

# Measuring Regulating Ecosystem Services for the Impacts of Global Climate Change and Air Quality Service in Wageningen Case Area

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**Abstract**—Wageningen is a city of some 38.000 people and is located in the province of Gelderland on the North bank of the Lower Rhine. In this research, Lower Rhine river and around which covers 75.16 km<sup>2</sup> within the boundaries of Wageningen city, has chosen as a research area. The aim of this research is to evaluate the contribution of the vegetation canopy formed by trees and tall shrubs to the regulating ecosystem services in terms of improving the air quality and the economic estimation of these contributions in research area. I-tree canopy v7.1 tool was used to perform to analyse within the scope of the research. 8 land cover types and their distributions were identified in the area and a total of 3000 points were randomly assigned for each class. As a result of the research, it has been estimated that the vegetation covering 16.03 % of the research area removes a total of 103.34 tons of pollutant gas and particles from the air, the carbon amount captured by the tree canopy annually is 13.490 tons, and the total carbon stored by the tree canopy is estimated as 338.840 tons. In this context, increasing the amount and quality of open-green areas in the selected region, protecting trees and tall shrubs and increasing their diversity, ecosystem services provided from these areas will also increase and contribute to the city economy in the future.

**Keywords**—Air quality, i-Tree canopy, Regulating ecosystem services, Wageningen, the Netherlands

## I. INTRODUCTION

The concept of ecosystem services was first used in the literature by Ehrlich and Ehrlich in 1981, based on [1] term "Natural Services". The most accepted definition of the ecosystem services concept was stated in the Millennium Ecosystem Assessment (MEA) report published in 2005 as 'benefits that people derive from ecosystems' [2,3,4]. Ecosystem services are handled in 4 main categories as providing, regulating, supporting and cultural services [2].

Regulating ecosystem services are benefits derived from natural processes controlled by ecosystems. Improvement of air and soil quality, climate regulation, mitigation of natural disasters such as floods and landslides, disease

control, water filtration, waste management, pollination, biodegradation or control of harmful species can be listed as regulating services [2].

Outdoor air quality are important to human health. The average 70 kg adult inhales about 20 m<sup>3</sup> of air per day [5]. Pollutants that cause outside air pollution are found in the atmosphere in the form of gas (C-carbon, NO<sub>2</sub>-nitrogen dioxide, O-ozone, SO<sub>2</sub>-sulfur dioxide) or particles (PM particle matter) [6]. Many groups of patients such as asthmatics, atopic patients, patients with emphysema and bronchitis, heart and stroke patients, diabetes, pregnant women, the elderly and children as especially sensitive to the health effects of outdoor air toxicants [7].

CO<sub>2</sub> has a significant effect on the increase in air temperature by creating a greenhouse effect in the atmosphere, and the increase in air temperature causes long-term climate change, negatively affecting plants and agriculture. The increase in the concentration of O<sub>3</sub>, which is one of the greenhouse gases, in the atmosphere causes respiratory and heart diseases in humans, and the closure of the respiratory pores in plants disrupts the photosynthesis mechanism, causing less carbon dioxide absorption and a slowdown in growth rate [8].

Measuring ecosystem services and air quality by using mathematical methods are very important in recent years [9]. I-tree canopy model used in this research is a tool that gives rapid results and is used in the calculation of regulating ecosystem services for improving air quality, which is a factor that significantly affects climate change, based on tree canopy. The results obtained from the model clearly reveal the data on the benefits of the trees and tall shrubs forming the canopy to the ecosystem [10].

In this study, it was aimed to determine the regulating ecosystem services for improving the air quality provided by the tree canopy available within the boundaries of the Lower Rhine region research area, where city, nature and culture coexist in the city of Wageningen and which is under the influence of intense recreational uses.

## II. MATERIAL AND METHOD

Lower Rhine river and around is chosen as a research area in Wageningen city, which covers 75.16 km<sup>2</sup> (Fig. 1)



Fig. 1: Location of research area [11]

Wageningen, Renkum, Randwijk, Zetten, Opheusden, Kesteren are urban landscapes; Historical Brick Factory,

Ironworks Ruins, Outbuildings are as historical and touristic landscapes, located in the research area (Fig. 2).



Fig. 2: A view of the research area (Original, 2021)

Within the scope of the research, I-tree canopy tool, which was developed by the Forest Service unit of the United States Department of Agriculture, was used to analyze the tree cover and to calculate the regulating ecosystem services provided by the tree canopy for the improvement of air quality. i-Tree Canopy v7.1 is a free web-based application tool that uses random point sampling and works in conjunction with Google MapsTM satellite imagery [12].

To calculate the tree cover and the monetary value for the research area, the free online tool i-Tree Canopy Version 7.1 in 2021 was also used. The boundary of research area ESRI shape files were imported into the i-Tree Canopy tool. A total of 3000 random points were interpreted for the research area.

8 land cover classes (Agricultural areas, Grass/Herbaceous, Impervious Buildings, Impervious Roads, Impervious Other, Soil/Bare Ground, Tree/Shrub, Waters) identified in research area and a total of 3.000 points were randomly assigned for each class (Fig. 3).

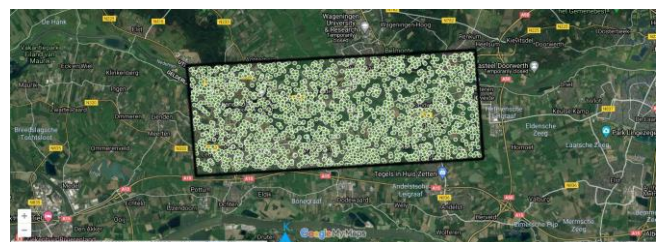


Fig. 3: Distribution of sampling points in the area

After the classes corresponding to the points were defined, the results were taken as a report on the same module.

### III. RESULTS AND DISCUSSION

#### 3.1. Land Cover Types of Research Area

8 different land cover classes determined as a result of the study carried out in the 75,16 km<sup>2</sup> research area, the number of sample points for each class, the area covered by each class in the district (%) and standard error rates (%) are given below (Table 1).

Table 1: Land cover types analysis with i-Tree canopy tool in the area

N o	Land cover types	Number of points	% Cover ± SE
1	Agricultural areas	1254	41.80 ± 0.90
2	Grass/Herbaceous	434	14.47 ± 0.64
3	Impervious Buildings	195	6.50 ± 0.45
4	Impervious Other	71	2.37 ± 0.28
5	Impervious Roads	205	6.83 ± 0.46
6	Soil/Bare Ground	100	3.33 ± 0.33
7	Tree/Shrub	481	16.03 ± 0.67
8	Waters	260	8.67 ± 0.51
	<b>Total</b>	3000	100.00

31.35 km<sup>2</sup> of which constitutes 41.8% of the research area is followed by agricultural areas, followed by forest areas consisting of trees and shrub vegetation with 12.03 km<sup>2</sup>. The least common land cover types in the study area are other impervious surfaces (1.78 km<sup>2</sup>), soil/bare areas (2.5 km<sup>2</sup>) and impervious buildings (4.88 km<sup>2</sup>).

The pollutants removed from the atmosphere and the carbon capture and storage amounts in one year by means of tree cover measurement in the research area with the i-Tree tool are given in Table 2. With a general evaluation, it was found that the tree cover removed a total of 103.34 tons of pollutant gases and particles from the air in the study area in one year. Among these, the annual amount of carbon captured by the tree cover has been estimated as 13,490 tons, and the total amount of carbon stored by the crown cover has been estimated as 338,840 tons (Table 2).

Table 2: I-tree canopy estimates and analysis results of benefits from crown canopy in the area

Pollutants removed from the atmosphere	Amount	±GD	Value (USD)	±GD
Carbon Monoxide removed annually	1.22 tons	0.05	114	5
Nitrogen Dioxide removed annually-	6.63 tons	0.28	196	8

NO <sub>2</sub>				
Ozone removed annually - O <sub>3</sub>	66 tons	2.76	10.220	427
Particulate Matter less than 2.5 microns removed annually - PM2.5	3.21 tons	0.13	21,126	883
Sulfur Dioxide removed annually- SO <sub>2</sub>	4.18 tons	0.17	34	1
Particulate Matter greater than 2.5 microns and less than 10 microns removed annually - PM10-2.5	22.11 tons	0.92	7.419	310
Carbon dioxide captured by woody plants - CO <sub>2</sub> seq (annual)	13.490 tons	0.56	691.787	28,904
Carbon dioxide stored by woody plants - CO <sub>2</sub> stor	338.840 tons	14.16	17.373.373	725,880

Classification of the sizes and densities of urban environmental components is important in terms of understanding the ecosystem dynamics in these areas and the services they provide. In this study, the annual economic value of the regulating ecosystem services provided by tree covering 16.03% of the selected sample area and aimed at improving the air quality was calculated as approximately 17 million USD (Fig. 4).

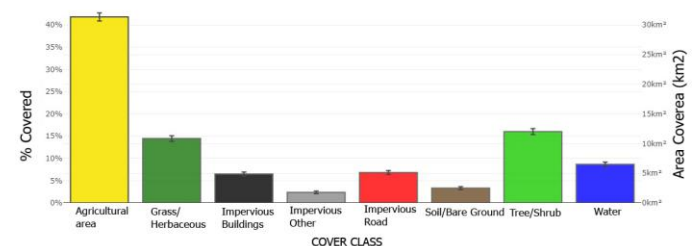


Fig. 4: Graphic of land cover and cover classes of the area

Some plant species commonly seen in open-green areas of Wageningen city are [13]; *Abies alba*, *Abies grandis*, *Acer campestre*, *Acer platanoides*, *Acer pseudoplatanus*, *Aesculus hippocastanum*, *Alnus glutinosa*, *Alnus incana*, *Betula pendula*, *Betula pubescens*, *Carpinus betulus*, *Castanea sativa*, *Chamaecyparis lawsoniana*, *Corylus avellana*, *Crataegus laevigata*, *Crataegus monogyna*,



*Fagus sylvatica, Fraxinus excelsior, Ilex aquifolium, Juniperus communis, Larix decidua, Larix kaempferi, Malus sylvestris, Mespilus germanica, Picea abies, Picea omorika, Picea orientalis, Pinus mugo, Pinus nigra, Pinus pinaster, Pinus strobus, Populus alba, Populusxcanadensis, Populus nigra, Populus tremula, Prunus avium, Prunus padus, Pseudotsuga menziesii, Prunus spinosa, Pyrus communis, Quercus petraea, Quercus robur, Quercus rubra, Salix alba, Sambucus nigra, Tilia cordata, Tilia x vulgaris, Ulmus glabra, Ulmus x hollandica, Ulmus minor.* With i-Tree tool, species distinction is not made by considering the tree cover of all trees and tall shrubs. With this method, statistical estimations are made regarding the air quality of the area and the economic value it provides [14]. This situation creates contradictions regarding ecosystem services and economic returns, but even if it is considered as a deficiency in determining real values, i-Tree and similar applications are very important in making planning decisions by making simple, short time and low-cost evaluations for large-scale studies applied in large areas.

#### IV. CONCLUSION

In recent years, ecosystem services provided by open and green spaces in urban areas have come to the forefront with their ecological and economic benefits in many studies. It is known that carbon dioxide and carbon monoxide gases are among the greenhouse gases that have the highest share in global warming. Forest areas have climate protection functions by protecting settlements, agricultural areas and recreational facilities from the harmful effects of cold weather and wind, extreme weather changes and improving the regional climate [15]. Among the studies on forests, especially in the determination of regulating ecosystem services, data such as age, height, distribution of vegetation are discussed. In this respect, it is very important to consider each plant species separately. In this sense, although I-tree canopy applications are criticized for not making a very detailed examination, it is an application that makes quick, easy and low-cost evaluations in large areas. In addition, this practice is criticized because it calculates data such as climate and vegetation according to the United States and brings a statistical standard [16,17]. However, it is stated that good results are obtained with the I-tree canopy application in many countries around the world. Countries such as Australia, Canada, England, the Netherlands, Switzerland can be given as examples to these countries [18].

The sensitivity increases as the number of points selected in the I-tree canopy application increases. To give an example from similar studies, a total of 1000 points were

defined in Florida, Atlantic Beach city study in which the tree cover was analyzed in the 33.6 km<sup>2</sup> [19].

Within the scope of this research, it has been determined that open and green areas, which constitute an important part of the research area, make significant contributions to improving the climate, air quality and therefore the economy of the city. It has been determined that the existing tree cover, which covering 16.03% of the total research area with 3000 points defined in the area removes a total of 103.34 tons of pollutant gases and particles from the air annually. The regulating impact of the ecosystem service is estimated to contribute to the economy at 17 million USD annually. [20] calculated in their study that Ege University Lodgings Campus made important contributions to improve the air quality and the wide and dense tree cover in the campus removed a total of 324.47 tons of harmful pollutants annually from the atmosphere and stored 8.107,86 tons of CO<sub>2</sub> throughout their lifetime, which is very important contribution to the city. [18], in their study conducted in 6 central districts of Aydın province, Efeler district, determined that the existing tree cover, which covers only 14.22% of the study area, removes a total of 2,851.98 kg of pollutants per year from the atmosphere and provides an estimated economic contribution of 3,741,791 Turkish Lira.

It is an undeniable fact that vegetation, especially in cities and regions close to cities, contributes to the regional economy by removing pollutants from the atmosphere, increasing the air quality, and increasing the amount and quality of green areas with each unit.

Forest ecosystems provide terrestrial carbon sinks by providing natural carbon retention with the amount of carbon they store in soil and plant (biomass structure). Accurate estimates of forest biomass carbon sinks can improve our understanding of carbon cycles and help in developing sustainable landscape planning and management policies in the face of climate change [15]. In this sense, it is extremely important to increase the similar studies that constitute the regulating services of ecosystem services and to integrate them into planning studies around the world.

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