 b	0.624 a	**0.466 B**
Kianabad	North (N)	0.342 b	0.289 b	0.261 b	0.771 a	**0.416 B**
Mean		0.372 C	0.447 B	0.369 C	0.577 A	

Means of rows with the same lowercase letter are not significantly different.
Means of the last row and last column, followed by the same capital letters, are not significantly different.

impact on their growth, development, and productivity (Diaconu et al., 2020). Research aimed at assessing the dust trapping efficiency of various plant species revealed that *Conocarpus erectus* and *Cordia myxa* exhibited the greatest capabilities for capturing particulate matter compared to other species. These plants are endowed with unique morphological and physiological characteristics that enhance their dust-trapping effectiveness (Nawaz et al., 2022). Our findings indicated that the leaves of *Conocarpus erectus* and *Cordia myxa* achieved the highest dust trapping efficiency, followed closely by *Eucalyptus camaldulensis* and *Albizia lebbeck*. This highlights the importance of selecting specific plant species for urban environments to effectively mitigate dust pollution and improve air quality.

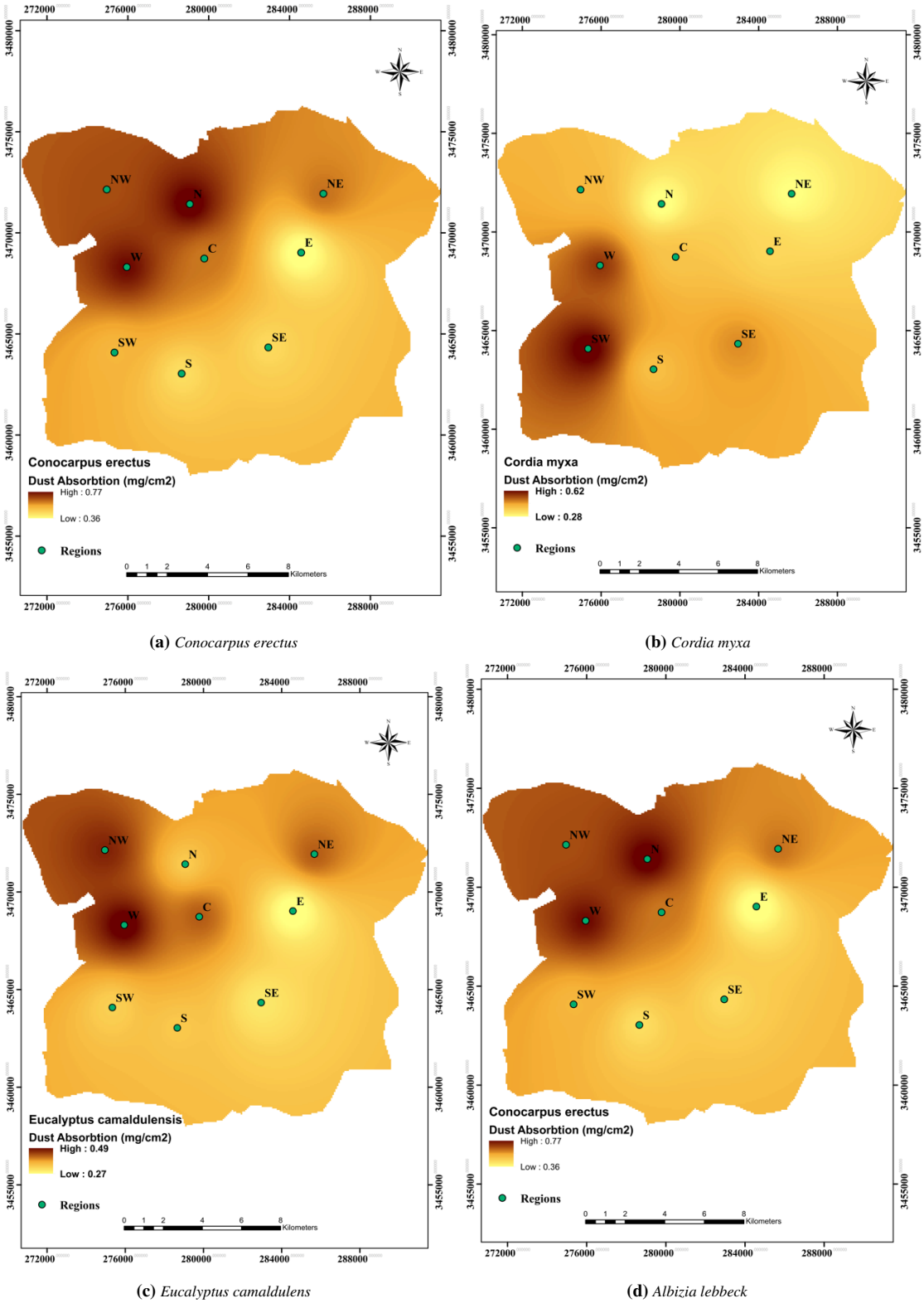
According to the zoning results, the highest dust trapping was observed for the surveyed species in the western, northwestern, southwestern, and southeastern regions of Ahvaz. Conversely, the efficiency of dust trapping was reduced in the central, southern, and northeastern areas, reaching its lowest levels in the northern and eastern parts of Ahvaz, which is consistent with Dinarvand et al. (2023). They find that approximately 9% of the Khuzestan plain is recognized as a dust source, featuring seven major hotspots. Their study, conducted from 2016 to 2020, focused on the types of vegetation, floristic composition, and phytogeography in these areas by collecting vascular plants. The Inverse Distance Weighting (IDW) interpolation method was used to map the spatial distribution of dust pollution. The Inverse Distance Weighting (IDW) interpolation method is widely utilized in various fields, including environmental science, agriculture, and geology, for spatial data analysis. This method is based on the principle that the influence of a known point decreases with distance, allowing for the estimation of values at unmeasured locations based on nearby observed points (Dinarvand et al., 2023).

Conclusion

Overall, it was concluded that bio-detection is a valuable approach for assessing urban dust, offering the advantages of being cost-effective, fast, and non-destructive compared to other methods of air pollution measurement. Consequently, the cultivation of *Conocarpus erectus*, *Cordia myxa*, and *Albizia lebbeck* species in urban environments is recommended, as these plants serve as a canopy over the city, effectively trapping dust pollution.

In this research, the highest efficiency in trapping dust was observed in the leaves of *Conocarpus erectus* and *Cordia myxa*, with average values of 1.066 and 0.976 mg/cm^2, respectively, followed by *Albizia lebbeck* and *Eucalyptus camaldulensis* with values of 0.290 and 0.478 mg/cm^2, respectively. Based on the zoning results of the dust distribution, it was observed that local sources of dust greatly affect the southwestern and southeastern regions with values of 1.880 and 0.870 mg/cm^2, respectively. Tree planting was recommended for species such as *Conocarpus erectus*, *Albizia lebbeck*, and *Cordia myxa* in urban environments to trap air dust and pollution. Because the prevailing wind direction of Ahvaz City is from northwest to southeast, it can be expected that dust accumulation is high in the southeast. The zoning results also showed that the accumulation of dust in the southeast with high values, and it was concluded that the internal centers of dust have been effective in these areas.

Acknowledgment
The authors gratefully acknowledge the financial support for this work that was provided by Arak University.



(a) *Conocarpus erectus* **(b)** *Cordia myxa*

(c) *Eucalyptus camaldulens* **(d)** *Albizia lebbeck*

Figure 3. The maps of dust distribution on the leaf surface of samples in autumn in Ahvaz city. Full name of Ahvaz city regions and geographical directions are presented in Table 3.

Authors Contributions
All authors have contributed equally to prepare the paper.

Availability of Data and Materials
All available and required data have been incorporated in the manuscript.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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