A GIS-BASED STUDY TO ESTIMATE AND ANALYSE CARBON DIOXIDE EMISSIONS IN ODUNPAZARI DISTRICT OF ESKISEHIR

Master of Science Thesis

Creck Svonsky REVEGHE DASSI T.

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MASTER OF SCIENCE THESIS

Remote Sensing and Geographical Information Systems Program

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Anadolu University

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FINAL APPROVAL FOR THESIS

This thesis titled **"A GIS-Based Study to Estimate and Analyze Carbon Dioxide Emissions in Odunpazari District of Eskişehir"** has been prepared and submitted by Creck Svonsky REVEGHE DASSI T. in partial fulfillment of the requirements in "Anadolu University Directive on Graduate Education and Examination" for the Degree of Master of Science in Remote Sensing and Geographical Information Systems Program has been examined and approved on 26/05/2017.

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ÖZET

ESKİŞEHİR İLİ, ODUNPAZARI İLÇESİNDE KARBON DİOKSİT EMİSYONLARININ TAHMİN EDİLMESİ VE ANALİZİ İÇİN CBS TABANLI ÇALIŞMASI

Creck Svonsky REVEGHE DASSI T.

Uzaktan Algılama ve Coğrafi Bilgi Sistemleri Anabilim Dalı

Anadolu Üniversitesi, Fen Bilimleri Enstitüsü, Mayıs, 2017

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Küresel ısınma ve iklim değişikliği, her yıl atmosfere salınan artan karbon dioksit miktarı ile ilgili olarak, günümüzün iki önemli çevresel konusudur. Her ne kadar bu sorunlar dünya kamuoyunda kritik bir yere sahip olsa da ve iklim değişikliği üzerine çeşitli çalışmalar yapılmış olsa da atmosferdeki sera gazlarının yoğunluğunun kademeli olarak nasıl azaltılabileceğinin bulunması gerekir.

Bu çalışma Eskişehir ili, Odunpazarı ilçesindeki karbondioksit emisyonlarını değerlendirmeyi ve analiz etmeyi amaçlamaktadır. Bu çalışma şehir düzeyinde karbon emisyonlarını envanterlemek, analiz etmek ve haritalamak konusunda ilk çalışmadır ve önemli bir adımdır. Çalışmada Odunpazarı ilçe sınırları içinde bulunan mahallelerin 2016 yılında doğal gaz ve elektrik tüketimine göre CO2 emisyonları hesaplanmış ve haritaları hazırlanmıştır. Sonuç çıktılarını gösteren haritalar elde etmek için bir açık kaynak kodlu CBS yazılımı kullanılmıştır. Analiz için, AB Belediye Başkanları'nın iklim ve enerji için emisyon faktörlerine ilişkin AB Sözleşmesi kapsamları göz önüne alınmıştır.

Uygulanan hesaplama yöntemleri ile 2016 yılında Odunpazarı ilçesinde toplam 1235785.81 ton CO2 emisyonu, 2016 yılında kişi başı ortalama 3.33 ton CO2 emisyonu olduğu belirlenmiştir. Bu değer 2012 yılında ise tüm Eskişehir için 2.36 ton CO2 olduğu bilinmektedir.

Anahtar Sözcükler: Karbon Emisyonları, Küresel Isınma, İklim Değişikliği, CBS, Uzaktan Algılama, Odunpazarı, Eskişehir.

ABSTRACT

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Global warming and climate change are two major environmental issues of these days, regarding the increasing amount of carbon dioxide released into the atmosphere every year. Although it seems these problems have taken a critical place in the world public opinion and even though various studies on climate change has been carried out since, we still need to figure out how to gradually reduce the concentrations of greenhouse gases in the atmosphere.

This study aims to assess and analyze the carbon dioxide emissions in Odunpazarı district of Eskişehir. And this is a first and significant step to inventory and analyze carbon emissions at the city level. A GIS open source program was used to obtain several maps showing the outputs CO_2 emissions according to the natural gas and electricity consumption of each neighborhood in 2016. For the analysis, the EU Covenant of Mayors for Climate and Energy related to the emission factors, scopes and tiers was taken into consideration.

The results, regarding the applied calculation methods, was determined to be 1235785.81 ton of CO_2 emissions for Odunpazarı district in 2016, with an average of 3.33 ton of CO_2 per person in 2016 while this average was 2.36 ton of CO_2 per person for the whole Eskişehir in 2012.

Keywords: Carbon Emissions, Global Warming, Climate Change, GIS, Remote Sensing, Odunpazarı, Eskişehir.

RÉSUMÉ

UNE ÉTUDE BASÉE SUR LES SIG POUR ESTIMER ET ANALYSER LES ÉMISSIONS DE DIOXYDE DE CARBONE DANS LE DISTRICT D'ODUNPAZARI DE ESKISEHIR

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Le réchauffement et changement climatiques sont deux grands problèmes environnementaux auxquels nous devons faire face ces jours, surtout lorsqu'on voit la quantité grandissant de carbone rejetée chaque an dans l'atmosphère. Et bien que l'opinion publique mondiale semble avoir donné une place cruciale à ces problèmes, ajouté à cela les nombreuses études qui ont été menées sur le sujet, il reste encore à trouver comment réduire les concentrations des gaz à effet de serre dans l'atmosphère.

La présente étude vise à estimer et analyser ces émissions de CO_2 dans le district d'Odunpazarı de la ville d'Eskişehir, ceci étant un premier et non-négligeable pas vers l'analyse et l'inventaire des émissions de CO_2 au niveau des villes. Plusieurs cartes montrant les émissions de CO_2 en fonction de la consommation de gaz naturel et d'électricité de chaque quartier en 2016 ont été obtenues par l'utilisation d'un logiciel SIG libre. Le mouvement européen La Convention des Maires pour le Climat et l'Énergie, a été pris en compte dans l'analyse quant aux facteurs d'émission, aux cadres et aux niveaux.

Les résultats quant à la méthode appliquée ont donné des émissions de 1235785.81 tonnes de CO_2 avec en moyenne 3.33 tonnes par personne en 2016 pour le district d'Odunpazarı, comparé à 2.36 tonnes par personne en 2012 pour Eskişehir.

Mots-clés : Emissions de Carbone, Réchauffement Climatique, Changements Climatiques, SIG, Télédétection, Odunpazarı, Eskişehir.

STATEMENT OF COMPLIANCE WITH ETHICAL PRINCIPLES AND RULES

I hereby truthfully declare that this thesis is an original work prepared by me; that I have behaved in accordance with the scientific ethical principles and rules throughout the stages of preparation, data collection, analysis and presentation of my work; that I have cited the sources of all the data and information that could be obtained within the scope of this study, and included these sources in the references section; and that this study has been scanned for plagiarism with "scientific plagiarism detection program" used by Anadolu University, and that "it does not have any plagiarism" whatsoever. I also declare that, if a case contrary to my declaration is detected in my work at any time, I hereby express my consent to all the ethical and legal consequences that are involved.

....

Creck Svonsky REVEGHE DASSI T.

DEDICATION

I dedicate this document to my entire family that has always been present in the greatest moments of my life. I want them to find in this paper my gratitude for their love, their abnegation and all their sacrifices.

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My first thanks go to my supervisor Prof. Dr. Can Ayday, I want him to know how infinitely grateful I am for what he has done for me; for guiding me throughout this thesis and providing all necessary data and documentation about carbon studies as well as being available. His remarks and comments at every stage of this study were very rewarding.

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Finally, I will not omit to reserve a special acknowledgment to my friends, mates, acquaintances and all the very nice people I met here in Turkey. It was a real pleasure. They all participated in a certain way to my success and made it possible.

Dans la vie, on nous donne rien, c’est à nous de prendre !

(A man makes his own way. No one gives it to you. You have to take it.)

Les infiltrés (The Departed), Frank Costello

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ACRONYMS AND DEFINITIONS

ECI	Eskişehir Chamber of Industry
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
GRASS	Geographic Resources Analysis Support System
IPCC	Intergovernmental Panel on Climate Change
NDVI	Normalized Difference Vegetation Index
OIZ	Organized Industrial Zone
PCEDI	Per Capita Economic Development Index
PDI	Provincial Development Index
QGIS	Quantum Geographical Information System
TDFT	Technology Development Foundation of Turkey
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Fund for Population Activities
WMO	World Meteorological Organization

CHAPTER I

INTRODUCTION

1.1. Background

The consequences of an excessive and uncontrolled use of fossil fuels such petroleum, natural gas and coal, these last decades are the major threats to the environment. Accordingly, the most important problem we face today is climate change, which is mainly due to the global warming caused by the release of greenhouse gases, especially carbon dioxide. The main source of global warming is the increase in the density of greenhouse gases released into the atmosphere. Carbon dioxide, which is the most important of these gases, is released into the atmosphere as a result of the burning of fossil fuels to firstly meet the basic necessity of economic growth [1]; and secondly to provide energy (electricity, natural gas and coal, etc.) for supporting the residential, industrial and transportation sectors. As shown in the **Figure 1.1.**, the main contributors of carbon dioxide are principally human activity and environmental (natural) sources. Because there is no way to control emissions from natural sources, it is preferable to focus on emissions from human activity, that may be reduced.

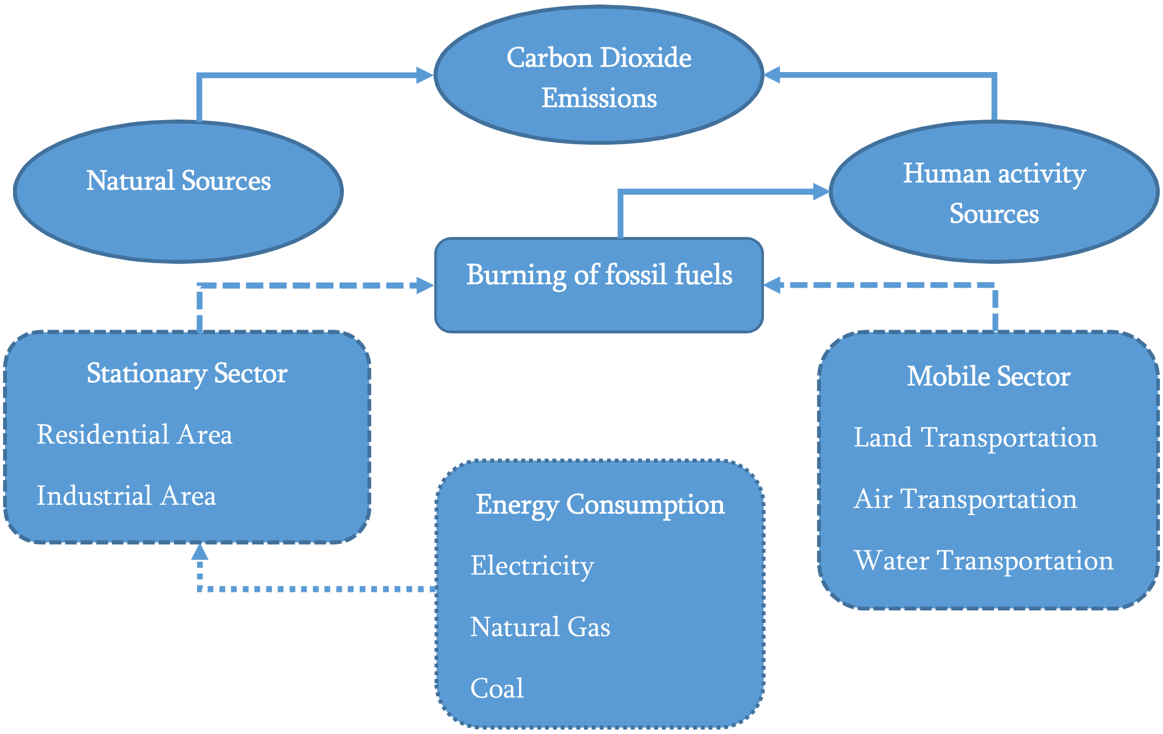

Figure 1.1. *Sources of carbon dioxide emissions*

1.2. Problem Statement

Global warming and climate change, which are increasingly influential nowadays, have been proven by scientific discoveries; even though there are many people that still wonder whether it is real. However, the facts and the data collected by these scientists leave no doubt as the planet is warming. In 2016, scientists from the Intergovernmental Panel on Climate Change (IPCC) carrying out global warming research predicted that average global temperatures could increase between 1.4 and 5.8 °C by the year 2100 [2].

In recent years, the problem about the danger of extreme temperature and lack of water of has been discussed in Turkey, but it has been put on the agenda by the World Meteorological Organization (WMO) a long time ago. At present, the evaluation reports published regularly by the Intergovernmental Panel on Climate Change reveal the scientific findings of the relationship between greenhouse gas emissions and climate change that are linked to human activities. These reports are widely accepted in the international community and in the scientific circles as the key references for global climate change in the world.

About global climate change, as a result of the decisive struggle of the related institutions, they are moved to the agenda of the society and a unity of understanding has been reached on a global scale. The solution to the problem is that the greenhouse gases emissions are controlled and their concentrations in the atmosphere are gradually reduced [3].

Today, cities are among the main sources of this problem because of their rapid population growth and high energy demands [4]. In October 31st 2011, the United Nations Fund for Population Activities (UNFPA) reported that the world's population approximate reached 7 billion people. And 50% of this population lives in cities. According to United Nations Habitat (UN-Habitat) data, about 75% of the world's energy consumption and 80% of global greenhouse gas emissions come from these locations. It is imperative that each country and city determine their own emission rates and take measures to ensure the sustainable energy consumption required for mitigation [4].

1.3. Objectives

First, this thesis focuses on techniques and methods to analyze and estimate carbon dioxide emissions from road traffic and housing energy consumption for the full 2016 year, at the level of Odunpazarı district of Eskişehir regarding to each neighborhood. A geographical information system (GIS) methodology using the open source QGIS software will be set and tested for calculating the energy consumption associated with distribution of electricity, natural gas; the associated CO2 emissions will be estimated based on the calculated energy consumptions. In addition to that, other calculations based on mobiles sources such as fuel type on the road traffic data will be made.

Second, this study aims to introduce carbon footprint and analysis based on carbon dioxide emissions, by combining methods derived from GIS and conventional methods.

Finally, using a computer-based component such as GIS technology along this project will benefit to:

- Make easy the identification of areas of high carbon emissions over the municipality;
- Produce information products such as maps;
- Provide georeferenced spatial data;
- Help decision-making for a better environmental policy.

1.4. Scopes

The main objectives mentioned above helped to define the scope of this study, which is to analyze and estimate carbon emissions distribution from the consumption of electricity and natural gas in the urban land use sectors of Odunpazarı district. Some utility consumption such as waste or water are not included in this study. In another hand, there are carbon emissions from land transportation; only emissions from road traffic were selected, which included personal cars, bus and trucks, according to the type of liquid fuel. Because of lack of time, it was very difficult to enclose air transportation neither water transportation to the limitations of this project.

The **Figure 1.2.** below, resulting from the application guide of the standard ISO14064 WD3 of March 2011, defined the 3 potential scopes.

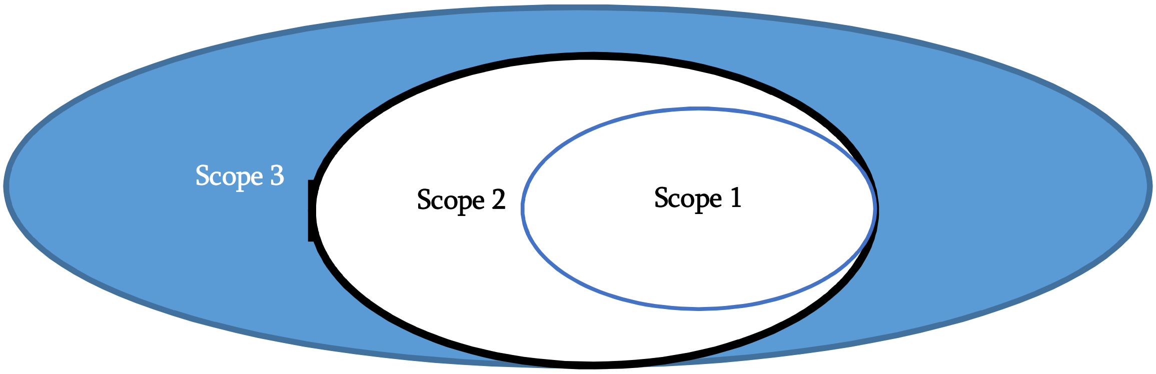

Figure 1.2. *Definition of the 3 potential scopes (ISO14064 WD3)*

The following **Table 1.1.** is an abstract of these 3 scopes, and show us that we will work throughout the Scope 1 and Scope 2.

Table 1.1. *Definitions of the scope of emissions*

Category of emission	Station of emissions	Example of emission sources
Direct sources of emission (Scope 1)	Direct emissions from stationary combustion sources	Combustion of energy from stationary sources
	Direct emissions from mobile thermal power sources	Combustion of fuel from mobile sources
	Direct emissions from biomass (soils and forests)	Biomass related to activities on land, wetlands or forest use
Indirect sources of emission related to energy (Scope 2)	Indirect emissions related to the consumption of electricity	Production of electricity, transportation and distribution
	Indirect emissions related to the consumption of steam, heat or cool	Production of steam, heat or cool, transportation and distribution
Other indirect sources of emission (Scope 3)	Waste	Transportation and treatment of waste
	Purchase of products or services	Extraction and production of material and non-material inputs not included in other stations
	Immobilization of goods	Extraction and production of tangible and intangible goods

CHAPTER II

LITERATURE REVIEW

This chapter will give background and answer some questions related to the necessity of estimating carbon dioxide emissions at a local level. There will be four sections in this chapter. The first section will talk about causes global warming and climate change; the second one will give an overview of the main sources of carbon dioxide emissions; the third one will concern the general economic structure of the Eskişehir province; and the last section will provide a summary of the perception of global warming and climate change by people of Eskişehir, as well as a similar study conducted for the whole city of Eskişehir in 2014.

2.1. Causes of Global Warming and Climate Change

Global warming is accelerated by natural causes as well as by human activities. Some of the gases emitted due to these activities may increase the greenhouse effect by performing a significant heat holding function even though they are found at very low rates in the atmosphere [5].

Global warming refers to an increase that can lead to climate change in the world's average temperature values, while climate change refers to the changes above or below the mean limits of meteorological values such as seasonal temperature, precipitation and humidity in a given area [6].

According to the United Nations Framework Convention on Climate Change (UNFCCC), Climate change means ‘‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods''. A second assessment report published in 1995 by the Intergovernmental Panel on Climate Change (IPCC), jointly conducted by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), found "a discernible human influence" on global climate change [7].

2.2. Main Sources of Carbon Dioxide Emissions

There are both human sources and natural sources of carbon dioxide emissions. Natural sources include decomposition, ocean discharge and respiration. Human sources come from activities such as cement production, deforestation and the use of fossil fuels, such as coal, oil and natural gas.

Due to human activities, the atmospheric concentration of carbon dioxide has increased considerably since the Industrial Revolution, now reaching dangerous levels, nonexistent during the last 3 million years [8]. Carbon dioxide emissions from humans are much lower than naturally occurring emissions, but they have disrupted the natural balance that has existed for thousands of years before the influence of humans.

The natural balance is due to the fact that natural carbon sinks eliminate at least the same amount of carbon dioxide present in the atmosphere as the amount of carbon dioxide produced by natural sources. Up to now, this mechanism has kept carbon dioxide levels in balance and within a safety margin. Nevertheless, human sources have disrupted this natural balance by adding carbon dioxide to the atmosphere without removing it [8].

2.2.1. Human sources

Since the Industrial Revolution, human sources of carbon dioxide emissions have multiplied. Human activities, such as the burning of oil, coal and gas, as well as deforestation, are the main causes of the increased concentration of carbon dioxide in the atmosphere.

Nearly 87% of human-made carbon dioxide emissions come from burning fossil fuels, such as coal, natural gas and oil. The remainder comes from forest clearing and other land use changes (9%), as well as some industrial processes, such as cement manufacturing (4%) [8].

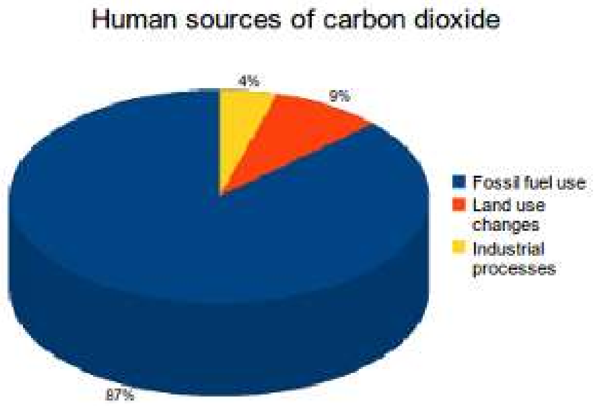

Figure 2.1. *Human sources of carbon dioxide* **[9]**

The most significant human source of carbon dioxide emissions comes from the burning of fossil fuels. This activity produces 87% of the carbon dioxide emissions from human sources. Combustion of these fuels releases energy, most of which is transformed into heat, electricity or fuel used in the transportation sector.

The three types of fossil fuels that are most used are coal, natural gas and oil. According to the website VotreImpact [8], coal is responsible for 43% of carbon dioxide emissions from fuel combustion, 36% is produced by oil and 20% comes from natural gas.

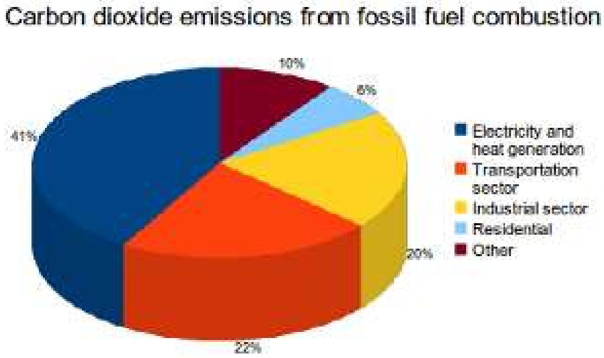

Figure 2.2. *Carbon dioxide emission from fossil fuel combustion* **[10]**

2.2.2. Human sources

In addition to being produced by human activities, carbon dioxide is also released into the atmosphere through natural processes. Oceans, soils, plants, animals and volcanoes are all natural sources of carbon dioxide emissions.

Human sources of carbon dioxide are much weaker than natural emissions, but they disrupt the balance in the carbon cycle, a balance that existed before the industrial revolution. The amount of carbon dioxide produced by natural sources is fully offset by natural carbon sinks, and has been so for thousands of years. Before the influence of humans, carbon dioxide levels were fairly stable due to this natural balance.

The IPCC report of 2007 estimates that, from all the naturally occurring carbon dioxide emissions, 42.84% originates from the exchange between the ocean and the atmosphere.

Other important natural sources of plant and animal origin include respiration (28.56%), soil respiration and decomposition (28.56%). A small amount is also derived from volcanic eruptions (0.03%) [8].

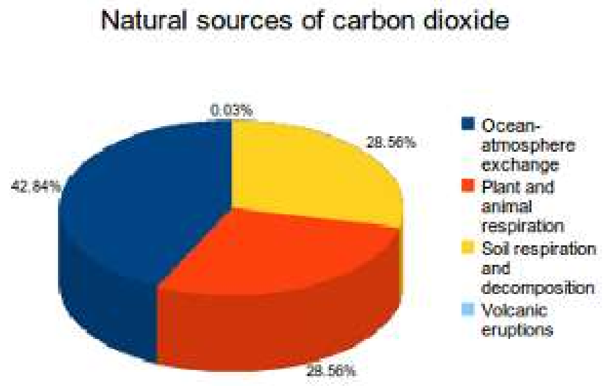

Figure 2.3. *Natural sources of carbon dioxide* **[11]**

2.3. General Economic Structure of the Eskişehir Province

Among 81 provinces in Turkey, Eskisehir ranks 7th with 2.87 according to Per Capita Economic Development Index (PCEDI). It is in the 22nd place with -0.3 in the Provincial Development Index (PDI) rankings [12].

In recent years, the most important share in the dynamism of Eskisehir's economic life is undoubtedly the industry. Rapid growth of urban population compared to rural population, qualified labor force, proximity to markets and availability of raw material resources, adequate infrastructure investment for the industry, ensuring that the region's industry develops gradually [13]. The Eskisehir Chamber of Industry Organized Industrial Zone (OIZ), which was established in 1973 as the result of planned investment of industrial investments in Eskişehir and importance of protecting the environment and modern urbanism concept, has been providing services to investors and businesses with large production and employment opportunities. If we look at the share of the sectors in the provincial economy, the Services Sector takes the first place with 60%, this is followed by the Industry Sector with 30% and the Agriculture Sector with 10%. Among the total industrial enterprises in the country, the industry is among the developed ones with a rate of 0.8%.

When the sectoral distribution of the industry in Eskişehir - one of the important industrial centers in Turkey - is examined, it is seen that not only a single sector but also many sectors which generate high value added generally show improvement. As well, three sectors of Eskişehir will also have a frontline and heavy structure over the coming years: Machinery Manufacturing and Metal Goods Industry, Aviation and Defense Industry, and Ceramics and Advanced Ceramics Industry [14].

A study was conducted by the Technology Development Foundation of Turkey (TDFT) and the Eskişehir Chamber of Industry (ECI) to determine the Eskişehir Industrial Zone Environmental Competency Level between 2008-2009. The step of environmental competence is the level of competence and knowledge that firms have about environmental issues. When the average level of environmental competence of 116 firms contributing to the work is taken, information/awareness and capabilities of the 1.63 value regional firms about these issues were obtained. The score corresponding to this step can be interpreted as the fact that the firms in the city are reactively approaching environmental issues and prefer to deal with more current problems. From this point of view, it is not possible to say that firms have a strategic and managerial approach in the environmental field.

2.4. Previous Works

2.4.1. Global warming and climate change perception of the Eskişehir people

A study has been carried out to determine in general how conscious the people of Eskişehir are against the global warming and climate change problem, which can overturn the experience in every level, especially consumption habits [15]. When the research results, analyzed by the field survey made for the people living in Eskişehir city center were evaluated, there was no doubt that people living in the center of Eskişehir was aware of the global warming reality in the world; but still, they did not have a sufficient level of awareness on the economic, social and political effects of the global warming problem. From this perspective, the most important factor on which to reach was then to ensure that awareness of individuals [16].

2.4.2. The impact of energy consumption in the Eskişehir city center on global warming and climate change: Carbon Footprint

As result of global studies on global climate change and climate change that are increasingly taking place in the world, it seems that a certain amount of understanding has been achieved in the world public opinion. And Turkey has recognized the importance of struggling with climate change. According to the recent figures, approximately 75% of the world's energy consumption and 80% of global greenhouse gas emissions are responsible of this global warming and climate change. The solution to figure out about the problem is to gradually reduce the concentrations of greenhouse gases, especially carbon dioxide, in the atmosphere by taking the shakes of the greenhouse gases under control [17].

Carbon emissions, which perturb the environment by causing global warming, is turning to an individual contribution or "carbon footprint". A carbon footprint is commonly defined as "the total amount of greenhouse gases produced directly and indirectly, by an individual, organization, event or product" and expressed as carbon dioxide equivalent [18]. It is usually measured by how much CO_2 you produce each year. It has become an indicator for sustainable development in numerous sectors.

The study conducted in Eskisehir provincial center made an inventory and analysis as a first good step in the reduction of city-based carbon emissions. Eskişehir provincial center aims to not reveal the carbon footprint based on the energy consumption of the year 2012; The energy consumption in the provincial center was determined to be globally **4 427 895,2** tons of carbon dioxide emissions. Among others **1 495 511, 4** tons of CO_2 for Natural Gas sector; **2 009 031,8** tons of CO2 for the Electricity sector; **653 468,8** tons of CO2 for the Liquid Fuel; and **179 883, 2** tons of CO_2 for the Coal sector. It is necessary to establish a model of sustainable energy action and carbon management through the achievement of the struggle with global warming in the Eskişehir scale, the appropriate targets to be determined according to the results obtained from this work, and accessible mechanisms. Handy results; While recognizing the global warming and climate change issues to the people of the city, opinion leaders and decision-makers, it is crucial to identify these problems and make sustainable development sustainable [17].

2.5. Geographical Information Systems

A Geographic Information System is a computerized tool to represent and analyze all the things that exist on earth as well as all the events that occur there[19]. GIS offers all the possibilities of databases (such as queries and statistical analyzes) and this, through a unique visualization and geographical analysis specific to the maps [20].

GIS technology can be used for estimating comprehensive land use related carbon emissions [21]. A review on the recent case studies reveals the applicability of geoinformation technology to the screening and analysis of emission sources, transportation and storage possibilities of CO_2 [22]. In addition, GIS can be utilized as tools to assess store locations in terms of CO_2 emissions from private cars used for consumer traffic [23].

In this study case, GIS will have the ability to be integrated with tabular data to produce the dispersion maps of CO_2 emissions in a selected area. In addition, calculations could be executed and it will be possible to analyze and compare the CO_2 emissions following defined geographical coordinates.

2.6. Remote sensing

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." [24]

The main reason to regard it as a science is because of the technique that is applied for it; it uses sensors in order to measure the quantity of electromagnetic radiation that leaves an object without touching the object and then extracts worthy information by using statistical and mathematical algorithms [25]. It is also an art because of the process of visual interpretation which needs experience gained through the lifetime of the analyst, in order to extract information from the images.

Remote sensing technology can be carried out at a global scale to observe vegetation and carbon cycle [26]. In addition, study involving the integrated spatial technology such remote sensing and geographical information systems has been conducted, as they are considered as a comprehensive tool for the quantification and evaluation of carbon pollution from crop [27].

2.7. Normalized Difference Vegetation Index (NDVI)

An index is a combination of several spectral bands intended to highlight the peculiarities of a given surface. Many methods of processing and interpreting satellite images exist, each method giving us different results than the other, either reality or precision [28]. In remote sensing, indexes are part of the processing methods called multispectral transformations. They consist in converting the luminance measured at the level of the satellite sensor into quantities having a significance in the field of the environment.

NDVI which stands for Normalized Difference Vegetative Index, is an important vegetation index, widely applied in research on global environmental and climatic change. It is calculated by a ratio difference between measured canopy reflectance in the red (where the mineralized surfaces have high reflectance) and near infrared (where the vegetation cover has strong reflectance) bands respectively [29].

NDVI gives the vegetative proportions in a region or area. The formula to calculate NDVI is:

$$\textbf{NDVI} = \textbf{(NIR - Red) / (NIR + Red)}$$ [30].

The value of NDVI ranges from -1 to +1.

CHAPTER III

MATERIALS & METHODS

In this chapter, first, we will define our region of interest. Then, we will be talking about the data gathered as well as the software used in this study. Finally, we will concern a long and full detailed report about the methodology applied through this study.

3.1. Study Region

2.4.1. Presentation

Our study region is the district of Odunpazarı, which is located in the city of Eskişehir. Odunpazarı is a metropolitan district of Eskişehir Province in the Central Anatolia region of Turkey, as indicated in Figure 1-3. Along with the district of Tepebaşı, it is one of the central districts of Eskişehir. In the website Nufusu.com, it is said that the population of Odunpazarı in 2016 was 391 106 while the population of Eskişehir city in 2016 was 844 842.

2.4.2. Location

The district of Odunpazarı is located in Eskişehir city, between Ankara (Administrative capital of Turkey) and Istanbul (touristic and cultural capital of Turkey), as it is 324 km from Istanbul and 233 km from Ankara. It has boundaries with six provinces from different direction: Bilecik from the northwest, Ankara from the east, Konya from the south, Kütahya from the west, Bolu from the north, and Afyon from the southwest. The coordinates to locate the district of Odunpazarı are 39°46′N 30°32′E.

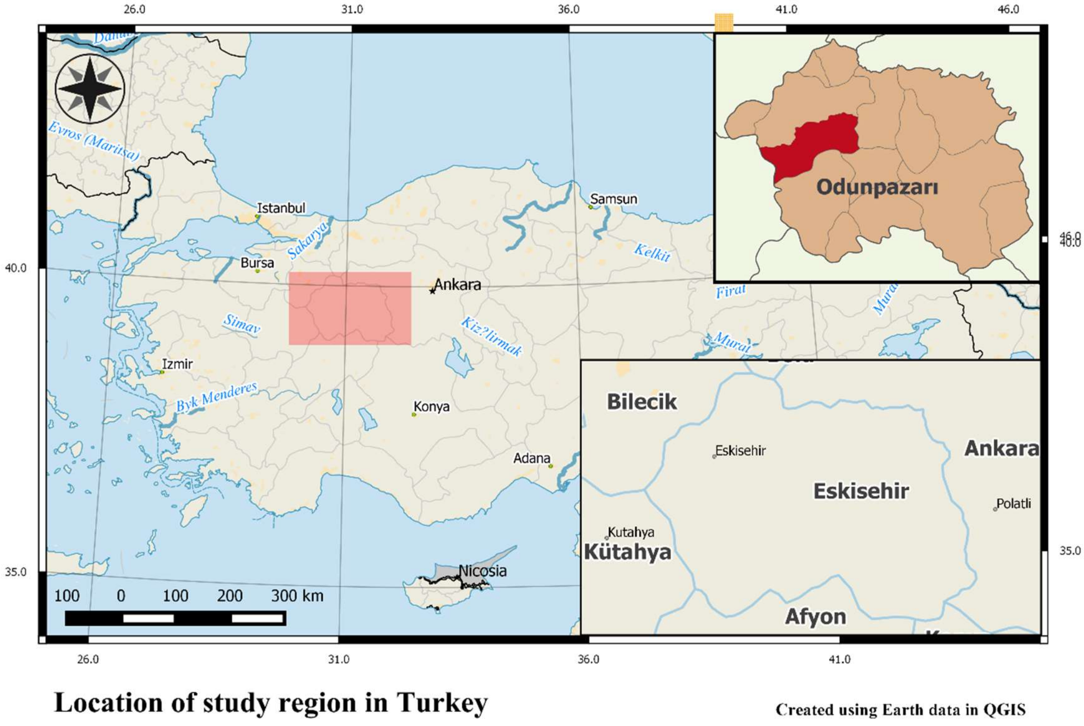

Figure 3.1. *Location of the district of Odunpazarı* (**Source:** *Earth data*)

3.2. Data Preparation

It is a total of 37 neighborhoods that have been selected for this study. The amount of data was collected for each month of the year 2016. These data were gathered following the scientific and academic nature of this study.

3.2.1. Energy consumption

Electricity and heat production are the economic sector that generates the largest amount of carbon dioxide emissions from man. In 2010, this sector produced 41% of carbon dioxide emissions from fossil fuels, according to Wikipedia. Worldwide, this sector is highly dependent on coal, which is the most intensive fossil fuel among all. EPA said that coal combustion is generally more carbon intensive than burning natural gas or petroleum for electricity. This explains the enormous carbon footprint of this sector.

Almost all industrialized countries obtain the majority of their electricity from the combustion of fossil fuels (about 60-90%). Only Canada and France are the exception. The industrial, housing and trade sectors are the main users of electricity, covering 92% of the utilization [31].

Data consumption of electricity and natural gas were respectively obtained from the OEDAŞ (Osmangazi Elektrik Dağıtım Anonim Şirketi) and ESGAZ (Eskişehir Gaz), as summarized in the Table 4.

3.2.1.1. Electricity

For electricity data, values are expressed in kWh (kilowatt-hours), which is a measure unit of energy that is often used to describe an amount of electricity. A typical family home would use approximately 3 to 4 MWh of electricity a year [32]. For this study, unfortunately it was not possible to get electricity data per each neighborhood, only for the whole city of Eskişehir. Refer to the coming **Table 3.1.**

Table 3.1. *Electricity data consumption of Odunpazarı* (**Source:** *OEDAŞ*)

Months	**Electricity Consumption (kWh)**
January	**154099171**
February	**135463078**
March	**141918512**
April	**138814372**
May	**142329118**
June	**153012419**
July	**166104252**
August	**160712322**
September	**132627412**
October	**139869579**
November	**143435063**
December	**160056723**
Total	**1768442021**

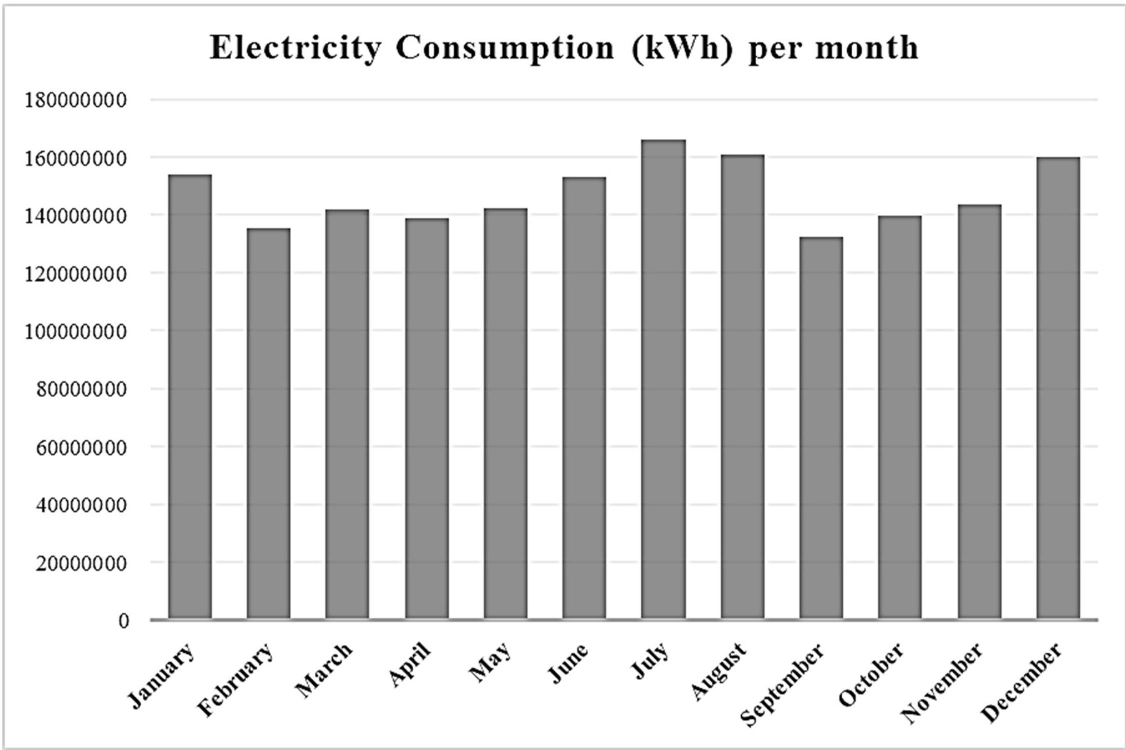

Figure 3.2. *Electricity consumption in 2016* (**Source:** *OEDAŞ*)

3.2.1.2. Natural Gas

For natural gas data (See **Table 3.2.**), the values obtained from the gas firm were expressed in m^3 (cubic meter). Natural gas can be measured by energy content or volume in metric or imperial units. This is due to its many properties that it has become a popular fuel of choice in residential, commercial, and industrial applications, as well as for electric power generation.

Table 3.2. *Natural Gas data consumption of Odunpazarı neighborhoods* (**Source:** *ESGAZ*)

Neighborhoods	**Natural Gas Consumption (m^3)**
71 Evler	**6491143.31**
75. Yıl	**5891784.02**
Akarbaşı	**9313492.15**
Akçağlan	**1021869.84**
Akcami	**309288.55**
Alanönü	**1872043.87**
Arifiye	**5119438.96**
Büyükdere	**19108685.08**
Çankaya	**3572800.84**
Cunidiye	**458884.86**
Dede	**1245546.3**
Deliklitaş	**4384868.85**
Emek	**13859482.84**
Erenköy	**3748475.34**
Gökmeydan	**10817453.02**
Göztepe	**1437008.32**
Gültepe	**5802705.2**
Gündoğdu	**3630125.3**
Huzur	**2322114.19**

Table 3.2. (continued) *Natural Gas data consumption of Odunpazarı neighborhoods*

Neighborhoods	**Natural Gas Consumption (m^3)**
Ihlamurkent	**2381606.13**
İstiklal	**5591375.35**
Karacahöyük	**No data**
Karacaşehir	**No data**
Karapınar	**828460.47**
Kırmızıtoprak	**7882583.62**
Kurtuluş	**9099472.98**
Orhangazi	**3683606.58**
Orta	**225372.33**
Osmangazi	**3903596.86**
Paşa	**324299.16**
Şarkiye	**143040.17**
Sümer	**9673019.04**
Vadişehir	**3762918.17**
Vişnelik	**11151681.55**
Yenidoğan	**3911166.38**
Yenikent	**5687541.07**
Yıldıztepe	**3457848.75**

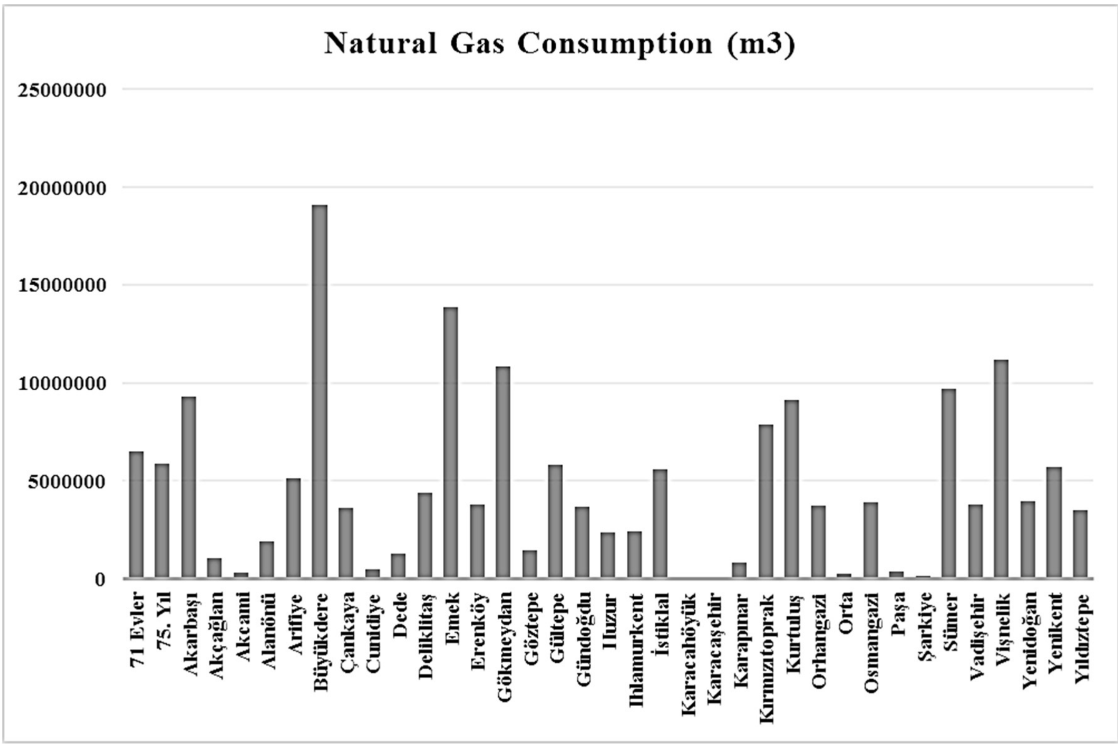

Figure 3.3. *Natural Gas consumption in 2016* (**Source:** *ESGAZ*)

3.2.2. Roads

The transportation sector is the second major source of carbon dioxide emissions from man. It includes the movement of people and goods by cars, trucks, trains, ships, airplanes, etc. [33]. This sector requires very high energy consumption, and almost exclusively uses fuels derived from petroleum (petrol, diesel, kerosene, etc.) to meet its needs.

Although transportation sector contains 3 types: land-type (bus, trucks, trains, etc.), air-type (airplanes) and water-type (ships, boats, etc.), in this study it was decided to just focus on the land-type of transportation, especially personal cars, bus and trucks.

3.2.3. Administrative neighborhood boundaries

The administrative boundaries of Odunpazarı District were provided by CVM (Coğrafi Veri Modelleme San. ve Tic. Ltd. Şti.). These data were georeferenced in the Coordinate Reference System - shortened CRS - (EPSG:23036, ED50 / UTM Zone 36N).

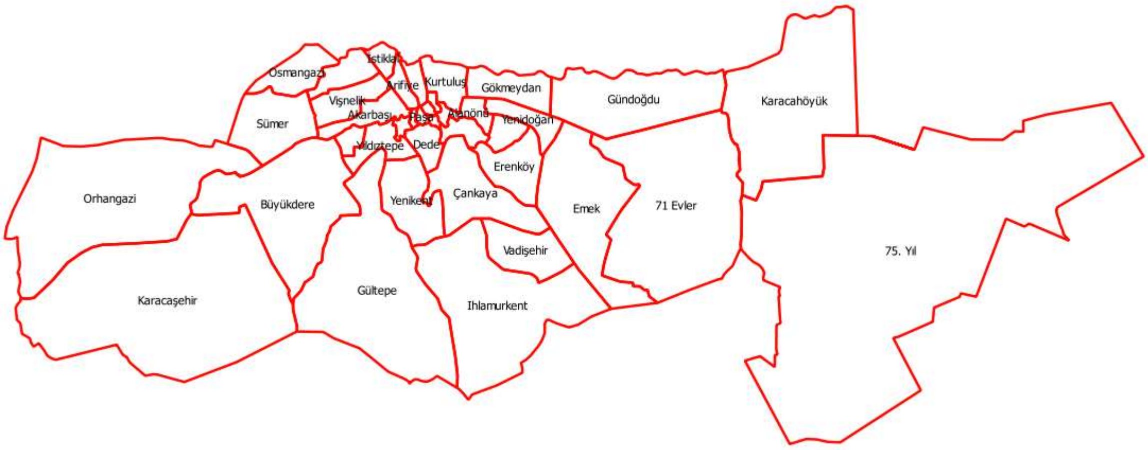

Figure 3.4. *Administrative neighborhood boundaries of Odunpazarı district*

(**Source:** *CVM*)

3.2.4. Landsat satellite image

A Landsat 8 Level-1 Data Products held in the USGS archives were used to obtain a satellite image of Eskişehir region in 2016.

Figure 3.5. *Multispectral image of Eskişehir region from Landsat 8 satellite*

(**Source:** *USGS*)

3.2.5. Odunpazarı population records

The data about population of each neighborhood were acquired from internet, especially in the website http://www.nufusune.com. They are resumed in the next **Table 3.3.**

Table 3.3. *Population records of Odunpazarı neighborhoods* (**Source:** *www.nufusune.com*)

Neighborhoods	**Population**
71 Evler	**21959**
75. Yıl	**11476**
Akarbaşı	**19099**
Akçağlan	**2460**
Akcami	**590**
Alanönü	**5917**
Arifiye	**5929**
Büyükdere	**27506**
Çankaya	**10509**
Cunidiye	**1255**
Dede	**1651**
Deliklitaş	**7093**
Emek	**46567**
Erenköy	**12667**
Gökmeydan	**26824**
Göztepe	**4163**

Table 3.3. (continued) *Population records of Odunpazarı neighborhoods*

Neighborhoods	**Population**
Gültepe	**14581**
Gündoğdu	**11058**
Huzur	**7327**
Karacaşehir	**241**
Karapınar	**2788**
Kırmızıtoprak	**18518**
Kurtuluş	**19123**
Orhangazi	**7123**
Orta	**528**
Osmangazi	**9635**
Paşa	**377**
Şarkiye	**506**
Sümer	**8289**
Vadişehir	**9151**
Vişnelik	**21115**
Yenidoğan	**7178**
Yenikent	**11367**
Yıldıztepe	**11632**

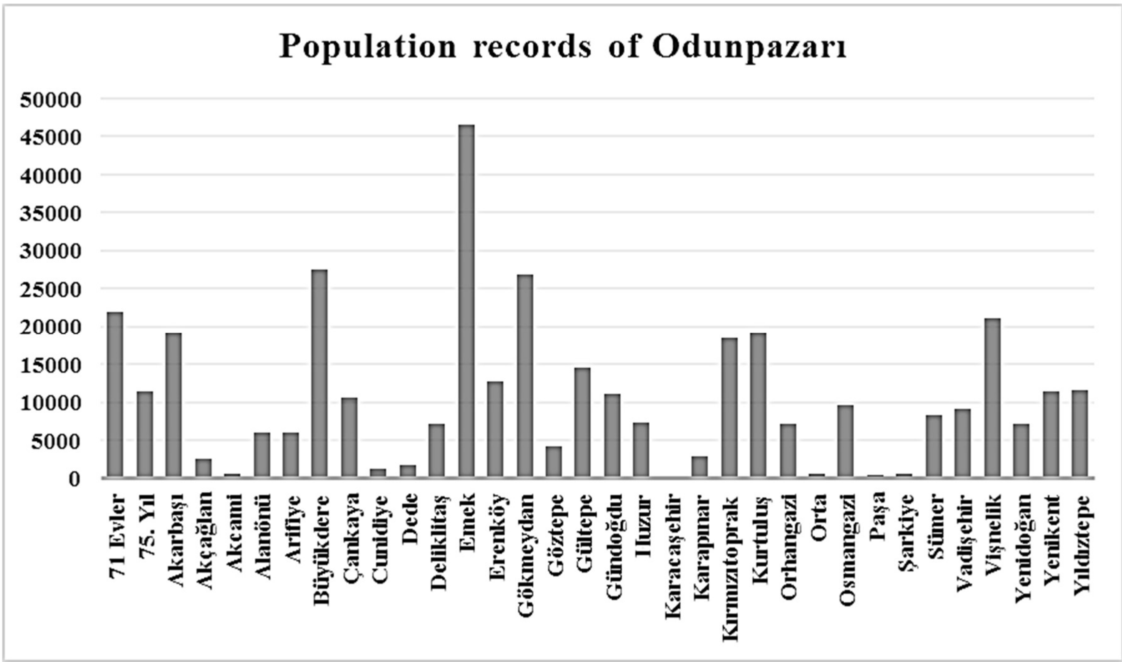

Figure 3.6. *Population records of Odunpazarı in 2016*

(**Source:** *www.nufusune.com*)

The table below is summarizing all data collected to be used in this study as well as their sources.

Table 3.4. *Summary of data collected and their sources*

No	Description	Type	Sources	Acquisition
01	Consumption data of natural gas within neighborhoods in 2016	Tabular	ESGAZ (Eskişehir Gaz)	02/18/2017
02	Consumption data of electricity for the whole Eskişehir in 2016	Tabular	OEDAŞ (Osmangazi Elektrik Dağıtım Anonim Şirketi)	05/03/2017
03	Road data	Tabular	Technical Service of Odunpazarı Municipality	11/29/2016
04	Population	Tabular	Nufusune.com (Türkiye Nüfusu İl ilçe Mahalle Köy Nüfusları)	05/03/2017
05	Administrative neighborhood boundaries	Vector	CVM (Coğrafi Veri Modelleme San. ve Tic. Ltd. Şti.)	02/18/2017
06	Eskisehir Region Landsat 8 image	Raster	USGS	03/20/2017

3.3. Software used

3.3.1. QGIS

For this study, the main application to work on is the free and open source software Quantum GIS, also referred to as QGIS. QGIS was chosen as a platform for this study due to its functionalities. In fact, it is a fully functioning desktop GIS and includes all the features that spatial professionals and general users would expect such as importing data from multiple sources, digitizing, editing, on the fly reprojection, data analysis, geoprocessing, database connectivity and raster processing (www.qgis.org). As well, the highly capable print layout functionality is intuitive and easy for new users to create professional looking maps.

In this study, the version QGIS 2.12.3 - Lyon was chosen for creating maps, making calculations, and analyzing results.

3.3.2. GRASS GIS

Remote sensing tasks will be performed on GRASS GIS software. As defined on their own website https://grass.osgeo.org/, GRASS GIS, commonly referred to as GRASS (Geographic Resources Analysis Support System), is a free and open source GIS software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization. GRASS is currently used in academic and commercial settings around the world. In this study, the version GRASS 7.0.3 was used for.

GRASS will be used in this study to obtain a NDVI map of our study region, and will help to find green area or vegetation by performing filtering analysis.

3.3.3. Others

Microsoft Excel 2016 was used for processing the tabular data that we obtained for electricity and natural gas consumption. Microsoft Word 2016 was used as support for writing this thesis dissertation. Microsoft PowerPoint 2016 will be used for the thesis defense before a jury. As well, the software EndNote X7 was used for listing and citing references.

3.4. Proposed methods

3.4.1. Emissions calculations

Calculating carbon emissions can help society to prioritize the steps it can eventually take to shrink it, by identifying what the biggest opportunities for reductions are.

This section will explain the methodology used to calculate a carbon emissions for each sector that has been considered in this study: housing - including electricity and natural gas - and transportation. This calculation method is based on consumptions in each sector. For simplicity and clarity, all our calculations follows one basic method: multiplication of a use input by an emissions factor to calculate each emission [34].

3.4.1.1. Housing

To calculate housing carbon emissions, it need to work out personal shares of home energy use, such as electricity and natural gas. Which means collecting figures for annual energy use After that, you just need to multiply these information gathered by an emission factor (EF) to calculate the housing emissions [35].

The calculations proposed the electricity sector will be this:

$$\textbf{\textit{Electricity: use (MWh) * EF = emissions (t } CO_2\textbf{\textit{) (1)}}}$$

Where:

- The electricity use is expressed in MWh and will be get from electricity data consumption of Odunpazarı;
- The emission factor is value calculated for Turkey considering all electricity generation sources in 2016;
- The emissions calculated are expressed in ton of CO_2.

And for the natural gas sector:

$$\textbf{\textit{Natural Gas: use (MWh) * EF = emissions (t } CO_2\textbf{\textit{) (2)}}}$$

Where:

- The natural gas use is expressed in MWh and comes from data that we were provided for each neighborhood of Odunpazarı;
- The emission factor is value got from “HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP),– GUIDEBOOK”, Covenant of Mayors for Climate and Energy EU /STANDARD CO2 EMISSION FACTORS (FROM IPCC, 2006) [11];
- The emissions calculated are also expressed in ton of CO_2.

3.4.1.2. Transportation

To calculate the transportation carbon emissions, it necessary to work out how much travel a person has done using different forms of transportation in the last year. Taking these distances, you can multiply by a carbon intensity for each form of transportation: Vehicle, Bus, Taxi, Rail, etc.

In general, the calculation proposed for any form of transportation is:

$$\textit{Vehicle: distance (km) * EF = emissions (t } CO_2\textit{)} \quad (3)$$

Where:

- The distance is expressed in km;
- The emission factor is defined value;
- The emissions calculated are expressed in ton of CO_2.

However, in transportation sector, the more complicated remains to calculate an accurate emissions factor, because estimating the driven distance may be simple with GIS tools. Therefore, in this study, roads were not includes as parameter and made not to apply any application of carbon emissions calculations based transportation sector.

3.4.2. NDVI calculations

After downloading a 2016 satellite image of Eskisehir from USGS website, it was required to clip that image according to the region of interest of this study. Once this is done the processing step could now get started.

As known, Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. The resolution for Band 8 (panchromatic) is 15 meters. In addition, it also have two Thermal IR bands with a spatial resolution of 100m (later resampled into 30 m) [36]. Here the IR and NIR bands are respectively 4 and 5.

To calculate NDVI, the ***Raster Map Calculator*** function of GRASS GIS was used The function requires 2 satellite bands: one with red values and the other near-infra red values. So, the function performs the calculation:

NDVI = float (band 4 - band 5) / float (band 4 + band 5) (4)

The table below from GrindGIS website shows the red and infrared bands reflectance values of features and their NDVI values. Water has an NDVI value less than 0, bare soils between 0 and 0.1, and vegetation over 0.1. Increase in the positive NDVI value means greener the vegetation.

Table 3.5. *Red and infrared bands reflectance values of features and their NDVI values* (**Source:** *http://grindgis.com*)

COVER TYPE	RED	NIR	NDVI
Dense vegetation	0.1	0.5	0.7
Dry Bare soil	0.269	0.283	0.025
Clouds	0.227	0.228	0.002
Snow and ice	0.375	0.342	-0.046
Water	0.022	0.013	-0.257

3.5. Scopes & Tiers

3.5.1. Definitions of the scopes of urban activities emissions

Scope 1: Emission sources owned or operated by urban boundaries.

Scope 2: Emissions due to consumption of electricity, central heating, steam and cooling processes.

Scope 3: All indirect emissions on the urban boundaries.

3.5.2. Tiers used in carbon emissions calculations

The tiers represent a methodological level of complexity in the carbon calculation methods. In order to classify the activity data as well as the emission factors, three tiers have been identified:

Tier 1: The calculation standards are designed for use with the available national and international statics, with default emission factors and additional parameters provided. Thus, it is possible to use it in all countries. It is the basic method that frequently uses the default values suggested by the IPCC. This tier is used in situations where it is not possible to reach clearer data such as countries and cities.

Tier 2: The calculation standards have a moderate complexity, and require that local emission data have been obtained.

Tier 3: The calculation standards are the most complicated and it is the most accurate tier required for a region. However, data requirements are more than complex. Therefore, it will not rational to use this tier for calculations at urban level. For this reason, cities that are studying their greenhouse gas emissions should use the most feasible tier of their work.

Because of the characteristics of the data that can be obtained in the urban studies within the framework of the related protocols, the Tier 1 and Tier 2 calculations methods are used.

CHAPTER IV

ANALYSIS

This chapter describes the process of requirements analysis for calculating carbon emissions from the electricity and natural gas data gathered. In a first step the focus will be on electricity data, then the second step will be working on natural gas data, and the final step will be talking about the total data.

4.1. Electricity

4.1.1. Converting kWh into MWh

As stated above for the calculation methods, first, the electricity data needed to be converted from kWh into MWh for the needs of this study:

$$1\ kWh = 0.001\ MWh \quad (5)$$

Following this equation, all electricity data collected were converted into MWh. Refer to the **Table 4.1**.

Table 4.1. *Electricity data converted into MWh*

Months	**Electricity Consumption (kWh)**	**Electricity Consumption (MWh)**
January	154099171	**154099.171**
February	135463078	**135463.078**
March	141918512	**141918.512**
April	138814372	**138814.372**
May	142329118	**142329.118**
June	153012419	**153012.419**
July	166104252	**166104.252**
August	160712322	**160712.322**
September	132627412	**132627.412**
October	139869579	**139869.579**
November	143435063	**143435.063**
December	160056723	**160056.723**
Total	1768442021	**1768442.021**

4.1.2. Performing statistical operations

Contrary to the data collected for natural gas, the main electricity company of Eskişehir OEDAŞ did not provide electricity consumption per neighborhood, it just provided the consumption for the whole district of Odunpazarı. Therefore, it was required to get these data for each neighborhood using some statistical tools.

Among data collected there was population of each neighborhood of Eskişehir - information that we have obtained from the website Nufusune.com [37] - then some calculations were made to obtain a coefficient of the total electricity consumption in Odunpazarı by the total population to get the electricity consumption per person:

Electricity cons. per pers. = Total electricity cons. / Odunpazarı population (6)

Table 4.2. *Electricity consumption per person*

Total electricity consumption (MWh)	**Odunpazarı population**	**Electricity consumption per person (MWh/per)**
1768442.021	379544	**4.66**

Next, this value of **4.66** was multiplied by the number of population of each neighborhood, and doing so, data to estimate the electricity consumption in every neighborhood of Odunpazarı was extrapolated:

Electricity cons. of neighbor. = Electricity cons. per pers. * population of neighbor. (7)

Then, all electricity data prepared were ready for the next step, which was to determine the emission factors in ton of CO_2 of this sector, using the corresponding scope and tier in defined for this study:

- ***Emission Factor (EF)*** was calculated to be ***0.505*** for Turkey considering all electricity generation sources in 2016;
- ***Scope 2*** was determined following the scope stated above;
- ***Tier 2*** was determined in accordance with Turkish standards of studies based on estimating CO_2 emissions.

Table 4.3. *Electricity consumption per neighborhood*

Neighborhoods	**Population**	**Consumption per person (MWh/per)**	**Electricity consumption per neighborhood (MWh)**
71 Evler	21959	4.66	**102329**
75. Yıl	11476	4.66	**53478**
Akarbaşı	19099	4.66	**89001**
Akçağlan	2460	4.66	**11464**
Akcami	590	4.66	**2749**
Alanönü	5917	4.66	**27573**
Arifiye	5929	4.66	**27629**
Büyükdere	27506	4.66	**128178**
Çankaya	10509	4.66	**48972**
Cunidiye	1255	4.66	**5848**
Dede	1651	4.66	**7694**
Deliklitaş	7093	4.66	**33053**
Emek	46567	4.66	**217002**
Erenköy	12667	4.66	**59028**
Gökmeydan	26824	4.66	**125000**
Göztepe	4163	4.66	**19400**
Gültepe	14581	4.66	**67947**
Gündoğdu	11058	4.66	**51530**
Huzur	7327	4.66	**34144**

Table 4.3. (continued) *Electricity consumption per neighborhood*

Neighborhoods	Population	Consumption per person (MWh/per)	Electricity consumption per neighborhood (MWh)
Ihlamurkent	7348	4.66	**34242**
İstiklal	5935	4.66	**27657**
Karacahöyük	59	4.66	**275**
Karacaşehir	241	4.66	**1123**
Karapınar	2788	4.66	**12992**
Kırmızıtoprak	18518	4.66	**86294**
Kurtuluş	19123	4.66	**89113**
Orhangazi	7123	4.66	**33193**
Orta	528	4.66	**2460**
Osmangazi	9635	4.66	**44899**
Paşa	377	4.66	**1757**
Şarkiye	506	4.66	**2358**
Sümer	8289	4.66	**38627**
Vadişehir	9151	4.66	**42644**
Vişnelik	21115	4.66	**98396**
Yenidoğan	7178	4.66	**33449**
Yenikent	11367	4.66	**52970**
Yıldıztepe	11632	4.66	**54205**

4.1.3. Calculating electricity CO_2 emissions

Finally, the next calculation to perform is to multiply the electricity data in our hand by the emission factor value for the electricity sector, so that the electricity carbon dioxide emissions will be obtained.

Electricity CO_2 emissions of neighbor. = Electricity cons. of neighbor. * EF (8)

The table below is a sum up of the calculations performed to get carbon emission of electricity sector in Odunpazarı.

Table 4.4. *Sample of CO_2 calculations for Electricity data*

Neigh.	**Pop.**	**Elec. cons. per person**	**Elec. cons. per neigh.**	**EF**	**Scope**	**Tier**	**Electricity CO_2 emissions**
A	***x***	***4.66***	***4.66 * x***	***0.505***	***2***	***2***	***4.66 * x * 0.505***

Where:

- ***A*** represents any neighborhood;
- ***x*** represents the population record of the given neighborhood.

At the end, the carbon emissions values that we have obtained are resumed in the next **Table 4.5**.

Table 4.5. *Electricity CO_2 emissions*

Neighborhoods	**Consumption per neighborhood (MWh)**	**Emission Factor**	**Electricity Emissions (ton of CO_2)**
71 Evler	102329	0.505	**51676.145**
75. Yıl	53478	0.505	**27006.39**
Akarbaşı	89001	0.505	**44945.505**
Akçağlan	11464	0.505	**5789.32**
Akcami	2749	0.505	**1388.245**
Alanönü	27573	0.505	**13924.365**
Arifiye	27629	0.505	**13952.645**
Büyükdere	128178	0.505	**64729.89**
Çankaya	48972	0.505	**24730.86**
Cunidiye	5848	0.505	**2953.24**
Dede	7694	0.505	**3885.47**
Deliklitaş	33053	0.505	**16691.765**
Emek	217002	0.505	**109586.01**
Erenköy	59028	0.505	**29809.14**
Gökmeydan	125000	0.505	**63125**
Göztepe	19400	0.505	**9797**
Gültepe	67947	0.505	**34313.235**
Gündoğdu	51530	0.505	**26022.65**
Huzur	34144	0.505	**17242.72**

Table 4.5. (continued) *Electricity CO_2 emissions*

Neighborhoods	Consumption per neighborhood (MWh)	Emission Factor	Electricity Emissions (ton of CO_2)
Ihlamurkent	34242	0.505	**17292.21**
İstiklal	27657	0.505	**13966.785**
Karacahöyük	275	0.505	**138.875**
Karacaşehir	1123	0.505	**567.115**
Karapınar	12992	0.505	**6560.96**
Kırmızıtoprak	86294	0.505	**43578.47**
Kurtuluş	89113	0.505	**45002.065**
Orhangazi	33193	0.505	**16762.465**
Orta	2460	0.505	**1242.3**
Osmangazi	44899	0.505	**22673.995**
Paşa	1757	0.505	**887.285**
Şarkiye	2358	0.505	**1190.79**
Sümer	38627	0.505	**19506.635**
Vadişehir	42644	0.505	**21535.22**
Vişnelik	98396	0.505	**49689.98**
Yenidoğan	33449	0.505	**16891.745**
Yenikent	52970	0.505	**26749.85**
Yıldıztepe	54205	0.505	**27373.525**

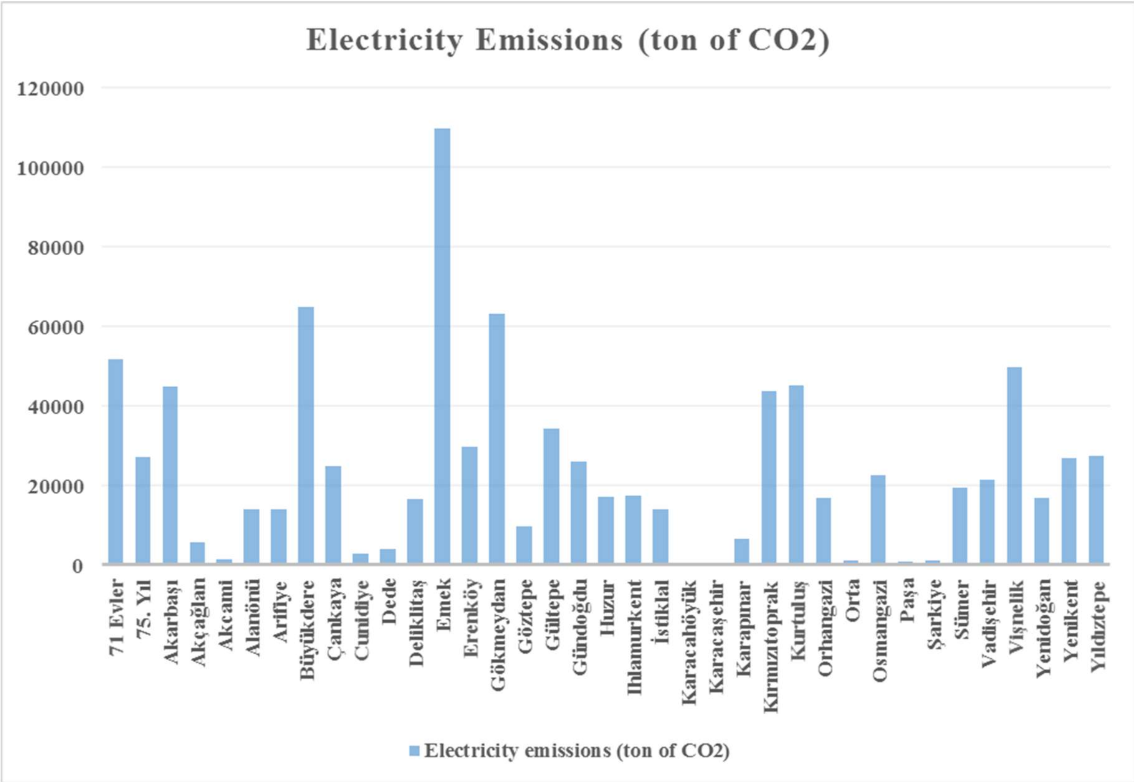

Figure 4.1. *Electricity CO2 Emissions in 2016*

4.1.4. Displaying the outputs in QGIS

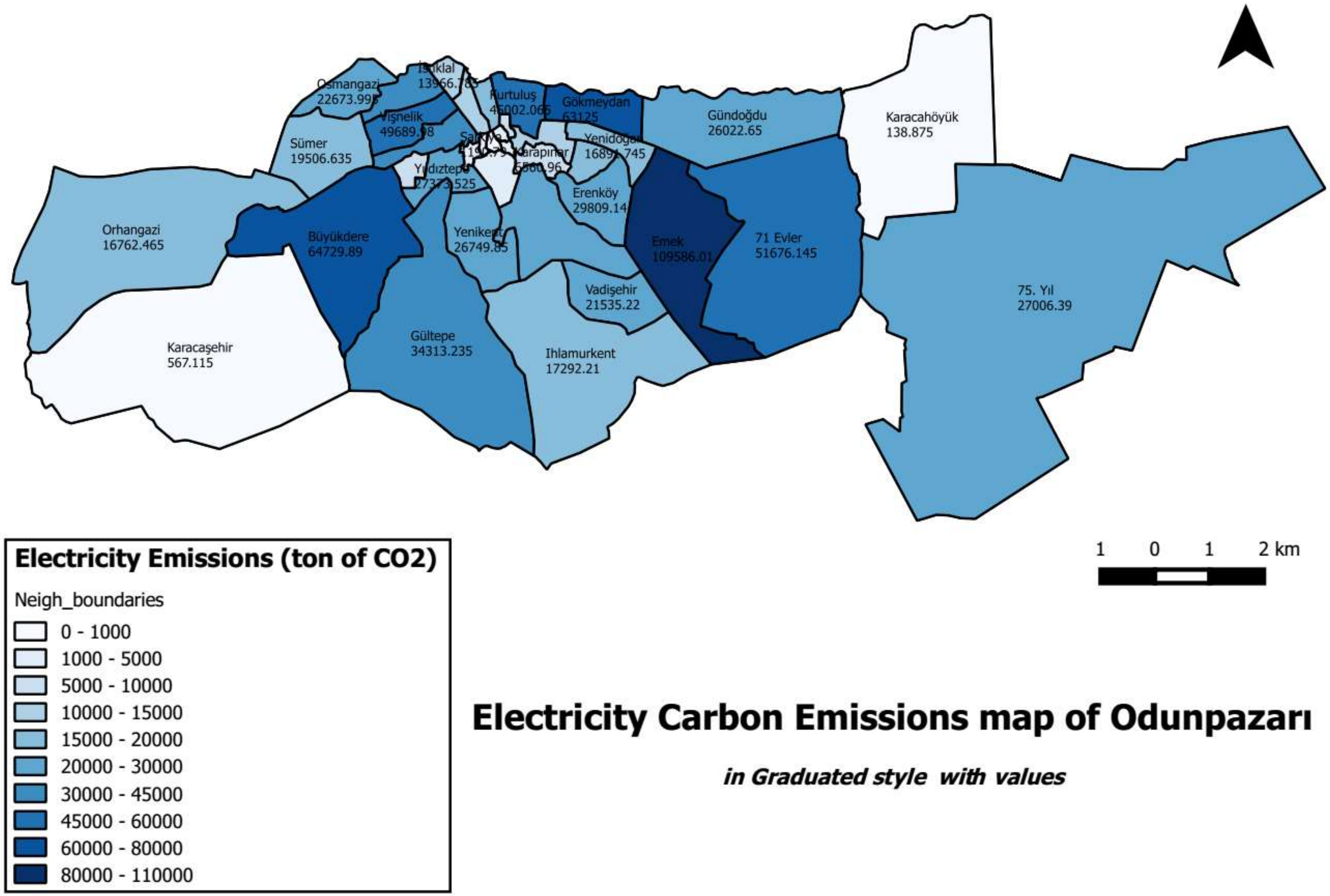

Figure 4.2. *Electricity CO_2 emissions map in Graduated style with values*

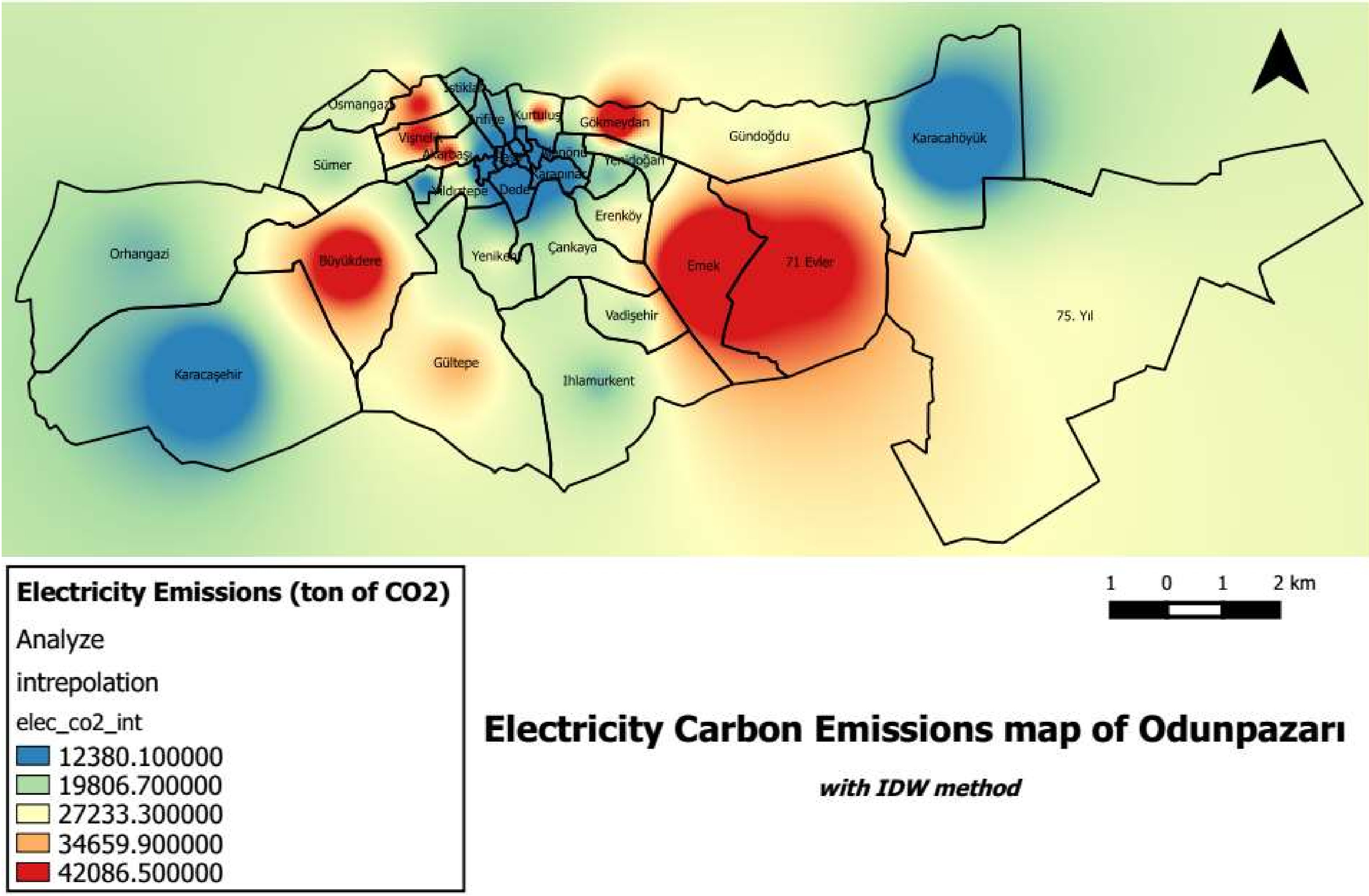

Figure 4.3. *Electricity CO_2 emissions map with IDW method*

4.2. Natural Gas

4.2.1. Converting m^3 into MWh

Following the requirements of the calculation methods, before starting the application step the gathered values needed to be converted from m^3 into the MWh unit. Neil Packer [38] gives in his paper some fuel comparisons, amongst others:

$$1\ m^3 \text{ of natural gas} = 10.8\ kWh \quad (9)$$

Then, the outputs will be divided by 1000 to get the natural gas consumption in MWh unit.

For the natural gas consumption, data acquired were directly sorted by neighborhoods, so no further steps were necessary.

Once this is done, it just remains to determine the emission factors of natural gas sector and the scope and tier that will be used, same as what was done for the electricity sector:

- ***Emission Factor (EF)*** was calculated to be ***0.202*** regarding the "HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP),– GUIDEBOOK", Covenant of Mayors for Climate and Energy EU /STANDARD CO2 EMISSION FACTORS FROM IPCC [11];
- ***Scope 1*** was determined following the scope stated above;
- ***Tier 1*** was set in accordance with the European standards of studies based on estimating CO_2 emissions.

4.2.2. Calculating natural gas CO_2 emissions

From now on, what has to be done is to multiply data of each neighborhood by the emission factor value for natural gas sector, to finally get carbon emissions from natural gas.

Natural Gas CO_2 emissions of neighbor. = Nat. Gas cons. of neighbor. * EF (10)

The calculations performed here for natural gas data are summarized in the **Table 4.6**.

Table 4.6. *Sample of CO_2 calculations for Natural Gas data*

Neigh.	Nat. Gas cons. per neigh.	EF	Scope	Tier	Natural gas CO_2 emissions
B	***y***	***0.202***	***1***	***1***	***y * 0.202***

Where:

- ***B*** represents any neighborhood;
- ***y*** represents the population record of the given neighborhood.

At the end, the carbon emissions values that we have obtained are resumed in the next **Table 4.7**.

Table 4.7. *Natural Gas CO_2 emissions*

Neighborhoods	Consumption per neighborhood (MWh)	Emission Factor	Natural Gas Emissions (ton of CO_2)
71 Evler	69092.6328	0.202	13956.71183
75. Yıl	62268.804	0.202	12578.29841
Akarbaşı	99435.6324	0.202	20085.99774
Akçağlan	10845.5328	0.202	2190.797626
Akcami	3305.3832	0.202	667.6874064
Alanönü	19946.5092	0.202	4029.194858
Arifiye	54541.8576	0.202	11017.45524
Büyükdere	203116.7556	0.202	41029.58463
Çankaya	37770.2352	0.202	7629.58751
Cunidiye	4879.8828	0.202	985.7363256
Dede	13128.858	0.202	2652.029316
Deliklitaş	46667.7072	0.202	9426.876854
Emek	147372.9444	0.202	29769.33477
Erenköy	39873.6	0.202	8054.4672
Gökmeydan	115170.8436	0.202	23264.51041
Göztepe	15275.8872	0.202	3085.729214
Gültepe	61531.8984	0.202	12429.44348
Gündoğdu	38745.648	0.202	7826.620896
Huzur	24695.3988	0.202	4988.470558

Table 4.7. (continued) *Natural Gas CO_2 emissions*

Neighborhoods	Consumption per neighborhood (MWh)	Emission Factor	Natural Gas Emissions (ton of CO_2)
Ihlamurkent	25253.0568	0.202	5101.117474
İstiklal	59228.172	0.202	11964.09074
Karacahöyük	No data	0.202	0
Karacaşehir	No data	0.202	0
Karapınar	8821.2132	0.202	1781.885066
Kırmızıtoprak	83847.7116	0.202	16937.23774
Kurtuluş	96844.3668	0.202	19562.56209
Orhangazi	39260.6244	0.202	7930.646129
Orta	2408.994	0.202	486.616788
Osmangazi	41496.6348	0.202	8382.32023
Paşa	3359.178	0.202	678.553956
Şarkiye	1530.5652	0.202	309.1741704
Sümer	101155.4676	0.202	20433.40446
Vadişehir	40173.2244	0.202	8114.991329
Vişnelik	118888.5816	0.202	24015.49348
Yenidoğan	41528.376	0.202	8388.731952
Yenikent	60797.574	0.202	12281.10995
Yıldıztepe	36809.1324	0.202	7435.444745

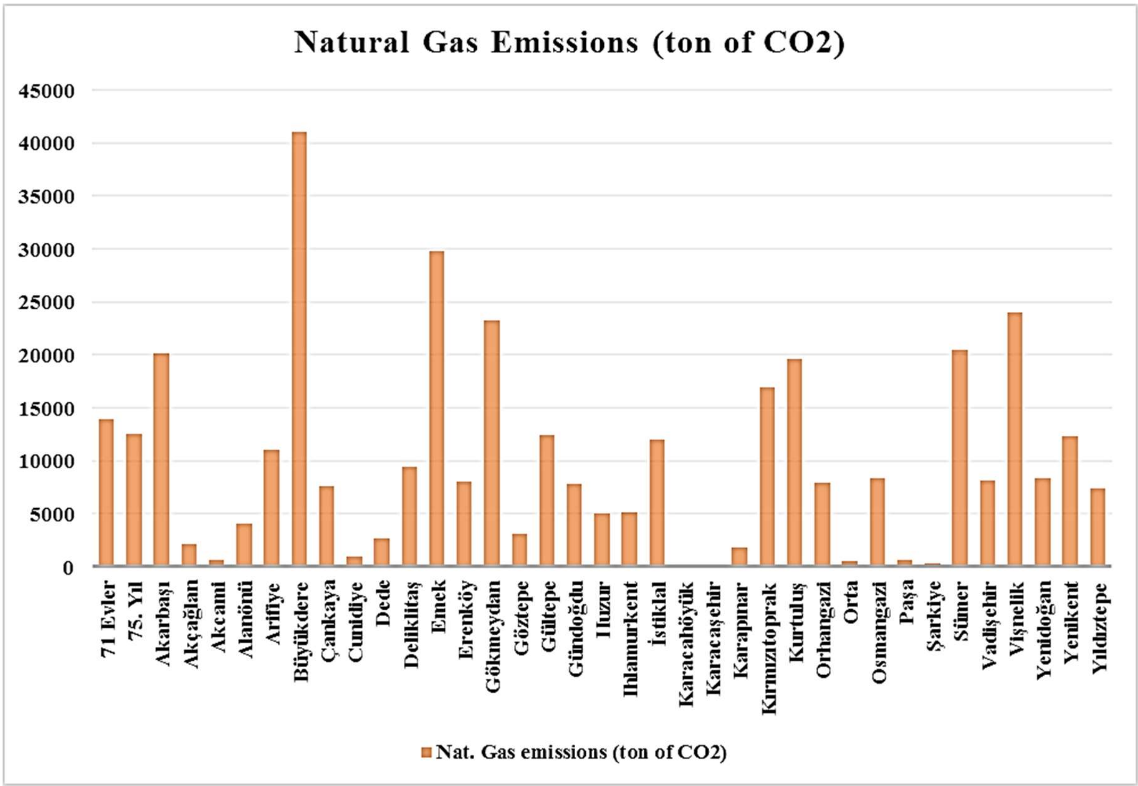

Figure 4.4. *Natural Gas CO2 Emissions in 2016*

4.2.3. Displaying the outputs in QGIS

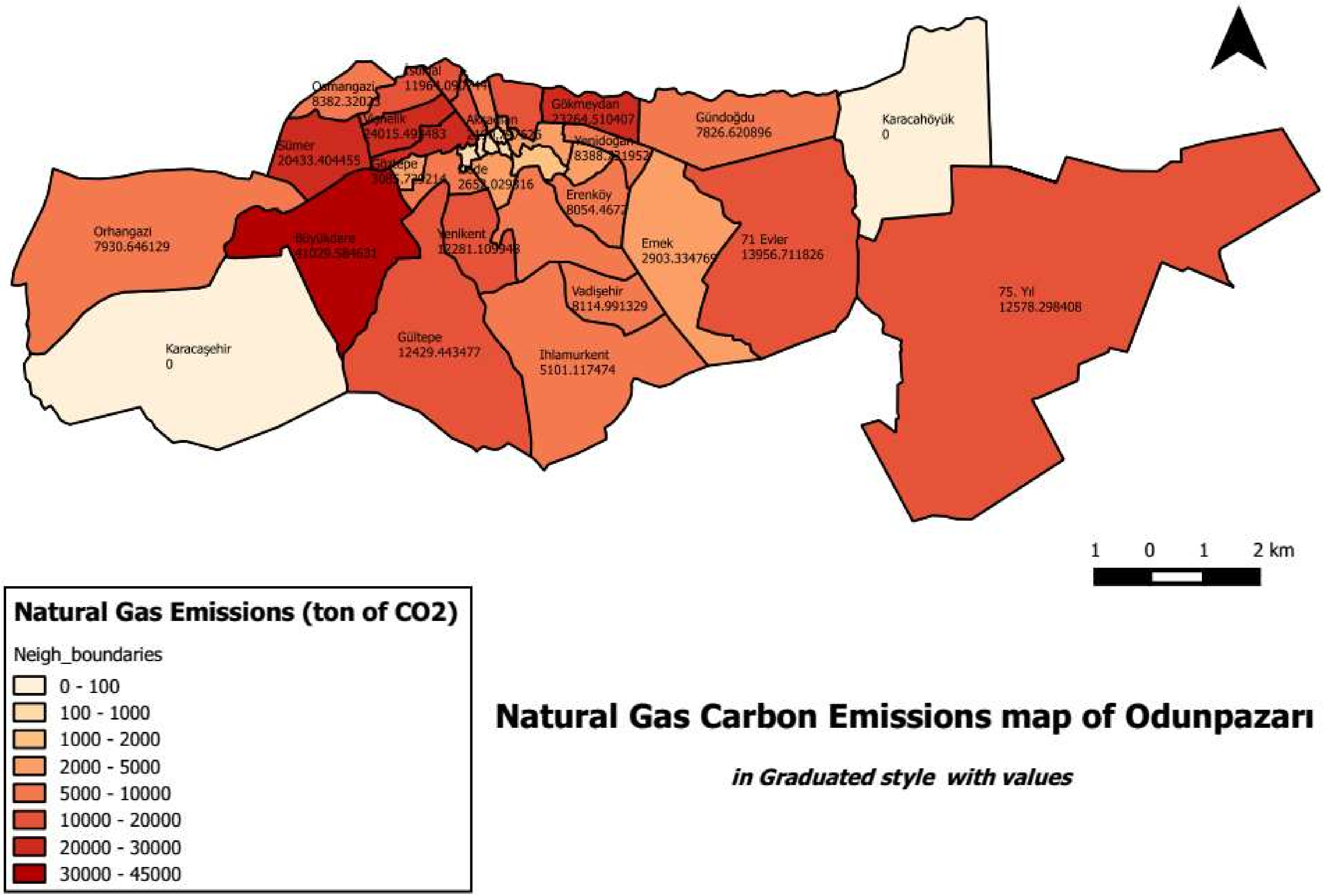

Figure 4.5. *Natural Gas CO_2 emissions map in Graduated style with values*

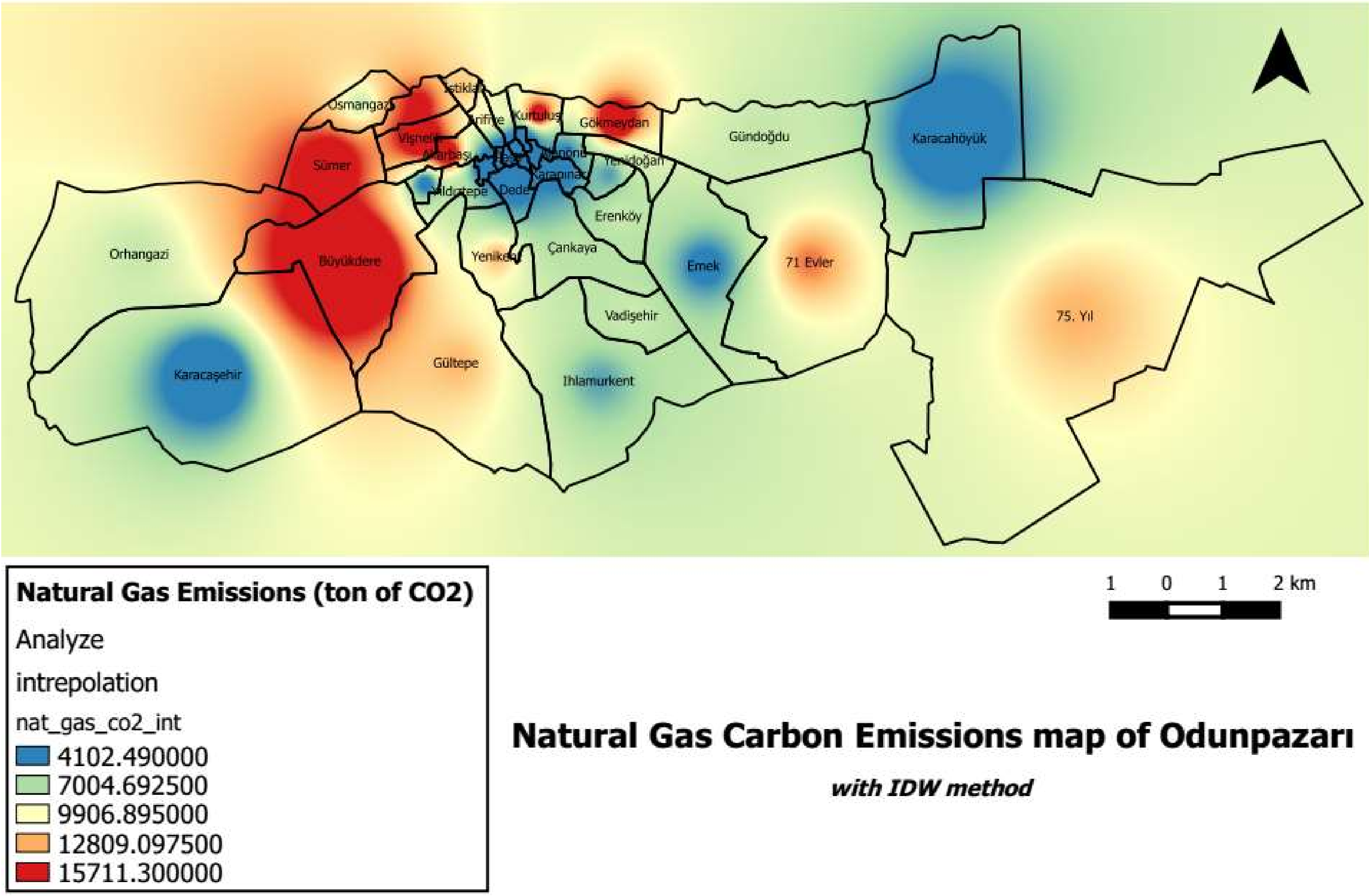

Figure 4.6. *Natural Gas CO_2 emissions map with IDW method*

4.3. Total

4.3.1. Performing summation

Table 4.8. *Total CO_2 emissions*

Neighborhoods	Electricity emissions (ton of CO_2)	Nat. Gas emissions (ton of CO_2)	Total emissions (ton of CO_2)
71 Evler	51676.145	13956.71183	**65632.86**
75. Yıl	27006.39	12578.29841	**39584.69**
Akarbaşı	44945.505	20085.99774	**65031.50**
Akçağlan	5789.32	2190.797626	**7980.12**
Akcami	1388.245	667.6874064	**2055.93**
Alanönü	13924.365	4029.194858	**17953.56**
Arifiye	13952.645	11017.45524	**24970.10**
Büyükdere	64729.89	41029.58463	**105759.47**
Çankaya	24730.86	7629.58751	**32360.45**
Cunidiye	2953.24	985.7363256	**3938.98**
Dede	3885.47	2652.029316	**6537.50**
Deliklitaş	16691.765	9426.876854	**26118.64**
Emek	109586.01	29769.33477	**139355.34**
Erenköy	29809.14	8054.4672	**37863.61**
Gökmeydan	63125	23264.51041	**86389.51**
Göztepe	9797	3085.729214	**12882.73**
Gültepe	34313.235	12429.44348	**46742.68**

Table 4.8. (continued) *Total CO_2 emissions*

Neighborhoods	Electricity emissions (ton of CO_2)	Nat. Gas emissions (ton of CO_2)	Total emissions (ton of CO_2)
Gündoğdu	26022.65	7826.620896	**33849.27**
Huzur	17242.72	4988.470558	**22231.19**
Ihlamurkent	17292.21	5101.117474	**22393.33**
İstiklal	13966.785	11964.090740	**25930.88**
Karacahöyük	138.875	0.000000	**138.88**
Karacaşehir	567.115	0.000000	**567.12**
Karapınar	6560.96	1781.885066	**8342.85**
Kırmızıtoprak	43578.47	16937.237740	**60515.71**
Kurtuluş	45002.065	19562.562090	**64564.63**
Orhangazi	16762.465	7930.646129	**24693.11**
Orta	1242.3	486.616788	**1728.92**
Osmangazi	22673.995	8382.320230	**31056.32**
Paşa	887.285	678.553956	**1565.84**
Şarkiye	1190.79	309.174170	**1499.96**
Sümer	19506.635	20433.404460	**39940.04**
Vadişehir	21535.22	8114.991329	**29650.21**
Vişnelik	49689.98	24015.493480	**73705.47**
Yenidoğan	16891.745	8388.731952	**25280.48**
Yenikent	26749.85	12281.109950	**39030.96**
Yıldıztepe	27373.525	7435.444745	**34808.97**

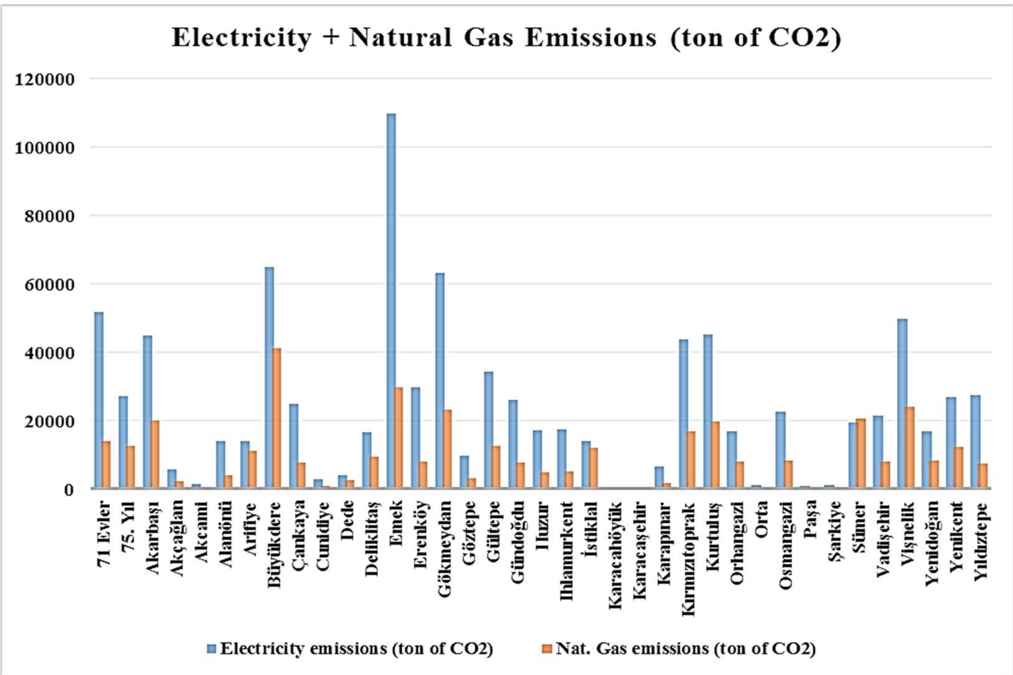

Figure 4.7. *Electricity + Natural Gas CO2 Emissions in 2016*

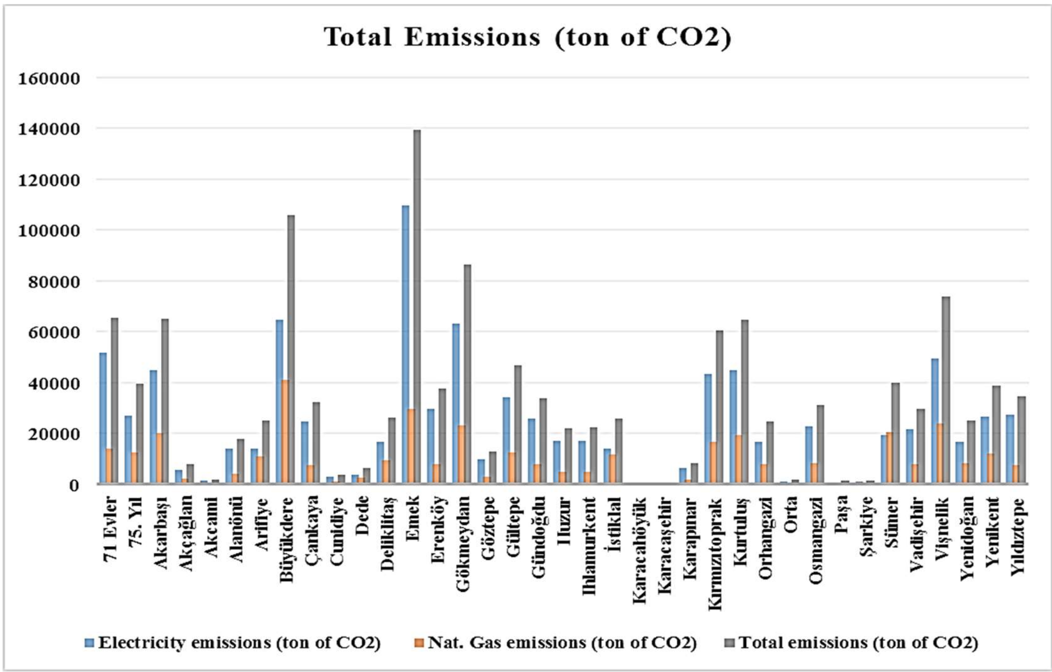

Figure 4.8. *Total CO2 Emissions in 2016*

4.3.2. Estimating CO_2 emitted per person

Table 4.9. *CO_2 emissions per person*

Neighborhoods	Total Emissions (ton of CO_2)	Population	Emissions per person (ton of CO_2)
71 Evler	65632.86	21959	**2.99**
75. Yıl	39584.69	11476	**3.45**
Akarbaşı	65031.50	19099	**3.4**
Akçağlan	7980.12	2460	**3.24**
Akcami	2055.93	590	**3.48**
Alanönü	17953.56	5917	**3.03**
Arifiye	24970.10	5929	**4.21**
Büyükdere	105759.47	27506	**3.84**
Çankaya	32360.45	10509	**3.08**
Cunidiye	3938.98	1255	**3.14**
Dede	6537.50	1651	**3.96**
Deliklitaş	26118.64	7093	**3.68**
Emek	139355.34	46567	**2.42**
Erenköy	37863.61	12667	**2.99**
Gökmeydan	86389.51	26824	**3.22**
Göztepe	12882.73	4163	**3.09**
Gültepe	46742.68	14581	**3.21**
Gündoğdu	33849.27	11058	**3.06**
Huzur	22231.19	7327	**3.03**

Table 4.9 (continued): CO_2 emissions per person

Neighborhoods	**Total Emissions (ton of CO_2)**	**Population**	**Emissions per person (ton of CO_2)**
Ihlamurkent	22393.33	7348	**3.05**
İstiklal	25930.88	5935	**4.37**
Karacahöyük	138.88	59	**2.35**
Karacaşehir	567.12	241	**2.35**
Karapınar	8342.85	2788	**2.99**
Kırmızıtoprak	60515.71	18518	**3.27**
Kurtuluş	64564.63	19123	**3.38**
Orhangazi	24693.11	7123	**3.47**
Orta	1728.92	528	**3.27**
Osmangazi	31056.32	9635	**3.22**
Paşa	1565.84	377	**4.15**
Şarkiye	1499.96	506	**2.96**
Sümer	39940.04	8289	**4.82**
Vadişehir	29650.21	9151	**3.24**
Vişnelik	73705.47	21115	**3.49**
Yenidoğan	25280.48	7178	**3.52**
Yenikent	39030.96	11367	**3.43**
Yıldıztepe	34808.97	11632	**2.99**

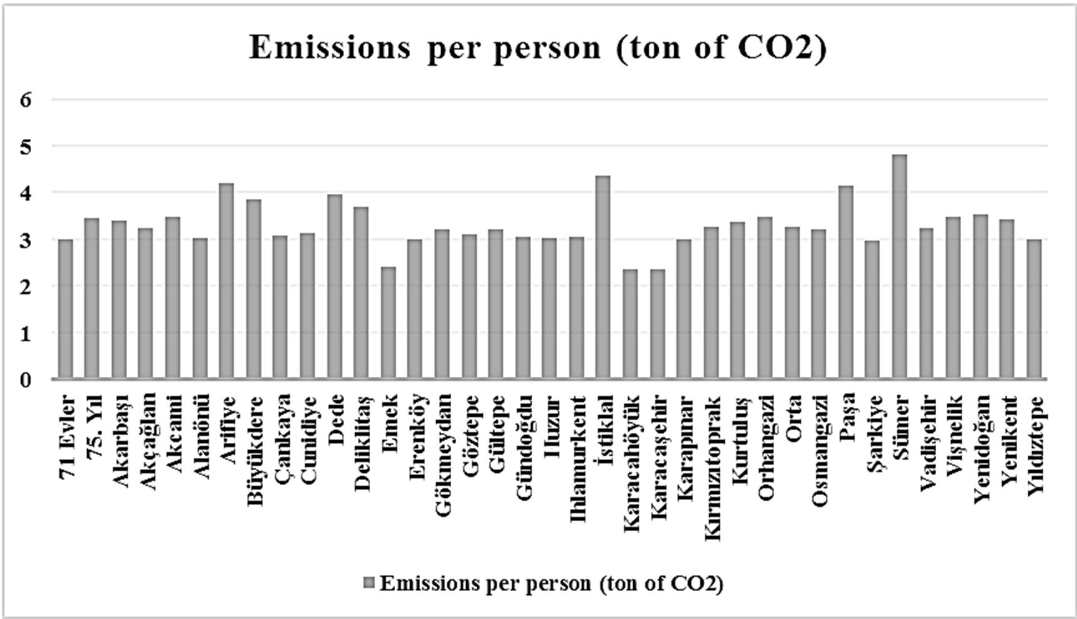

Figure 4.9. *CO_2 Emissions per person in 2016*

4.3.3. Displaying the outputs in QGIS

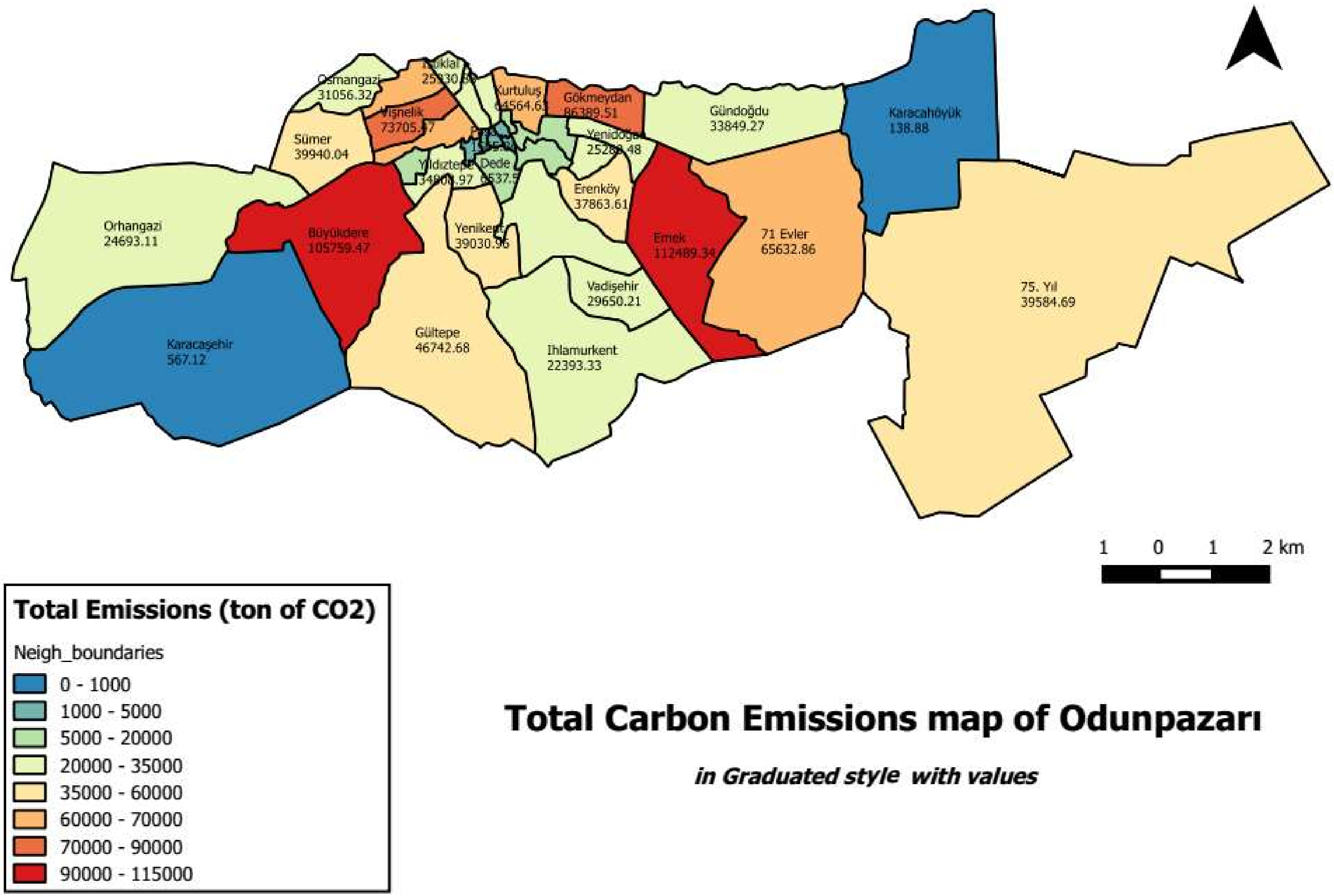

Figure 4.10. *Total CO_2 emissions map in Graduated style with values*

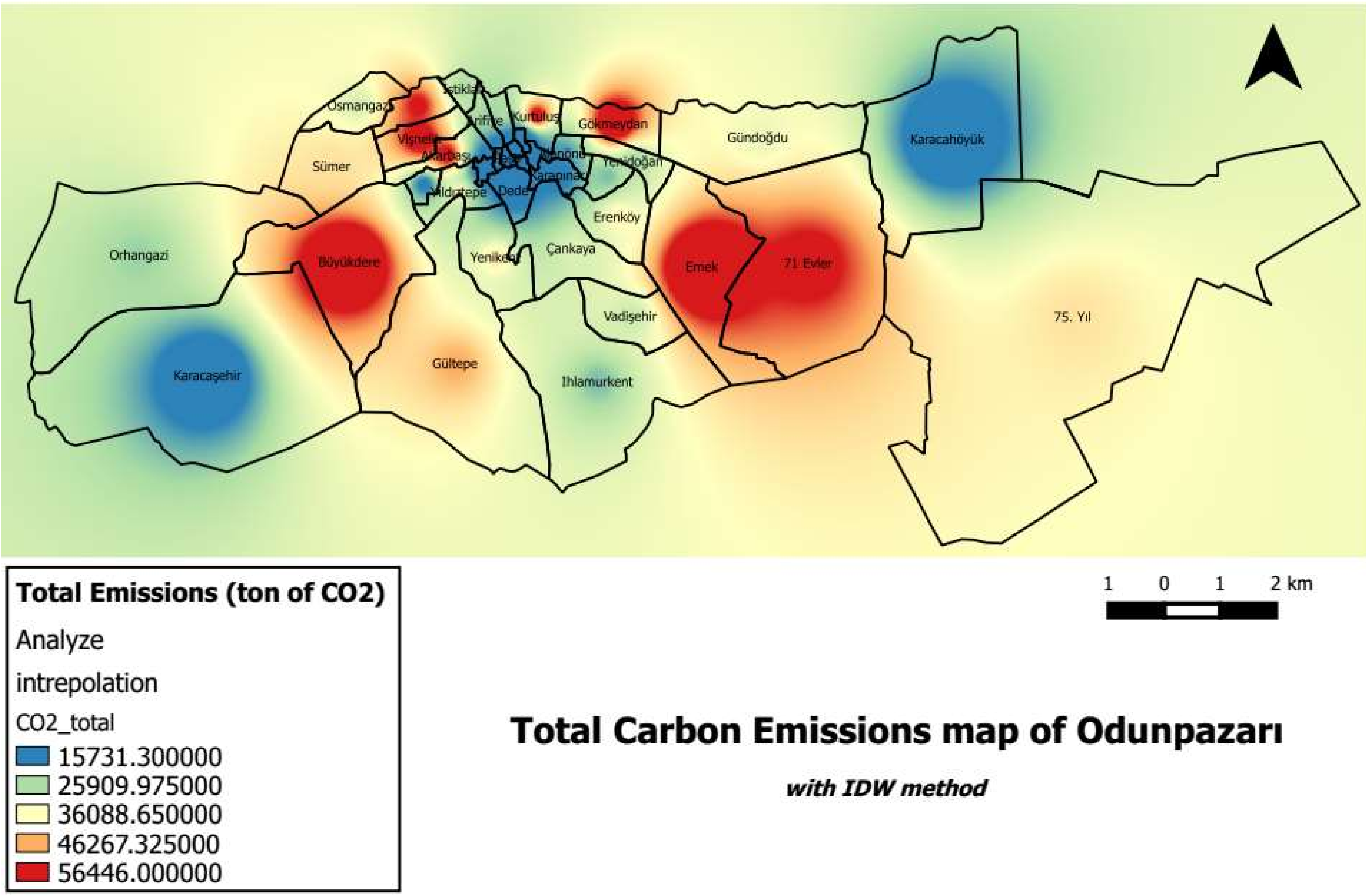

Figure 4.11. *Total CO_2 emissions map with IDW method*

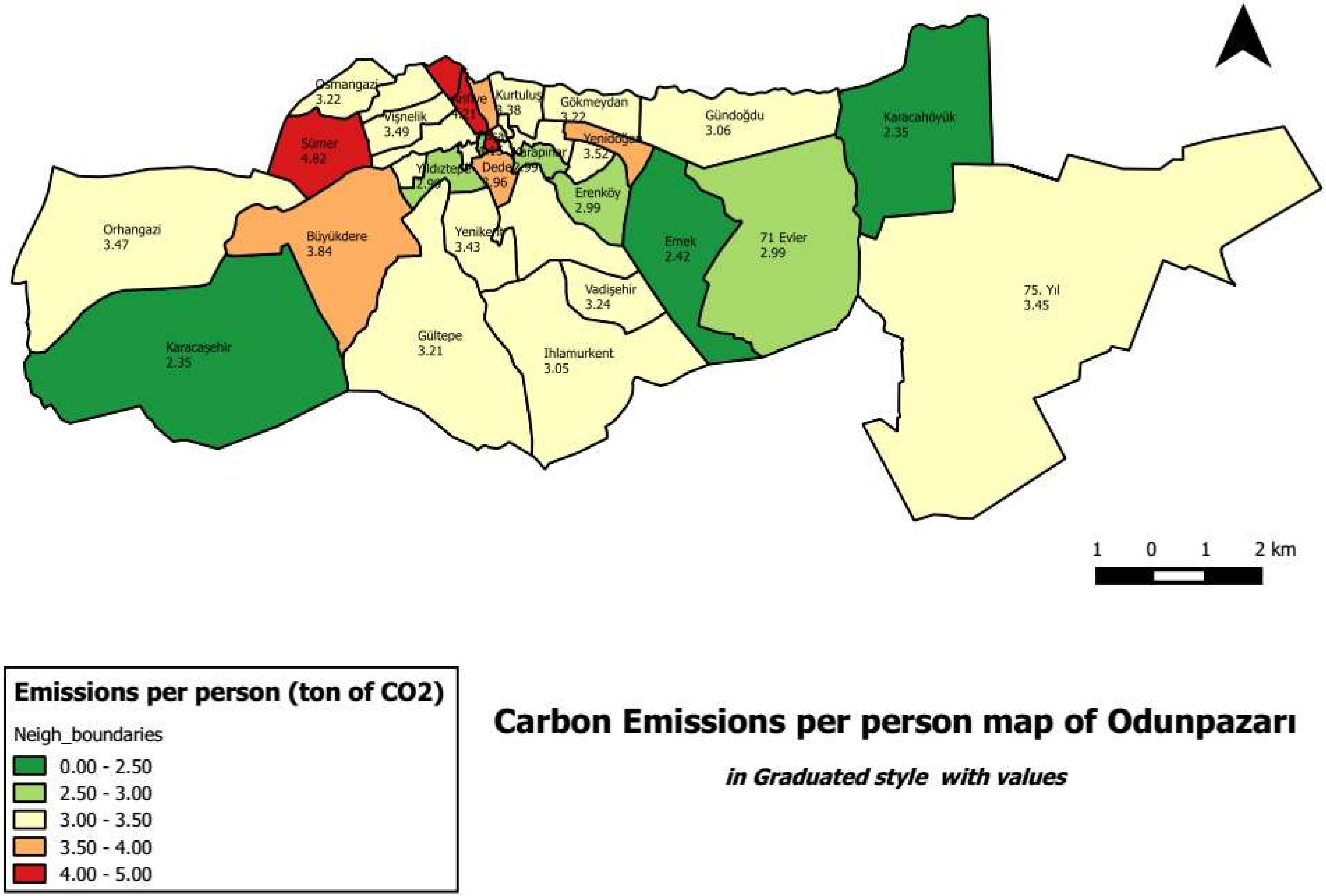

Figure 4.12. *CO_2 emissions per person map in Graduated style with values*

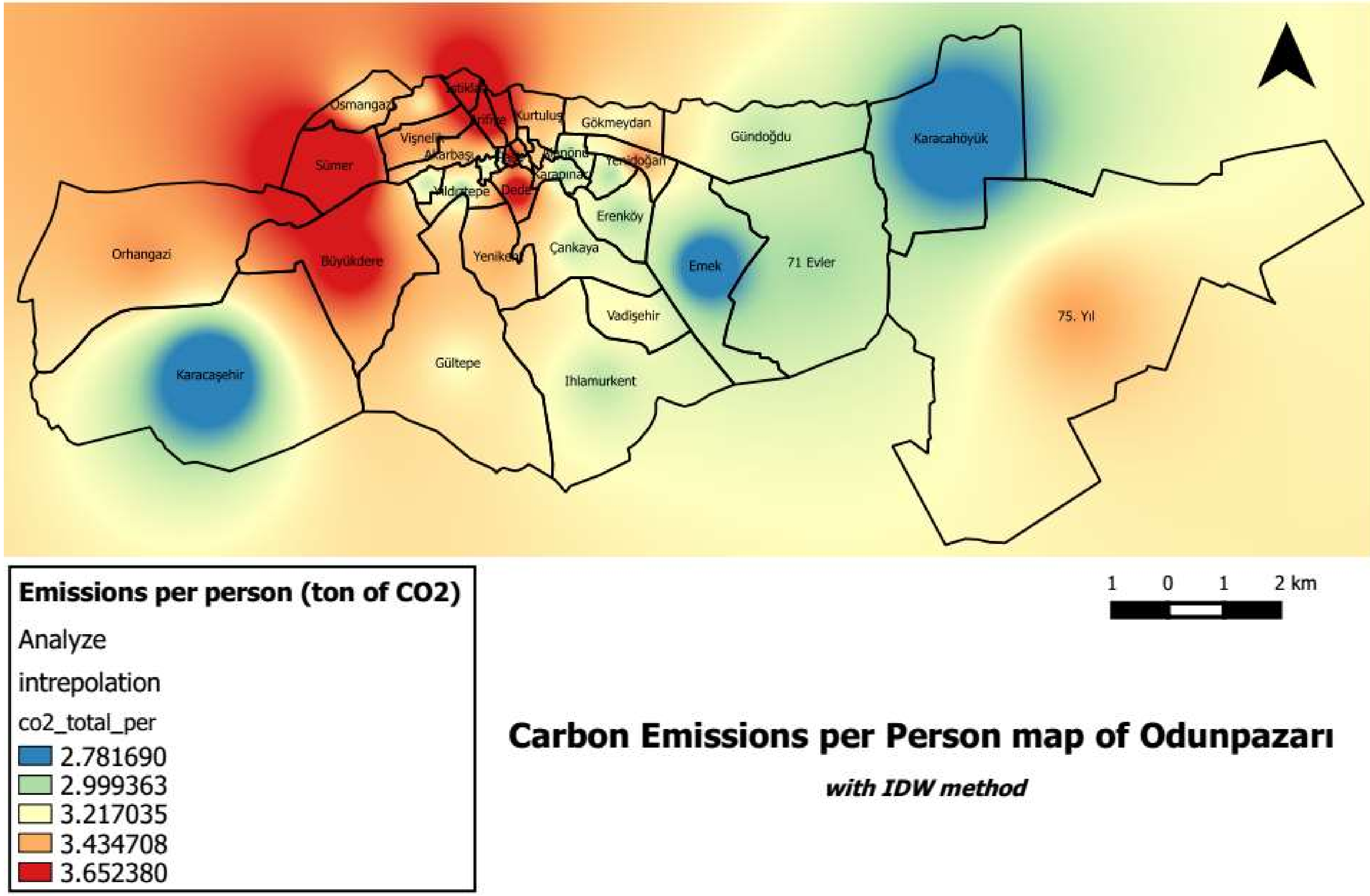

Figure 4.13. *CO_2 emissions per person map with IDW method*

4.4.NDVI

4.4.1. Clipping the satellite image in QGIS

The main file from USGS of Eskişehir region was extracted and stacked in a multispectral image, with bands ranged from 1 to 7. The Geoprocessing Tool ***Clip*** of QGIS has been applied. Then, that image was clipped according to the city limitations Layer (**sinir** in QGIS) in order to get a multispectral image of Odunpazarı district. The outputs, displayed in infrared color are shown below:

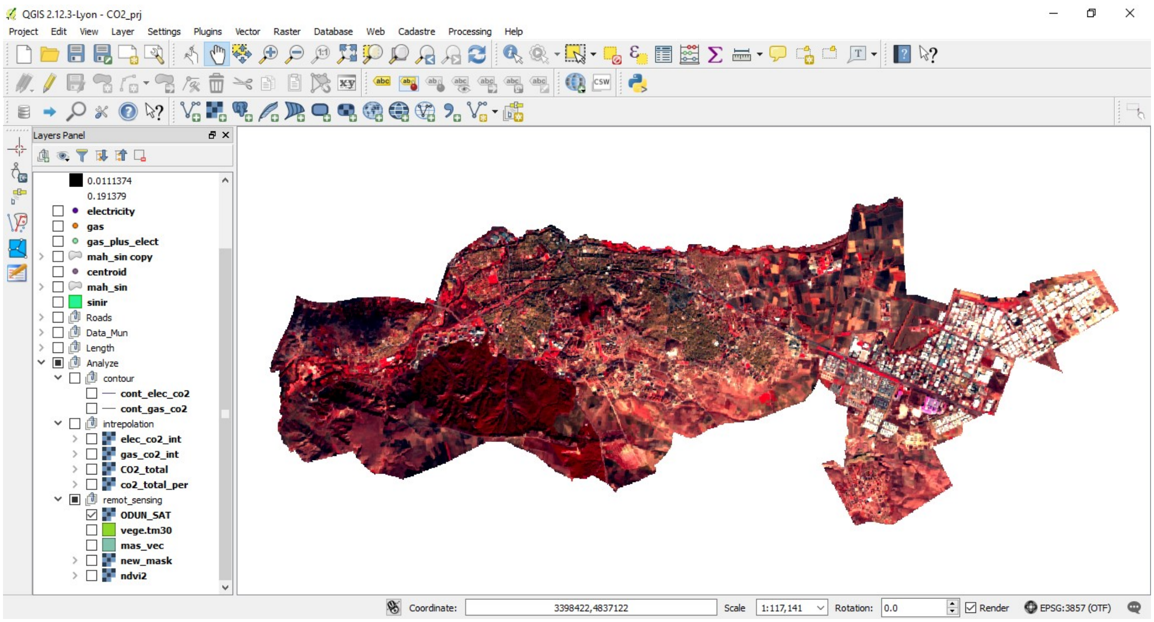

Figure 4.14. *Image clipped of Odunpazarı district*

4.4.2. Performing calculations in GRASS GIS

Then, moving to GRASS GIS, and using ***Raster Map Calculator*** tool, the calculation was performed as shown in the next figure.

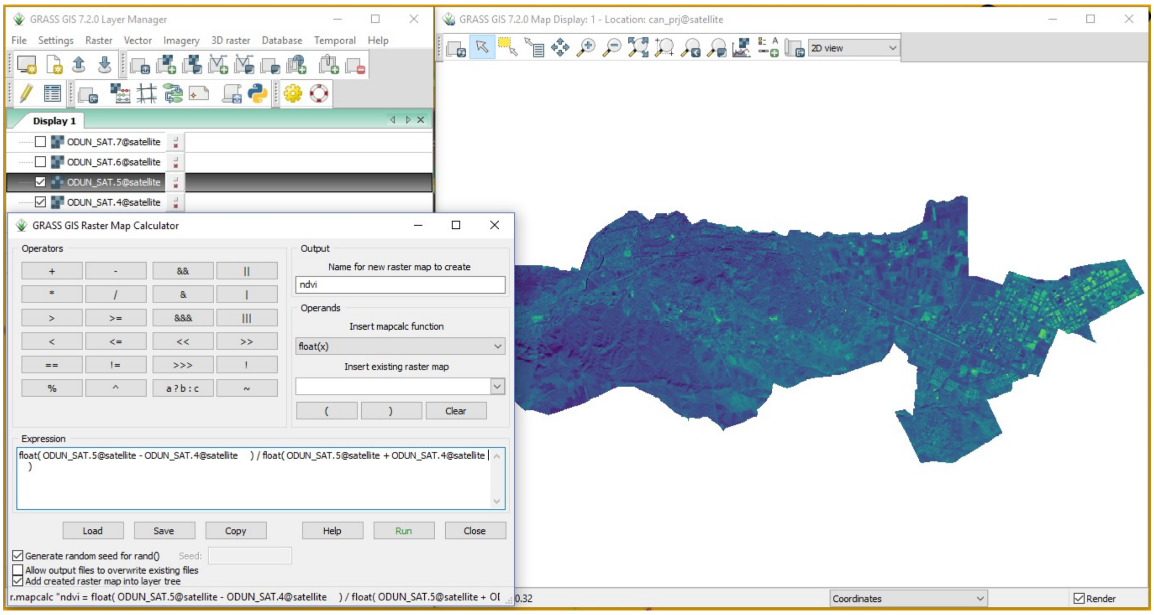

Figure 4.15. *Expressions for NDVI calculation*

4.4.3. Opening results in QGIS

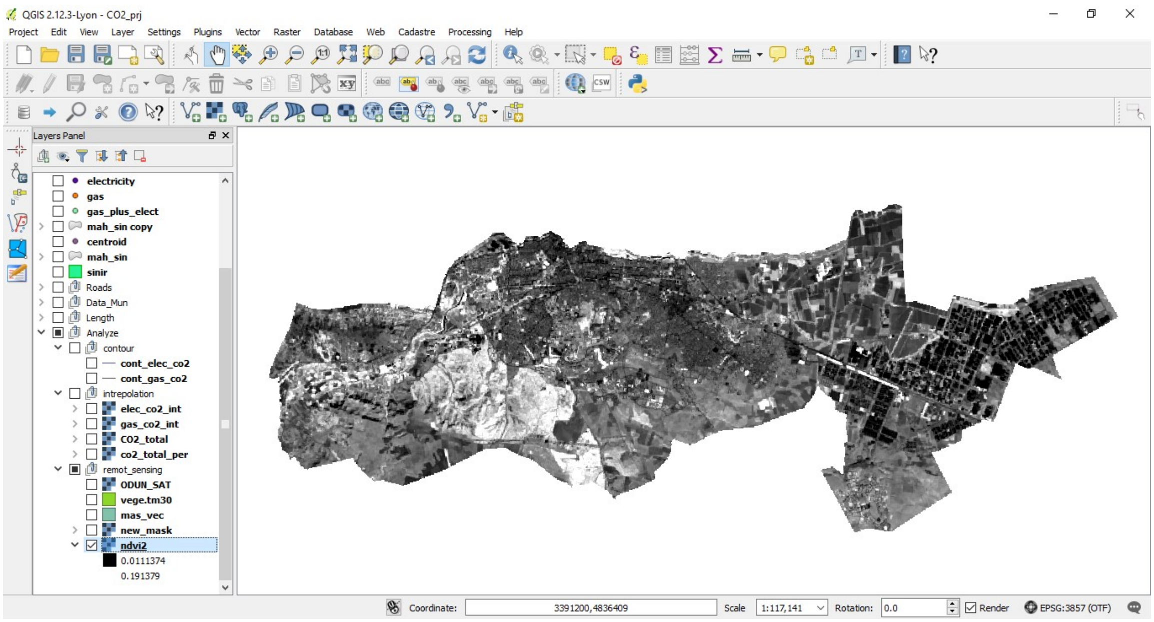

Figure 4.16. *NDVI image of Odunpazarı in QGIS*

Looking at the histogram of the raster obtained, it is shown that the minimum value of pixel is **0.0111374**, and the max is **0.191379**, as well as the statistical distribution of the map.

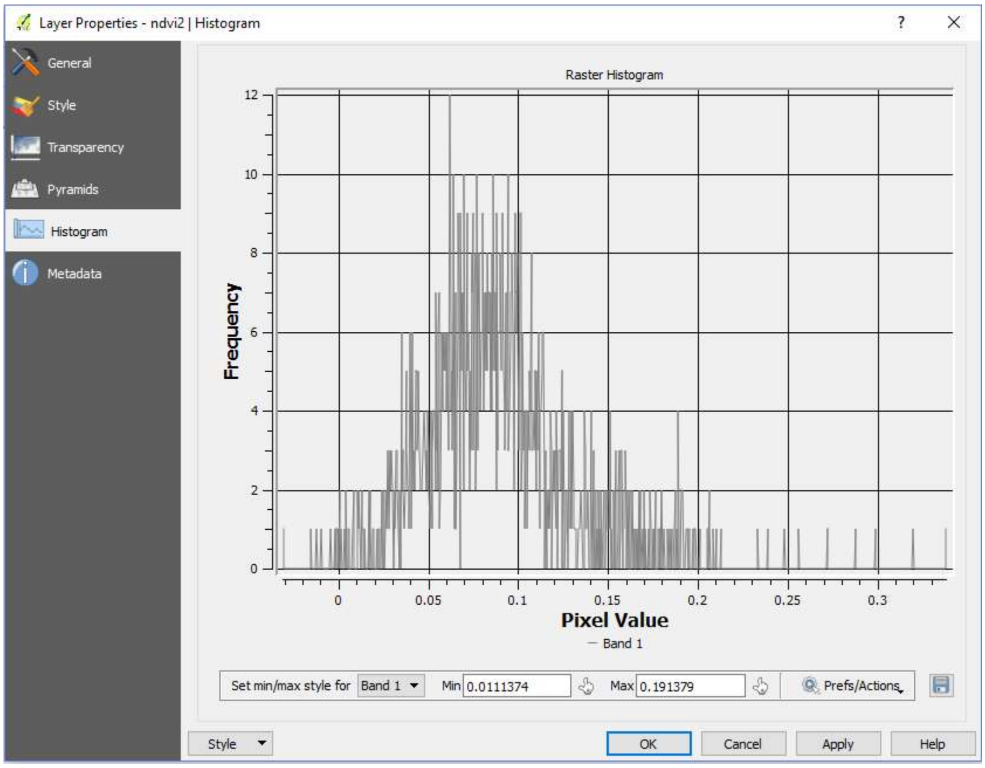

Figure 4.17. *Histogram of the NDVI image*

According to this statistical distribution and the photo-interpretation of that image, the value of **0.15** was selected as minimum pixel value of vegetation. A new calculation was performed then in GRASS to filter values of NDVI greater or equal to **0.15**. The results are dragged into QGIS and show this:

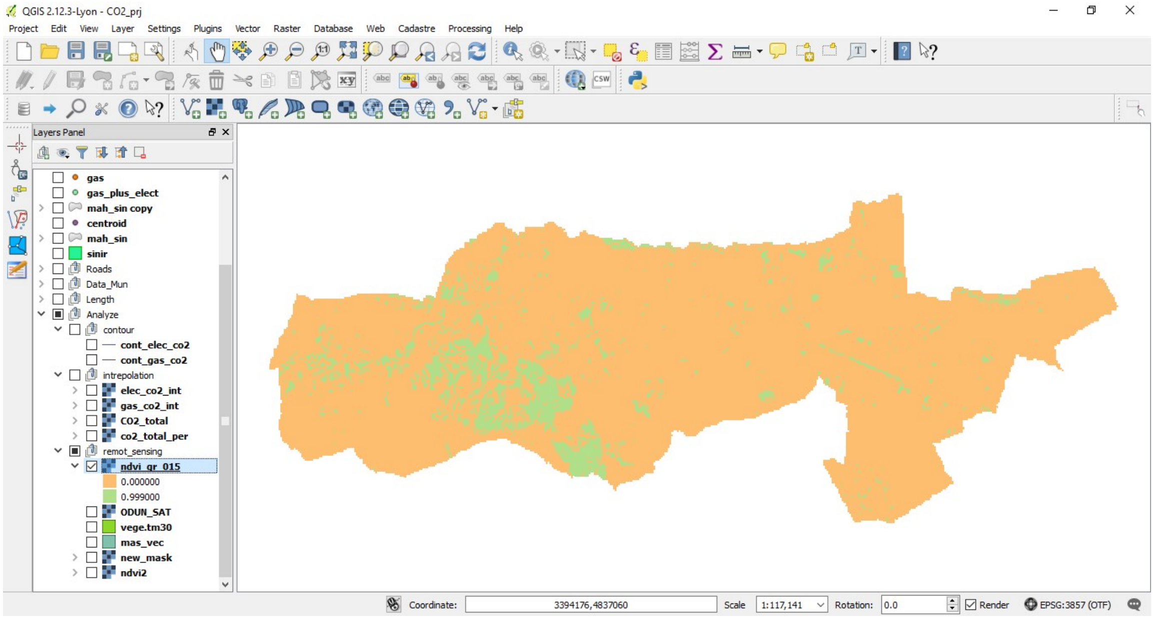

Figure 4.18. *NDVI image of values greater or equal to 0.15*

After that, the conversion tool ***Polygonize*** of QGIS was used to convert these outputs into vector files. As well, green areas were selected and saved as new shapefile. See next figure.

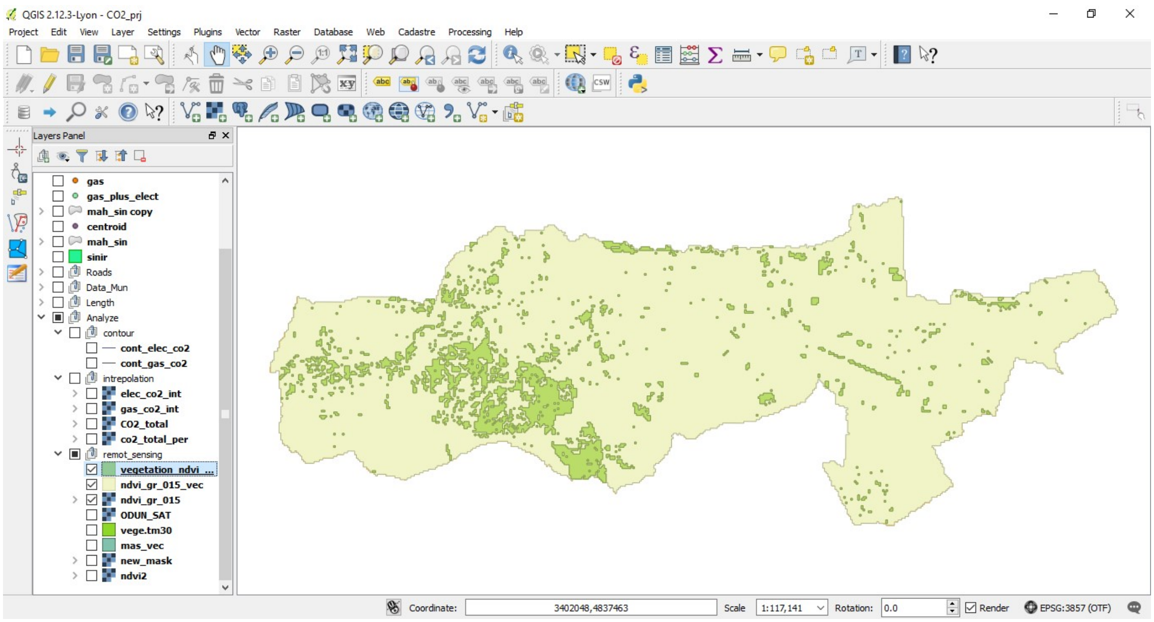

Figure 4.19. *Green areas obtained from NDVI image*

CHAPTER V

DISCUSSION

For the electricity calculations, the results reveal that the carbon emissions related to electricity consumption of the Odunpazarı district are estimated to be **893179.865** ton of CO_2 in 2016. And 8 neighborhoods have higher carbon emissions than the rest. These are: Emek, Büyükdere, Gökmeydan, 71 Evler, Vişnelik, Kurtuluş, Akarbaşı and Kırmızıtoprak. The highest emitter being Emek with **109586.01** ton of CO_2, followed by Büyükdere with **64729.89** ton of CO_2 released into the atmosphere for the whole year of 2016; while the lowest are Karacahöyük with **138.875** ton of CO_2 and Karacaşehir with **567.115** ton of CO_2 released for the same year. What could appear to be normal considering that Karacahöyük aside Karacaşehir are very less developed and urbanized compared to Emek or Büyükdere two big and very crowed neighborhoods.

For the natural gas calculations, the observed outputs show something a bit different from the previous calculations. Büyükdere neighborhood is indeed the highest emitter of carbon and peaks at **41029.584631** ton of CO_2 released by the year 2016, which is almost double the amount of Sümer and its **20433.404455** ton of CO_2 emitted. In addition, the total of CO_2 emissions related to the natural gas consumption was calculated for all the neighborhoods, and reveal an amount of **369471.915** ton of CO_2 released by the year 2016. It almost half of the amount released in electricity.

However, it is essential to be mindful that data collected in this study was just coming from natural gas, but still other sources such as coal are also more used in some neighborhoods than the natural gas, which might explain the lowest amount of carbon emissions noticed in these neighborhoods.

As well, in the study, natural gas consumption was not found for Karacahöyük and Karacaşehir neighborhoods, therefore, calculations of CO_2 emissions have given null results.

Now, when the electricity and natural gas are taking into consideration totally, the final output shows almost the same results as for electricity; Emek aside Büyükdere coming firsts with respectively **112489.34** and **105759.47** ton of CO_2 released into the atmosphere. The overall carbon emissions of the Odunpazarı district by the year 2016 are estimated to be **1262651.780** ton of CO_2. This gives an average value of **3.33** ton of CO_2 emitted per person in 2016 for the only district of Odunpazarı.

In 2010 the average value of carbon emitted for Turkey was estimated to be **5.51** ton of CO_2 per person compared to **3.39** ton of CO_2 per person in 1990. The world average being **4.29** ton of CO_2 per person [39].

According to the website CO2-earth, the total carbon emissions in 2012 were estimated to be **9.7 billion** of ton of CO_2. This amount is the highest increase rate in the last 10 years [40].

In Eskisehir 2012, the same study conducted by Cengiz Türe - though using more parameters - were given a total of **4427895.2** ton of ton of CO_2, with an average value of **6.7** ton of CO_2 emitted per person [17]. While adjusting some parameters to fit with our scopes and tier, the average value of **2.36** ton of CO_2 per person regarding electricity and natural gas was estimated for Odunpazarı district in 2012. However, among the results obtained in 2016, only 2 neighborhoods (Karacahöyük and Karacaşehir) have an emission per person less than

2.36. For the rest, these values start from **2.96** until reaching **4.82**. This might seem normal, due to the fact that for these couple of neighborhoods, only electricity data were provided. In other words, that means almost all the neighborhoods have considerably increased their carbon emissions since 2012. Indeed, in 4 years the emissions increased from 2.36 to 3.33 per person.

Finally, NDVI map, thanks to it histogram, showed that some neighborhoods had vegetation, regarding pixel values above or equal to 0.15. It is then possible to say that these green areas could be very useful, and took into consideration to decrease the amount of CO_2 released every year into the atmosphere.

CHAPTER VI

CONCLUSION & RECOMMENDATIONS

The aim of this study was to calculate and analyze carbon dioxide emissions from road traffic and housing energy consumption by the year 2016, at the level of Odunpazarı district of Eskişehir regarding each neighborhood. The traffic data could not be obtained for this study. So, due to this, only natural gas and electricity consumption by the year 2016 was used for this research. A huge amount of data were collected for this purpose during the preparation stage, some data were tabular type and the others were spatial type (vector and raster). Therefore, the use of GIS (and at a certain level the use of remote sensing) was significant for managing these data and QGIS was chosen as main application of the study.

This study used calculations methods based mainly on IPCC guidebook 2006 volume 2 about Energy and climate.

The different steps throughout this study were essentially:

- Converting various data collected into MWh unit;
- Setting values of emission factors related to each sector;
- Limited the scope and tier to be used in every sector;
- Performing calculations according to each sector;
- Analyzing the results obtained;
- Displaying these results into the GIS application;
- Comparing these results.

As results, the amount of carbon dioxide estimated and displayed over the district of Odunpazari demonstrated that there was a constant increasing of carbon dioxide released into the atmosphere over the years. If 4 years ago in 2012, the average estimation of carbon emitted was 2.36 ton per person, last year in 2016 this value increased to an average of 3.33. Either almost 1 ton of CO_2 more in 4 years.

The NDVI was used as a very powerful remote sensing tool to identify green areas, especially natural forests that could be used in a way of decreasing carbon emissions.

The present report represents a first level of inventory that decision makers can use to support a better environmental policy, firstly within the city and maybe extend it to a large scale.

In this study, because of the availability, we just talked about 2 emission sectors (Electricity and Natural gas) among several emission sectors that actually do exist. So in the further works, for more accurate result, we regardless need to includes these sectors as well as enlarge our study region to the full city of Eskisehir. Doing so, another step for developing a methodology to estimate the total amount of carbon emissions produced by the whole Turkey will be set. In the meantime, try to figure out this amount for the whole city must be the next challenge.

As well, this study was carried out using data consumption for the whole neighborhoods instead of each separated building, residential areas, industrial and commercial areas, so that the result might be more accurate. But unfortunately finding these data were a bit difficult. According to the availability of such data, hopefully many project and studies to come will follow this way, and concern these major issues of nowadays called global warming and climate change.

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