The role of street and park trees to CO₂ removal and improving air quality and climate in urban areas in Najaf (Iraq)

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Abstract. The aims of this research is assessing ecosystem services and helping to integrate the multiplicity functions of urban ecosystems into city planning and management processes. Among the important impacts of trees in gardens and streets in removing CO₂ and improving air quality and climate, In the center of Al-Najaf (Iraq). This study included realistic statistics and was incorporated into a modified program (ITE Eco Model), where the trees were inventoried. Then assess the status of trees and the variation in tree types and use this information in the assessment of environmental services. According to this study, it is recommended to increase park areas and care for trees and not to cut them from the point of view of ecosystem service, according to the key to the ecosystem of afforestation.

Keywords: Urban Environment, Trees, Carbon Removal, Najaf, Iraq

1. Introduction

Global climate change and rapid population growth have put people in a great challenge to develop different coping strategies, mitigate climate conditions and create a healthy urban environment. The most important of these strategies is to conserve plants and increase green areas, especially trees and avoid cutting. Because the benefits of vegetation are improving the quality of population life by means of thermal and moisture regulation and increase the shade area. Remote sensing and field and statistical study contributed significantly to solving environmental problems [1]. It is also scientifically proven that urban trees modify the climate characteristics of the city and air quality, and reduce the impact of wind [2]. In addition, trees add to the city the values of beauty and sophistication and improve the psychological state of the population [3]. Several important international policy documents, such as IPBES (IPBES), refer to this platform and urge States to follow it. [4]. There is a strong correlation between the assessment of environmental services related to climate and air quality in urban areas and between population health and urban planning. Such as focusing on the population comfort by mitigating
the impact of heat [5]. Also, the importance of the greenhouse gas removal service, especially carbon, has a direct impact on human health, and air pollutants can be directly linked to certain diseases and deaths [6]. In addition to the main vegetation type and species characteristics, the services provided by some ecosystems are strongly influenced by the intensity of land management. Assessing and modeling these impacts is at the center of recent research on ecosystem service[7]. This approach has become more important in the case of urban tree stands as well. Some important management questions are: How long should the rotation cycle be in the case of urban tree groups? What type of tree maintenance should be used to maintain the highest possible tree delivery capacity? There are some published results aimed at comparing different age-grouped trees that are managed differently, especially from the United States [7 and 8]. As a result of all the above, an inventory of the trees was carried out within the measurement of a particular stalk and an estimate of the environmental services and cost for all trees. 

Analyzes refer to a census of trees was conducted in four areas in the center of Najaf (Iraq). The study included two objectives: first, to verify the importance of urban trees from the perspective of two services, carbon sequestration and storage, given the climatic conditions in the Middle East. This was achieved by adapting a target model (i-Tree Eco = ITE). The other objective was to assess the ability to provide services to various types, with respect to their general situation. The data is fully stored and is necessary for comparison. This information assesses the environmental status of trees in the city and their ability to improve public health, improve air and assess the actual value of trees.

2. Methodology

2.1. Najaf Governorate (studied areas)

It is one of 18 Iraq provinces of the Middle Euphrates and located in the line of length 44 and latitude 32. The center is Najaf city. A province of great religious and historical character because of the presence of many Shiite Muslim shrines, The Valley of Peace Cemetery and the Kufa Mosque. The population of the province is 1,500,522, according to the 2017 census [9]. Due to the city's limited size, thermal insulation is concentrated pollution sources. The study area is characterized by the presence of radial streets branching into small branches with central control, its the main area of this investigation. There are four districts area. 1288 trees were counted, mainly located in the tree lines, while the rest are parking lots in the squares. About two-thirds of the trees are protected (under local municipality regulation), Is that in alleyways protected from banned trees, trees can be cut down and replaced only accidentally, because of "poor condition" or for safety reasons. In this study, trees of approximately the same age were located, located in similar urban morphological areas representing the distinctive urban environments in downtown Najaf, which are considered "distinctive" by the administration. These areas are (Corniche Street, main street trees, Najaf sea trees and park trees). (Fig. 1)
2.2. Methods of data collection

The data was collected by conducting a full census of trees in the field, produced during the vegetation period of 2017 and 2018, with the application of the ITE model protocol (i-Tree, 2017). Photographing features of streets and parks in the study area is also required. The tree height, the vegetative growth base (crown) height and diameters were measured. The percentage of lost branches and lost canopy is also calculated to assess the condition of trees and adjust the area of the falling data and biomass, by dimensional measurement equations [6]. Percentages are repeated and data are calculated and estimates of missing ones are repeated at 5% intervals in the field. The growth of a particular individual is corrected using exposure data (CLE) which means the number of trees sides receiving sun but not exceeding the maximum 5. Data was collected, collected and stored from the field to the Green Environment Program, developed in Iraq specifically for urban tree records that can store the ITE dataset. From Green formatic, then process the data into MS Access format.

2.3. The ITE model

The broadest and most appropriate use internationally is ITE model (UFORE - Urban Forest Effects Model) (i-Tree Eco, Streets, Hydro, Design). It is a collection of units dealing with environmental services related to air quality and urban pollution. Environment. Typical calculations are based on the growth correlation between relevant ecosystem service indicators (amount of biomass and area of departure) and size measurement parameters for trees. The Characteristics of urban trees (leaf area, canopy size, tree condition, etc.). The state of the tree is calculated on the basis of the ratio of dead branches to total branches (excellent: < 1%, good: 1-10%, fair: 11-25%, poor: 26-50%, critical: 51-75% 99%). The second part of the study includes estimates for ecosystem services. ITE model should be modified for use in Iraq (Najaf Governorate). Basic geographic data, tree species growth information in the study area, local meteorological and air data must be collection. The overall climate characteristics
of the region affect annual growth rates, while high-precision meteorological data are needed to calculate the precipitation speed of pollutants. Meteorological data were obtained from the Najaf Meteorological Station (managed by the Meteorological Department of the Ministry of Transport). Air pollution removal of gas (CO) was calculated using air pollutant devices in the Department of Ecology / Faculty of Science. The above data (together with the inventory of trees) were then collected and coordinated data. The actual value of carbon sequestration was calculated based on carbon social cost data [9], while atmospheric decontamination was estimated using country-specific external values. Since these values existed only in previous years, the values were converted to the school year using PPI for the following years [10].

3. Results
The results showed the structural characteristics of Najaf city center (Iraq) and two environmental services. After describing the trees, their distribution and their ability to purify the environment

3.1 Tree planting systems

3.1.1. Total tree systems studied
Total tree data in Najaf city is characterized by a great diversity of species: exactly 100 species can be found in this region, which is estimated at about 2 km², and the proportion of trees that Iraq is home to (44%). The ten most common species reach 75% of entire urban trees (975 individuals, Table 1.). Most species have a dominant size (Table 1). Trees, which were counted by a large diversity but numbered less than 10 individuals, and this is the result of replacing previously planted individuals with new species. (Fig. 2). *Conocarpus erectus* prevails over the other species in the number of trees (168), the highest canopy (49,697.40 m² and the largest leaf area (129,455.50 m²).

While *Ficus* spp. The lowest number (42) and the lowest canopy. plant *Washingtonia filifera* (2014.90) m² and the plant *Dodonea viscosa* was the least leaf area (1567.10) m².


| Species               | Number of trees | Canopy cover (m²) | Leaf area (m²) | Avg. dbh (cm) | Std. dev. of dbh |
|----------------------|-----------------|-------------------|----------------|---------------|-----------------|
| *Conocarpus erectus* | 168             | 49,697.40         | 129,455.50     | 53            | 5.2             |
| *Eucalyptus spp*     | 143             | 9,080.00          | 26,249.40      | 38.4          | 6.7             |
| *Phoenix dactylifera*| 89              | 24,635.10         | 65,252.70      | 57.5          | 8.6             |
| *Acacia spp*         | 98              | 13,210.40         | 51,215.20      | 26.2          | 11.5            |
| *Bogainvillea spp*   | 120             | 3,375.10          | 29,355.90      | 28            | 11.1            |
| *Dodonea viscosa*    | 89              | 7,097.50          | 1,567.10       | 12.4          | 6.7             |
| *Nerium oleander*    | 76              | 6,119.10          | 17,978.80      | 27.2          | 3.9             |
| *Ziziphus spina-christi* | 83          | 4,164.10          | 10,737.50      | 36.2          | 6.8             |
| *Washingtonia filifera* | 67             | 2,014.90          | 23,547.90      | 45.3          | 12.9            |
| *Ficus spp*          | 42              | 2,216.10          | 8,807.00       | 351           | 10.9            |
3.1.2. Structural features of trees and their relationship to different management systems

For the purpose of assessing the various trees and their role in the ecosystem, it is necessary to study their main structural properties in Table 2.

The trees on Corniche Street have the largest of the samples, with an average dbh of 53.7 cm, the highest value in total urban trees. While the number of trees on Corniche Street is higher than the rest of the studied areas, the values of the dead branches are 12.8% and the (missing canopy) 4.6% is much lower than the city averages (33.3% and 33.5%). Due to its homogeneous protection and management.

The lowest values were in the park trees and this is due to the small total area of the parks, and is bounded by buildings from two floors to three floors. Despite the small space, the trees consist of large individuals. The amount of leaves area is considerably low, compared to the real average dbh of individuals. This is linked to the fact that the average percentage of lost crown value is very high (35.2%), and the average decline in the crown (26%) is also higher than the average total urban trees.

| study area          | Average dbh (cm) | Total leaf area (m²) | Average percent of missing crown (%) | Average percent of crown dieback (%) | Number of trees |
|---------------------|------------------|----------------------|---------------------------------------|--------------------------------------|-----------------|
| Corniche Street     | 53.7             | 49,805.50            | 12.8                                  | 4.6                                  | 387             |
| main street trees   | 43.8             | 24,374.20            | 33.3                                  | 33.5                                 | 378             |
| parks trees         | 41.4             | 9,033.20             | 35.2                                  | 26                                   | 97              |
| Najaf sea trees     | 12.1             | 866.3                | 2.6                                   | 1.5                                  | 113             |

The status of trees has a significant and influential role in the evaluation of the vegetative community and the total leaves area. However, in general, the plants studied can be termed good in terms of their health. Most individuals are classified as “excellent” or “good”
categories. This is partly due to the optimal choice of planted plants and for proper management where unsafe trees are replaced by correct ones. However, significant differences between species can be seen from the point of view of the status of trees, which strongly affects the amount of services provided. For example, *Conocarpus erectus* and *Eucalyptus spp.* trees are in good general condition (only 10% and 18% of individuals are in bad or worse condition). In contrast, large parts of the plant of two local varieties of *Washingtonia filifera* and *Ficus spp.* were classified into the “worst” health categories.

![Figure 3: Tree conditions in the populations of the ten most common species](image)

### Figure 3: Tree conditions in the populations of the ten most common species

#### 3.2 Provide ecosystem services

**3.2.1 Improve air quality by trees**

Differences in size distribution are determined mainly by differences between species in carbon sequestration and storage capacity. *Conocarpus erectus, Eucalyptus spp, Phoenix dactylifera* and *Acacia spp* can be distinguished by extremely high annual isolation, which can reach 60% or more for larger individuals, more than one third of the total carbon stored from the studied urban trees. This is directly proportional to (leave area which depends on primary production). However, in some cases, the health status of the species leads to slight differences. For example, *Bougainvillea spp, Dodonea viscosa, Nerium oleander* and *Ziziphus spina-christ* plants obviously have a relatively small leaf area compared to carbon storage capacity (Fig. 4). The area of the leave is the ecosystem indicator for the quantitative assessment of environmental service.
Figure 4: The share of the ten most common species in the whole leaf area and in the amount of stored carbon

3.2.2 Comparison of environmental services of studied trees
Table 3 shows the environmental services provided and their economic value for the four locations. Administrative interventions affect the results of the similarity of streets and gardens in the number of trees, but because of the distribution of sizes they differ in part. Corniche Street outperformed the rest of the studied areas in the case of carbon storage and sequestration 2092.10 kg/tree and 56.7 kg/year respectively, and also in economic values where the value in dollars, $ 1/year and 6.2 $ /year per tree. Despite the high percentages of the average lost canopy and dead branches on the main street, air decontamination appeared to be much lower than the trees in the rest of the areas. The values of carbon sequestration and decontamination of air on Corniche Street can be seen more than the main street trees. Differences in the economic value of services can be between $ 2 to $ 5/year per tree. Trees in the Najaf Sea and parks showed the lowest values compared to the rest of the regions, the total amount of carbon stored in the park trees, 5.7 kg/tree and the total carbon consumed 1.7 kg/year worth $0.01 and the rate of removal of 8.5 g./year per tree.

Table. 3 Ecosystem services provided by the investigated stands, by diameter class (cm).

| studied aeras         | Average carbon storage per tree(kg) | Average carbon sequestration per tree (kg/yr) | Average value of carbon sequestration per tree ($/yr) | Average removal amount(g/yr) | Average removal value per tree($/yr) |
|-----------------------|-------------------------------------|-----------------------------------------------|-----------------------------------------------------|-----------------------------|-------------------------------------|
| Corniche Street       | 2,092.10                            | 56.7                                          | 1                                                   | 1,490.30                    | 6.2                                 |
| main street trees     | 1,450.90                            | 32.8                                          | 0.6                                                 | 402.6                       | 1.5                                 |
| Najaf sea trees       | 723.8                               | 24.3                                          | 0.4                                                 | 669.3                       | 2                                   |
| parks trees           | 5.7                                 | 1.7                                           | 0.01                                                | 8.5                         | 0                                   |

4. Discussion
The structural characteristics of Najaf's urban trees are similar to structural characteristics of urban trees in East and Asian cities. Foreign species were found to be 50% or more, and this is also recorded in other cities, where ITE analyzes were performed e.g. [12 and 13]. It was also found that nonnative species are better adaptive to local environments than original species. The case of studied trees and may lead to improved capacity to provide ecosystem services as well as high diversity in a relatively small area. The choice of urban species and the structure of the parks depends on the features of ownership, policy of trees selection for municipal administrators and high diversity of tree species in Najaf urban environments led to a great diversity of environmental services. All of this led to different production capacities in different species. ITE system can handle this, where the analogue equations of hundreds of native species are stored on different continents, in the model's database of species. The units used in this study are adaptive to use in different countries and in different climatic zones. The species were compared (had smaller weight) of certain to the number of trees is mainly the result of size distribution. The status of individual is calculated by the ITE program, and the status of trees of the "good" and "excellent" status has been assessed as well as in ITE program [14]. The percentage of canopy and dead branch in crown use to classify state of trees, due to "poor", "critical" and "death" features are called in case of dead branches exceeds 25%. This happens very rarely, and in that time the municipalities cut dead branches or remove hole tree. This study showed the "worst" case of two species (Washingtonia filifera and Ficus spp.), in urban trees in downtown Najaf. Can use this information for species selection, indicating their low tolerance in urban areas, and larger need for more specific studies of this plants. While, the good state of growing plants (Conocarpus erectus, Eucalyptus spp, and Phoenix dactylifera contribute to the high leaf area, a common species grown mainly in Iraq and many countries in Asia. Good adaptation to urban conditions and the success of these species confirms that environmental services are linked to them [15]. In the analysis of urban trees in Toronto, the success of the species indicates their efficiency in capturing and storing carbon and decontamination of air. Thus, this type may be suitable for urban agriculture in the climatic conditions. It is worth mentioning that cities have a large variation in the level of air pollutants among themselves as well as in the same city every hour. The results obtained are comparable to those of [16], obtained from Zürich (Switzerland) using ITE Eco, and [17] by Bolzano (Italy). The ecosystem service of carbon sequestration by trees in a small, medium-sized Asian city compared to total GHG emissions is relatively good And improve the environment by giving far greater benefits than financial benefit. The health status of Najaf is statistically related to air pollution. This is very powerful in improving air quality and environmental status in general, which is especially important in city centers. The low values of the lost and returned canopy of Corniche Street trees are the result of tree protection during infrastructure development projects in previous years. In contrast, on the main street, huge parts of the crowns were cut. During the interest in the construction of cities more than attention to green spaces. The lack of interest in parks as their areas are very small compared to the number of residential neighborhoods in Najaf led to a deterioration in services and revenues from trees, which may also be expressed in economic value. Clearly, newly planted small trees cannot regulate the local climate as efficiently as large trees with a large leaf area. These streets continue to suffer from the severe impact of heat in the summer and for several years to come. The aesthetic value, great feeling and belonging of the place are actually associated with big trees. These observations indicate that complete tree changes are not recommended in view of ecosystem services.

5. Conclusions
It was concluded from this study that the diversity in tree planting and protection enables to serve the environment. Large trees are better able to improve air quality and yield more money. ITE was used after its development and this is the first assessment of the service of an individual tree-based ecosystem in Iraq according to the number of trees. To assess ecosystem services, this helps improve climate and air quality. Meteorological data collected by the National Meteorological Service, and carbon content data in the air, collected in a satellite measurement system were used and publicly available. This study opens the door to other studies. These studies can be conducted in other countries in Asia with the same evaluation process and adjustments can be made for other purposes, for example. Using the ITE model, there are many practical applications of this study (assessing the actual state of urban trees, assessing the effects of deforestation losses and reconstruction processes). In addition to these practical applications, a database can be used in many researches. Removal of biomass through pruning also affects ecosystem services. Successful and more adaptable species can be selected for the environment, so these analyzes may help formulate policies for the selection of urban tree species.

6. Recommendations

For the purposes of ecosystem services, it may be desirable to establish the largest possible base of cities in establishing and maintaining a tree database and analyzing ecosystem services similar to those presented in this study. As a result of the follow-up of the characteristics of plant species of different types, and follow the life cycles and efficiency of services and costs on the basis of conducting continuous statistics.

7. Acknowledgements

This work was supported by University of Kufa, Faculty of Science, Ecology Department.

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