ECOLOGICAL FOOTPRINT AS AN INDICATOR FOR REGIONAL SUSTAINABLE DEVELOPMENT: TURKEY, BURSA, KADIKOY

by

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ABSTRACT

Sustainable development is constantly gaining ground among the methods which measure whether an area is developing in a sustainable way, with ecological footprint to be the major index for assessing of the sustainability of a region. As Turkey constitutes one of the major rising economies; this study calculates and analyzes its ecological footprint both with them of Bursa and Kadikoy. Bursa is both a rural and provincial city among the most developed regions of Turkey while Kadikoy is one of the most crowded rural counties. These similar and contradicting characteristics of both places were the reasons for their choice in this study. In 2002, the per capita ecological footprint of Turkey was 5.78 gha and by 2011 it increased to 6.59 gha while that of Bursa in 2011 was 3.49 gha. Additionally, the ecological deficit of Turkey worsened, as from 3.78 gha in 2002 it increased to 4.81 gha in 2011. Simultaneously the ecological deficit of Bursa was again lower than that of the whole Turkey reaching 1.69 gha in 2011. Moreover, the per capita carbon ecological footprint of Kadikoy reached the 2.362 gha being the highest compared to the respective ones of Turkey and Bursa. Finally, from the eco-efficiency calculation it is inferred that its performance noted an overall improvement during that period, but again that of Bursa was higher by 1149 US $.

ÖZET

Bir bölgenin sürdürülebilirliğinin değerlendirilmesi için kullanılan yöntemler arasında, bir alanın sürdürülebilir bir şekilde gelişip gelişmediğini ölçen sürdürülebilir kalkınma başlıca gösterge olan ekolojik ayak iziyle, birlikte sürekli olarak önem kazanmaktadır. Bu çalışma, önemli yükselen ekonomilerden biri olan Türkiye'nin ekolojik ayak izini ölçme ve değerlendirmekte ayrıca aynı analizi Bursa ve Kadıköy için de yapmaktadır. Bursa ve Kadıköy yükselen bu coğrafyada en kalabalık bölgelerinden ikisi olmakla birlikte, tamamen farklı coğrafi özelliklere sahip durumdadırlar. Bursa hem kırsal hem de kentsel özellikleri taşırken Kadıköy en kalabalık kentsel bölge özelliği sergilemektedir. Bursa ve Kadıköy, benzerlik ve farklılık taşıyan karakteristik özellikleleri nedeni ile bu çalışmaya konu edilmişlerdir. 2002 yılında, Türkiye'de kişi başına düşen ekolojik ayak izi 5.78 küresel hektardı,2011 yılında Bursa'daki küresel hektar 3.49 iken, Türkiye'de bu 2011 yılına kadar 6.59 küresel hektar oranına yükselmiştir. Ayrıca, 3.78 küresel hektar olarak 2002 yılından itibaren 2011 yılına kadar 4.81 küresel hektara yükselen Türkiye'nin ekolojik açığı daha da kötüleşmiştir. Aynı anda Bursa'nın ekolojik açığı, 2011 yılında 1.69 küresel hektara ulaşarak Türkiye genelinde yeniden daha düşük olarak gerçekleşmiştir. Ayrıca, Kadıköy`ün kişi başına karbon ekolojik ayak izi, Türkiye ve Bursa ile ilgili olan değerlere göre kıyaslandığında, en yüksek oran olan 2.362 küresel hektara ulaşmıştır. Son olarak, eko-verimlilik hesaplamasından performansının o dönem süresince genel olarak bir iyileşme kaydettiği anlaşılmaktadır, ama yeniden Bursa`da olduğundan 1149 ABD Dolar daha yükselmiştir.

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LIST OF SYMBOLS/ABBREVIATIONS

Symbol	**Explanation**
ADNKS	Adress Based Population Registration System
EQF	Equivalence Factor
EBM	Ecosystem-Based Management
GCI	Global Competitiveness Index
GFN	Global Footprint Network
GHG’s	Greenhouse Gases
GDP	Gross Domestic Product
IEA	International Energy Agency
IMF	International Monetary Fund
IMM	Istanbul Metropolitan Municipality
NCCS	National Climate Change Strategy
RES	Renewable Energy Sources
SD	Sustainable Development
TURKSTAT	Turkish Statistical Institute
UNFCCC	United Nation Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WWF	World Wide Fund for Nature
YF	Yield Factor

Symbol	Explanation	Units used
Bbl/day	Barrels per day	-
BC	Biocapacity	gha
BCF	Billion cubic feet	-
CO_2	Carbon emissions	-
DR	Discard rate for by catch	-
EF	Ecological Footprint	gha
EXTRD	Mass ratio of derived product	-
FAF_D	Footprint allocation factor	-
gha	Global hectare	-
GWs	Gigawatts	-
Km^2	Square kilometers	-
MMCF	Million cubic feet	-
Mmst	Million short tons	-
Mtoe	Million tons of oil equivalent	-
MWs	Megawatts	-
NPP	Net primary production	-
PP_S	Total sustainably harvestable primary production requirement	-
S_{OCEAN}	Fraction of anthropogenic emissions sequestered by oceans	CO_2
TCF	Trillion cubic feet	-
TE	Transfer efficiency of biomass	-
TEP	Ton of Equivalent Petroleum	-
TFR	Total feed requirement	-
TL	Trophic level of fish species	-

1. INTRODUCTION

Soil, water, air and every form of life within them are in constant interaction with each other by creating a system of natural environment. However, over the last years, the rapid growth and development of industry in favor of the economy has been associated with the continuous shrinking of the natural environment and the emergence, development and evolution of major environmental problems; from the effects of which the sustainability of the global environment has been jeopardized.

The most important environmental problems result from the excessive consumption of natural resources and environmental pollution. Hence, in the effort of humankind to deal with these problems a method that has become increasingly popular among academics and practitioners is that of Sustainable Development (SD), which imposes a different way of living and development, equally shared between economic, environmental and social sector (Murty et al., 2008). Consequently, the measure which is used to monitor sustainable development is known as the Ecological Footprint (EF).

In this study, the sustainability of Turkey and two regions located in Turkey one urban and non-urban are investigated and assessed with the aim of making measure of a comparison between their ecological footprints. Not only the changes of the values of ecological footprint in the time series analysis were taken into account, but it was also examined whether economic development is attained in a sustainable way too. In 2011-2012, according to the Global Competitiveness Index (GCI), Turkey was 59th in rank, while in 2012-2013 it succeeded to move into the 43rd place (Schwab, 2012). The fact that Turkey is defined as one of the fastest growing economies, as well as a newly industrialized country (IMF, 2012) will be investigated so as to examine whether the economic development is associated with the negative impacts and the pressure that burden the environment. So, by introducing the concept of eco-efficiency, sustainability of Turkey is analyzed from an economic perspective by investigating the relationship between ecological footprint and economic growth.

1.1. Organization of the Thesis

The remainder of the thesis is structured as follows. Chapter 2 comprises of the theory and principles of Sustainable Development and Ecological Footprint followed by a short discussion about Eco-Efficiency. Moreover, a general idea and a brief reference about the regions that were studied, particularly on the focus of Turkey, are given. In Chapter 3, the methodology of ecological footprint that was used is presented. Subsequently, Chapter 4 displays the data that were collected, necessary for the calculations. In Chapter 5, the data have been elaborated on, the results are assessed and analyzed separately for each area and possible solutions are proposed. The conclusions of our work are presented in Chapter 6. Finally, database table specifications for the global average bioproductivity and Turkish average bioproductivity are given in Appendices A and B respectively.

2. LITERATURE SURVEY

2.1. Sustainable Development

SD is a controversial term with many given meanings. The most popular and frequently quoted definition is that given by Brundtland Commission, which reports and states that SD is “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In this definition two key concepts are contained:

- The concept of needs; where an overriding priority should be given to the essential needs of the world’s poor, and
- The concept of limitations, where the environment’s ability to meet present and future needs is inflicted by the state of technology and social organization (WCED, 1987).

SD means the mutual and equal economic development, social development and environmental protection. Essentially, the concept of sustainable development is based on the fact that social, economic and biophysical systems are absolutely interdependent, so social and economic systems could never exist without the biophysical environment as they depend on it now and in the future for their existence. More practically, SD is the result of the growing concerns of humans about the rising environmental problems combined with social-economic issues that are related with poverty, inequality and the precarious future of human health (Hopwood, Mellor & O’Brien, 2005). The core of SD is that world is seen as a united system where time and space are connected and absolutely related. To be able to represent the progress in SD several approaches have been adopted. EF constitutes such an approach.

2.1.1. Ecological Footprint

EF is an environmental sustainability indicator which can calculate the sustainability of an area, economy or population through the measurement of the pressure that society exerts on environment by linking the social and economic metabolism with land use. Hence, EF represents the human consumption of resources and waste generation compared to the productive capacity of the biosphere (biocapacity). It compares the biologically productive land and sea area needed to re-produce the resources that humans consume through their activities and absorb correspondigly the generated waste, through the use of prevailing technology and resource management. Substantially, EF is a consumption-based indicator involving all natural capital used directly or indirectly for domestically produced or imported goods and services which local population consumes and removing the natural capital used for exported goods and services (Wackernagel et al., 2002). The land area and sea area are expressed in global hectares (gha) for being easier the measurement of different land use types with different productivity (Haberl et al., 2003). According to Wackernagel et al. (2002), EF and biocapacity accounting are based on six fundamental assumptions:

1. The majority of the consumed resources and generated waste by people or their activities can be tracked and quantified.
2. Most of these resource and waste flows can be measured in terms of the biologically productive area necessary to maintain them but those that cannot be measured in terms of biologically productive area are excluded from the assessment by leading to a systematic underestimation of the true ecological footprint.
3. When each area is calculated in proportion to its bioproductivity then different types of areas can be calculated and converted into the common unit of average bioproductivity, the global hectare.
4. Because a global hectare represents only a single use and all global hectares in any given year represent the same amount of bioproductivity, they can be rounded up so as to give up an aggregate indicator for EF and biocapacity.

5. As both EF and biocapacity are expressed in global hectares, human demand is expressed as an ecological footprint that can be directly compared to biocapacity either if it is global, regional, national or local.
6. The demanded area can exceed the available area if demand of an ecosystem exceeds its own regenerative capacity. When human demand exceeds available biocapacity, it is referred to as an 'overshoot'.

According to Global Footprint Network (GFN) and in cooperation with Ewing et al. (2008a), there are six categories of EF and biocapacity: cropland, grazing land, forest land, fishing grounds, carbon and built up land footprints. The size of EF is in direct ratio to environmental impact and indirect ratio to the available land area for productive biological use per capita with a larger ecological footprint meaning a larger environmental impact and less available land area for productive biological use per capita respectively.

Cropland consists of the most bio-productive land area and represents the land areas used for food and fiber production for human consumption and oil crops and rubber production for feed for livestock. Grazing land consists of areas used to raise livestock for meat, dairy, and wool products. In contrast to cropland, grazing land is situated in the least suitable available land area of a country. Moreover, forest land area represents the amount of forest needed to supply lumber, timber, pulp and fuel wood production. Additionally, the fishing grounds footprint is calculated according to the annual primary production that is needed to sustain aquatic species that are harvested. Built-up land area is the land area that is covered by human infrastructure such as transportation, housing, industrial structures, and reservoirs for hydro power. Lastly, the carbon footprint is calculated according to the forest land area that is required to absorb the carbon emissions emitted by humans excluding the carbon emissions absorbed by the oceans (Ewing et al., 2008b).

Moreover, from the comparison of EF of a population with its corresponding biocapacity, the difference that occurs is known as ecological deficit or ecological reserve. An ecological deficit exists when the EF of a country or region exceeds the biocapacity of the land area available to that region while, an ecological reserve occurs when the biocapacity of a region or country exceeds the respective EF of its population. When an ecological deficit is present, it means that this region or country for being able to deal with the needs of its population, is importing biocapacity through trade, liquidating its own natural resources, or emitting wastes into the global atmosphere or oceans (Ewing et. al. 2010a).

2.2. The Concept of Eco-Efficiency

Eco-Efficiency is another indicator that promotes SD through the combination of both economic and environmental variables by measuring the environmental performance of a region or an enterprise with respect to economic performance. Hence, it is calculated as the ratio of the added value of production divided by the added environmental impacts coming from production (Vachon, 2012). According to the World Business Council for Sustainable Development (WBCSD), eco-efficiency is based on the concept of producing more goods and creating more services by using fewer resources, creating less waste and generating less pollution. The target of eco-efficiency was defined by WBCSD and it was described as a state where economic activity should be "...at least in line with the earth's estimated carrying capacity" (WBCSD, 1992). The way under which eco-efficiency can be achieved is through " the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity…" (Schmidheiny, 1992).

2.3. Country-Level Analysis: Turkey and its Situation of Energy Management

Turkey is a country which has the characteristic of being located both in Europe and Asia (Figure 2.1) and occupies a land area of 769630 km2 with a population of 74,724,269 citizens in 2011. The economy of Turkey relied strongly on agriculture and heavy industry, however, in recent years the economy has been in transition and service sectors have begun to play a more important role. In 2001, Turkey succeeded to exit from a severe economic crisis and since then it has been steadily growing. As far as the energy sector is concerned, in 2011, according to the Oil & Gas Journal, Turkey’s oil reserves were estimated to be 270 million barrels and its natural gas reserves at 218 billion cubic feet (BCF). Its oil production in 2009 was 52.98 thousand barrels per day (bbl/day) and its oil consumption was 580 thousands bbl/day. In general, in 2009 the primary energy production and consumption was equal to 30 and 106 million tons of oil equivalent (Mtoe) respectively (Toklu, 2012).

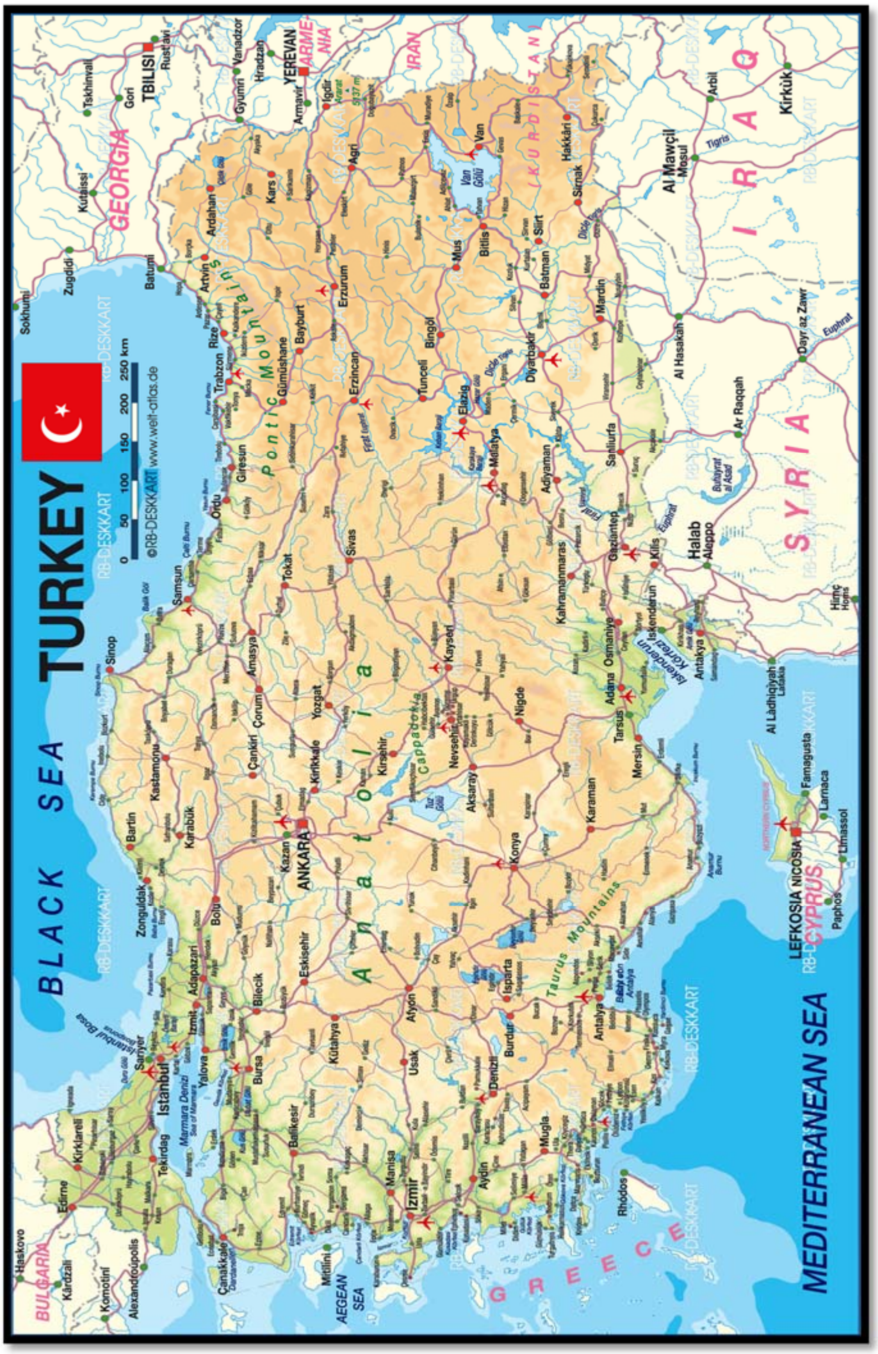

Figure 2.1. Map of Turkey

As a fact, Turkey does not constitute a major oil producer as it imports the majority of its oil. In 2009, it imported a 90% percentage of its total consumption. Its natural gas production in 2009 was 25 million cubic feet, while its consumption was 1.2 trillion cubic feet with numbers to show that imports made up the balance. In 2009, coal production in Turkey was 218 BCF with consumption at 102.5 million short tons (MMst) of total primary coal and imports 22 MMst. Nuclear power does not exist in Turkey but there are plans for the construction of nuclear power plants by 2030. The total Carbon Dioxide emissions from consumption of energy from fossil fuels were estimated to be 253.057 million metric tons (EIA, 2009).

As far as renewable energy is concerned, its production constitutes a 14.4% percentage of the total primary energy supply (Benti, 2012). In 2009, Turkey's solar energy generation volume was 750,000 m², wind energy generation volume to 802.8 megawatts (MWs), geothermal installed power to 77.2 MWs and energy from biomass to 66 thousand ton of Equivalent Petroleum (TEP) (Yuksel and Kaygusuz, 2011). At the end of 2010 Turkey was 2nd in the world wide ranking with an 8.4 GWth solar hot water installed capacity. Moreover, Turkey has a target for wind energy to reach 20 gigawatts (GWs) by the year 2023 and 30% percentage from the existing 20% for the share of electricity from renewable energy (REN21, 2011; Wennerstern and Spitsyna, 2009). With the current traditional energy sources and the growing population of Turkey, energy capacity will not be enough for the population. As a result, for Turkey to have a sustainable and secure energy future with less Greenhouse Gases (GHGs) emissions and the possibility of a simultaneous economic growth, the solution of renewable energy sources looks the most attractive (Kankal et al., 2009; Keles and Bilgen, 2012).

2.4. Turkey's Position Against to Climate Change

Under the National Climate Change Strategy (NCCS) and within the framework of United Nations Framework Convention on Climate Change (UNFCCC, 2005 ´´Article 2´´), "common targets but differentiated responsibilities", Turkey plans to combat climate change according to its capabilities. The action plan concerns a 2010-2020 period with measures and policies undertaken at a national level. This period is separated as short-term (within 1 year), mid-term (between 1-3 years) and long-term (over 10 years period). The vision and its basic principles against climate change prevention are based on sustainable development policies. Turkey will try to mitigate its GHGs through energy efficiency and use of more renewable energy sources so as to be able to offer a high quality of life and welfare to its citizens. Some goals undertaken are the decrease of energy intensity by 2020 in comparison to 2004 levels and the increase of a 30% share of renewable energy in total electricity generation by 2023 (Melikoglu, 2012). According to the strategy there must be a monitoring system that will track and report the progress of a more efficient implementation of the plan (NCCS, 2010).

Moreover, on 24 May of 2004, Turkey was acceded to the UNFCCC and as far as Kyoto Protocol is concerned, Turkey became a party of it on 26 August 2009. Therefore, due to the fact that it was not a member of UNFCC when the Kyoto Protocol was adopted, it was not obliged to any quantified emission limitations or reductions under the pre-2012 targets of Kyoto (Post, 2012 Climate Change Negotiaton Guidebook). The fact that Turkey is not obligated to achieve the goals of UNFCCC for GHGs reduction and climate change mitigation does not mean that it has not adopted its own targets.

2.5. From Country-Level to Regional: An Overview of Bursa

Bursa is a city in northwest Turkey located in the region of Marmara and it is the first region of Turkey that was chosen to be included in the study. The fact that it became the first capital of the early Ottoman Empire shows the significance of the region till today. Bursa is one of the most cultural cities of Turkey with many museums, mausoleums, thermal baths, theaters and universities. In 2011, with a population of 2,652,126 citizens it was the fourth most populous city of Turkey. Hence, Bursa is characterized as a rural area; however, with a representative 3.55 per cent of the whole population of Turkey and due to its geographical location and characteristics, it could either be characterized as a rural area.

The most predominant geographical feature of Bursa is the vast presence of green area and that's why it is also known as green Bursa. The parks and gardens in the urban center of the city constitute only a small part of the green area as the rich forests surrounding the region complete the landscape with the whole forest area to be 484,067 ha (Bursa Selected Indicators Report, 2011b).

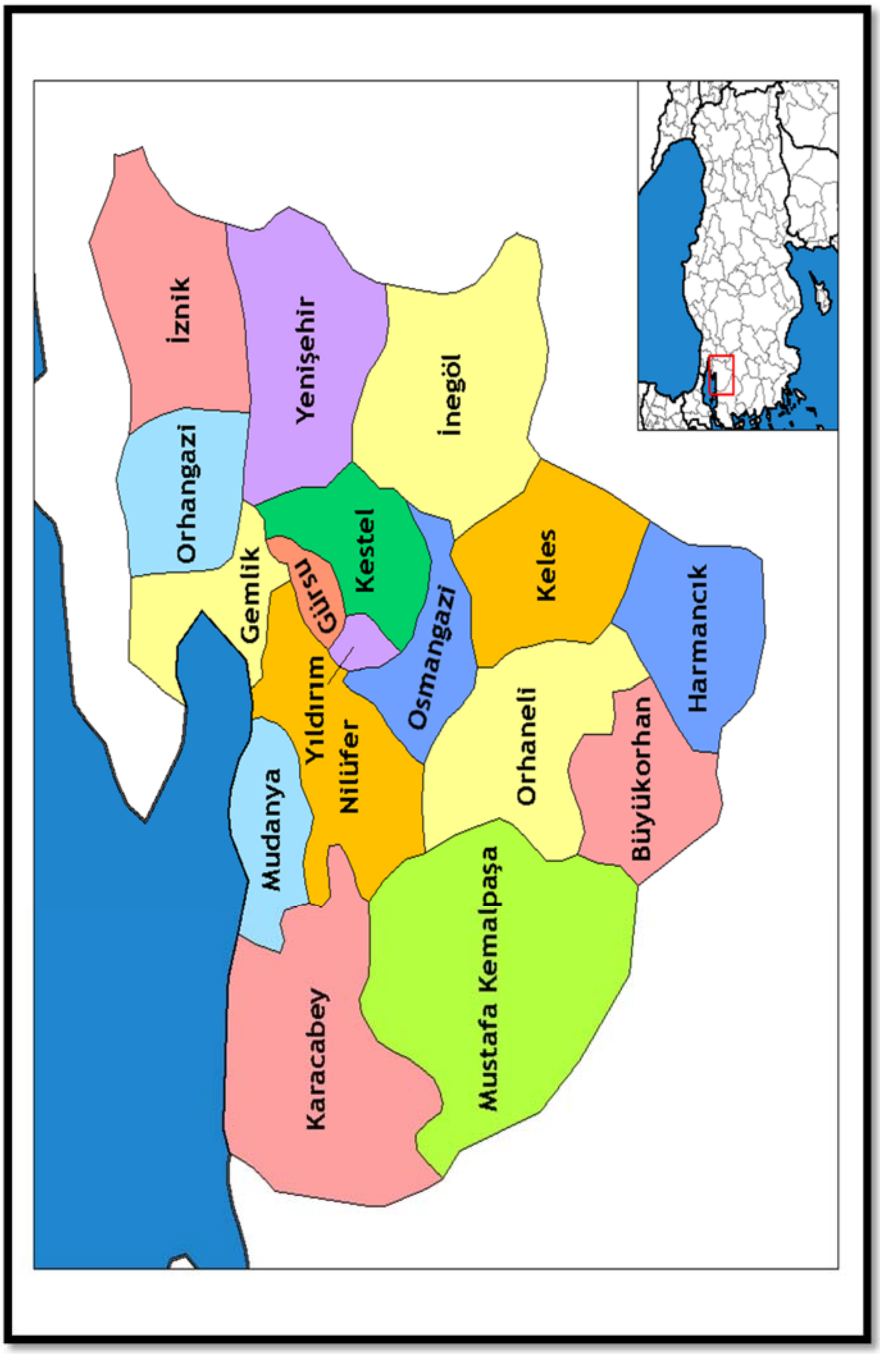

Figure 2.2. Map of Bursa

Historically, Bursa was known for being the center of the silk trade in the Byzantine and Ottoman empires. This has not changed throughout the years as till today it is considered to be a major center for textiles. Additionally, the fact that Bursa is the center of the automotive industry classifies it to be one of the most industrialized regions in Turkey. Renault, Fiat, Karsan, Bosch, Mako and Valeo are some of the brands of motor vehicles and automotive parts whose production procedure takes place in Bursa. Food industries play also an important role in the industrial sector of Bursa as brands such as Coca Cola, Pepsi Cola, Tat, Sutas and Uludag activate in the region. Furthermore, as the soil of Bursa is known for its fertility, agriculture was not possible not be present. Although, last year's agricultural activities have been decreased due to industrial outburst, Bursa produces fruits and vegetables and is widely known for its peaches. Therefore, the exports of Bursa hold an 8.67 per cent of the sum total of Turkish exports giving the region a strong and important part of the Turkish economy. In 2011, the value of exports of Bursa was 11,692 million dollars making it third in rank among the cities of Turkey with the highest exports.

2.6. Facts About a County within Marmara Region: The Case Study of Kadikoy

Kadikoy is the second region of Turkey included in the study. It is located on the southeastern and on the northern shore of the Bosporus Sea and that of the Marmara Sea correspondingly. It is considered as a district that belongs to the province of Istanbul and in 2011, according to the Address Based Population Registration System (ADNKS Address Based Population Registration System Home Page, 2011), its population was 531,997 citizens. Kadikoy became a district in 23 March of 1930 and occupies a land area of 25.2 km2 with no lakes existing. Kadikoy is considered as an urban area as it is one of the most crowded districts of Istanbul with a population density of 21110 citizens per square kilometer. The forest area runs up to 1310.18 m2 and holds an insignificant percentage of the total land area. The built-up land area of Kadikoy is occupied mostly by residences and shops with residential area to dominate. Agriculture area, livestock and industrial sector is insignificant or does not exist at all, with the general economic structure of the region made up of the service sector and the marine sector. Additionally, there is a healthy construction sector mostly because of the wealthy citizens and their willing to acquire a new and detached residence.

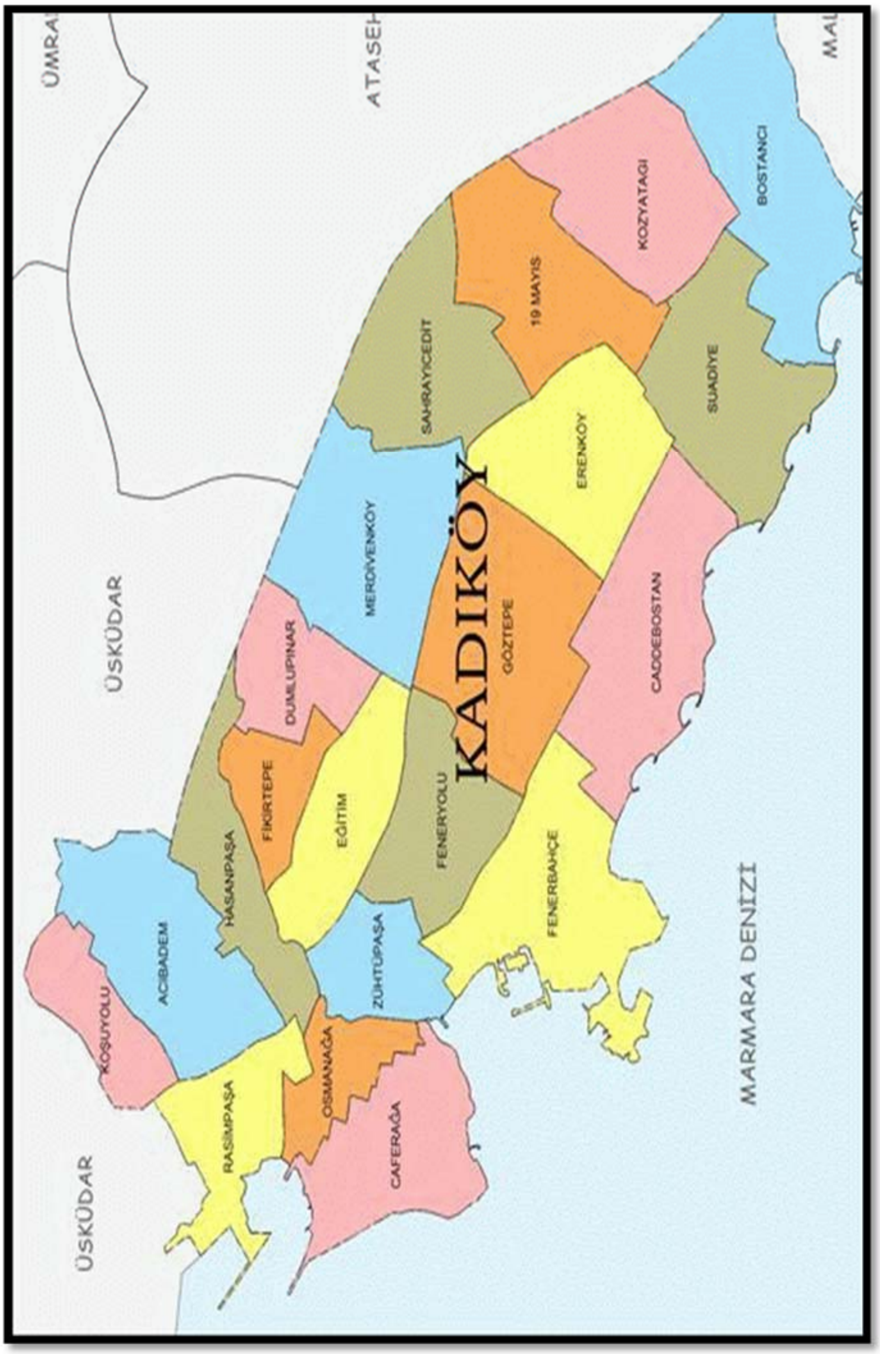

Figure 2.3. Map of Kadikoy

As far as the ecological profile is concerned, Kadikoy is one of the six cities which has signed and therefore participates in the Covenant of Mayors since July of 2012. Like all the members of the Covenant, Kadikoy is committed to reduce greenhouse gas emissions from municipal activity by the year 2020 keeping 2010 emissions as the baseline year. However, the fact that the contribution of municipal activity only makes up for an almost two per cent of the total greenhouse gas emissions shows that the participation into the Covenant of Mayors is not enough for the total reduction of emissions. Kadikoy has proofed loyal to its fight against climate change and in favor of sustainable development by adopting programs such as the “Cities for Climate Protection Campaign” that aims at climate change tackling, energy and water efficiency secure and renewable energy promotion and the “No Plastic Bag!” campaign that in Mart 2012 banned the usage of plastic bags in the area of the district. However, the most important step to that direction was the creation of an inventory for “The Calculation of the Greenhouse Gas Emissions” with 2010 to be the base year (Kadikoy Sustainable Energy Action Plan, 2010).

3. METHODOLOGY

3.1. Ecological Footprint

The study for being able to reach the EF it was relied on the calculation methods developed by GFN in cooperation with Ewing B. et al. (2010a, 2010b). According to GFN, the EF of production represents the primary demand for biocapacity and is calculated as:

$$EFP = P / YN * YF * EQF \quad (3.1)$$

Where EFP = primary demand for biocapacity, P = amount of product extracted or waste generated, YN = national-average yield for product extraction or waste absorption, YF = Yield factor (YF), EQF = equivalence factor (EQF).

YFs capture the difference between local and world average productivity for usable products and they are calculated as the ratio of national average to world average yields:

$$YFL = \sum_{i \in U} Awi \;/\; \sum_{i \in U} Ani \quad (3.2)$$

Where YFL are the local yield factors, U is the set of all usable primary products that a given land use type yields, and Aw,i and An,i are the areas necessary to furnish that country's annually available amount of product i at world and national yields, respectively and they are calculated as:

$$AN,i = Pi / YN \text{ and } AW,i = Pi / YW \quad (3.3)$$

where Pi is the total national annual growth of product i and YN and YW are the national and world yields, respectively. Thus AN,i is always the area that produces i product within a given country, while AW,i gives the equivalent area of world-average land yielding i. Except for cropland, all the other footprint land use types produce only a single primary product. Thus the equation for yield factors will be:

$$YF_L = Y_N / Y_W \tag{3.4}$$

EQFs convert the area of a specific land use type available or demanded into world average biologically productive area units and they are calculated as the ratio of the maximum potential ecological productivity of world average land of a specific land use type and the average productivity of all biologically productive lands on Earth. They vary by land use type and by year and their aim is to measure not only the quantity of biomass produced but also the quality. EQFs calculation assumes that within each country the most suitable land available will be planted to cropland, after which the most suitable remaining land will be under forest land, and the least suitable land will be devoted to grazing land. The EF of consumption (EFC) is calculated according to the following formula:

$$EF_C = EF_P + EF_I + EF_E \tag{3.5}$$

Where EFP is the EF of production, and EFI and EFE are the footprints of imported and exported commodity flows respectively. The EF of consumption is calculated in order to find the direct and indirect biocapacity that is needed to support human's consumption.

The equation for the biocapacity (BC) is:

$$BC = A * YF * EQF \tag{3.6}$$

Where BC is the biocapacity, A is the area available for a given land use type, YF is the yield factor and EQF is the equivalence factor for the country, land use type and year that we look for.

Although EF assessments measure the demand for biocapacity by final demand, the EF is corresponded to the primary harvest or carbon emission. So the tracking of EF in derived products is of great importance. Primary and derived goods are related with product specific extraction rates. The extraction rate for a derived product, EXTRD, calculates its effective yield as:

$$Y_D = Y_P * EXTR_D \quad (3.7)$$

where YP and YD are the yield for the primary product and the effective yield for the derived product, respectively. EXTRD is the mass ratio of derived product to primary input that is required and is denoted as TCFD. It is calculated as:

$$EXTR_D = TCF_D / FAF_D \quad (3.8)$$

This formula helps us to avoid the double counting of the derived products, a problem that originates from the fact that a lot of derived products are created simultaneously from the same primary product. To resolve this problem, the EF of the primary product must be shared between the simultaneously derived goods. FAFD is the footprint allocation factor that allocates the Footprint of a primary product between simultaneously derived goods according to the weighted prices which are represented by the symbol TCF. The prices of derived goods are according to their contributions to the harvest of the primary product. Footprint allocation factor of a derived product (FAFD) is calculated as:

$$FAF_D = TCF_D V_D / \sum TCF_i V_i \quad (3.9)$$

Where Vi is the market price of each simultaneous derived product. For a production chain with only one derived product, then, FAFD is 1 and the extraction rate is equal to the technical conversion factor.

For the calculation of the EF categories, first Cropland EF is calculated according to data on production, import and export of primary and derived agricultural products and it is considered as the area of cropland that would be required to produce the harvested quantity at world-average yields. Respectively, the combined productivity of all land devoted to growing crops is considered as the Cropland biocapacity.

The Grazing land comprises all grasslands that provide feed to animals including wild grasslands, prairies and cultivated pastures. Its ecological footprint is calculated according to Equation 3.1, where yield represents average above-ground Net Primary Production (NPP) for grassland and is calculated as:

$$P_{GR} = TFR - F_{Mkt} - F_{Crop} - F_{Res} \quad (3.10)$$

Where PGR is the total demand for pasture grass, TFR is the calculated total feed requirement, and FMkt, FCrop and FRes are the amounts of feed available from general marketed crops, crops grown specifically for fodder, and crop residues, respectively.

The fishing grounds Footprint is calculated according to the fishing annual primary production required to sustain a harvested aquatic species which is denoted PPR and it is the mass ratio of harvested fish to annual primary production needed to sustain that species, based on its average trophic level:

$$PPR = CC * DR * \left(\frac{1}{TE}\right)^{(TL-1)} \quad (3.11)$$

Where CC is the carbon content of wet-weight fish biomass and DR is the discard rate for by catch which is defined as the global average value of 1.27 for all fish species. This means that for every tone of fish harvested, 0.27 tones of by catch are also harvested. The by catch rate is applied as a constant coefficient in the PPR equation, assuming that the trophic level of the by catch is the same as that of the primary catch species. Subsequently, TE is the transfer efficiency of biomass between trophic levels which is assumed to be 0.1 for all fishes, meaning that 10% of biomass is transferred between successive trophic levels and TL is the trophic level of the fish species. The annually available primary production that calculates marine yields is based on estimations of the sustainable annual harvesting of 19 different aquatic species. Their quantities are converted to primary production equivalents (Equation 3.11) and their sum is the total primary production which global fisheries may sustainably harvest. So, the total sustainably harvestable primary production requirement (PPS) is calculated as:

$$PPS = \sum (Q_{S,i} * PPR_i) \quad (3.12)$$

Where QS,i is the estimated sustainable catch for species group i, and PPRi is the PPR value corresponding to the average trophic level of species group i. This total harvestable primary production requirement is allocated across the continental shelf areas allover the world so as to produce biocapacity estimates. Thus, the world average marine yield (YM), in terms of PPR, is calculated as:

$$YM = PPS / ACS \quad (3.13)$$

Where PPS is the global sustainable harvest from Equation 3.12, and ACS is the global total continental shelf area.

The forest land footprint measures the annual harvests of fuelwood and timber needed to supply forest products and it is the net annual increment of merchantable timber per hectare. It is calculated according to the production quantities of 13 primary timber products and three wood fuel products.

As far as carbon footprint is concerned, since forests absorb most of the carbon in the biosphere, carbon uptake land is assumed to be forest land so it is considered to be a subcategory of forest land. Carbon footprint EFC is calculated according to:

$$EFC = PC * (1\text{-}SOCEAN) / YC * EQF \quad (3.14)$$

Where PC are the annual emissions (production) of carbon dioxide and SOCEAN is the fraction of anthropogenic emissions sequestered by oceans in a given year constituting the one third of total emissions from average per capita carbon emissions (IPCC Intergovernmental Panel on Climate Change, 2001).Sebsequently, Yc is the annual rate of carbon uptake per hectare of forest land at world average yield that equals to 1.8 metric tons per hectare (Wackernagel and Rees, 1996) and EQF is the equivalence factor.

The built-up land footprint is calculated according to the covered area land by human infrastructure just like transportation, housing, industrial structures and reservoirs for hydroelectric power generation.

Wang et al. (2012) used the EF analysis to measure the SD of Taiwan. This study uses and follows their calculation methodology to measure the SD of Turkey respectively. For the Taiwanese footprint calculation the methods of Wackernagel and Rees (1996), Wackernagel et al. (1999) and Ewing et al. (2008a) were used. The only difference between the method of Wackernagel and Rees and that of GFN is the replacement of fossil energy land footprint with that of carbon footprint in GFN method.

For the calculation of YFs of farmland, grazing land, forest and fishing grounds the following formula was used:

$$\text{Food } YF_S = P + I - E/\text{global bioproductivity} \qquad (3.15)$$

Therefore, as consumption is calculated through the sum of the domestically producted (P) and imported quantities (I) minus exported quantities (E) all measured in tons and then divided by the global bioproductivity (gha/tons), the YFs of food can be found. The categories of food used for the calculation of farmland ecological footprint were the grains, potatoes, sugar and honey, nut and seed oil and fruits. Meat, fat and grease for grazing land, seafood caught into the sea and inland fishing grounds for fishing grounds and round wood for forest ecological footprint.

For the calculation of built-up land area YFs, the methodology of GFN assumes that built-up areas are productive areas for farming which have been occupied by human habitation and the rest buildings. So, the formula that was used was:

$$\text{Built-upYFs} = \text{built-up lands} * \text{farmland bioproductivity} \qquad (3.16)$$

where, built-up lands are the areas occupied by buildings (ha) and farmland bioproductivity (tons/ha) is the farming bio-productivity of the current built-up lands they would have before being built up, as farmlands.

As far as carbon land area is concerned, for the calculatıon of its YFs, it was assumed that a part of CO_2 emissions generated is uptaken by the forests. So the carbon absorption rate of forests is 1.8 metric tons per hectare (Wackernagel and Rees, 1996). Moreover, another rate of the total generated CO_2 emissions must be sequestered as it is assumed that the oceans have also a CO_2 emissions sequestration capacity. The CO_2 emissions absorbed by the oceans constitute the one third of the total CO_2 emissions (IPCC Intergovernmental Panel on Climate Change, 2001; Ewing et al., 2008a). As a result, taking into account the above assumptions, the formula used for the calculation of the YFs of carbon footprint is formed as:

$$\text{Carbon } YF_S = CO_2 \text{ emissions} * (1-1/3) / 1.8 \qquad (3.17)$$

At this point the importance of EQFs has to be mentioned. As long as, the YFs were found, their results have to be multiplied with the equivalence factors so as the bioproductivity of land categories to be balanced and be able to be compared. Essentially, EQFs take into account the differences among land types in world average productivity by relating the average primary bioproductivity of the different land types of a country with the global average primary bioproductivity in a given year. EQFs vary according to each land category and years but it is the same for all countries within a year. The above calculation methodology was used for the calculation (Borukce et al., 2012).

Lastly, through the division of the value added from the production of goods and services, known as Gross Domestic Product (GDP) by the added environmental impacts that result from production, eco-efficiency was extracted and so it became possible to measure how effectively ecological resources are consumed so as to meet human demand.

For the calculation of eco-efficiency, the equation which Wang et al. (2012) used in their paper for the calculation of eco-efficiency for Taiwan, was used too. The indicators that constitute the equation are them of GDP and E.F:

$$\text{Eco-efficiency} = \text{GDP} / \text{Regional E.F.} \tag{3.18}$$

In order to be easier to comprehend the process that was followed for the calculation of Ecological Footprint, the following figure (Fig. 3.1) represents in a simpler way the EF calculation methodology.

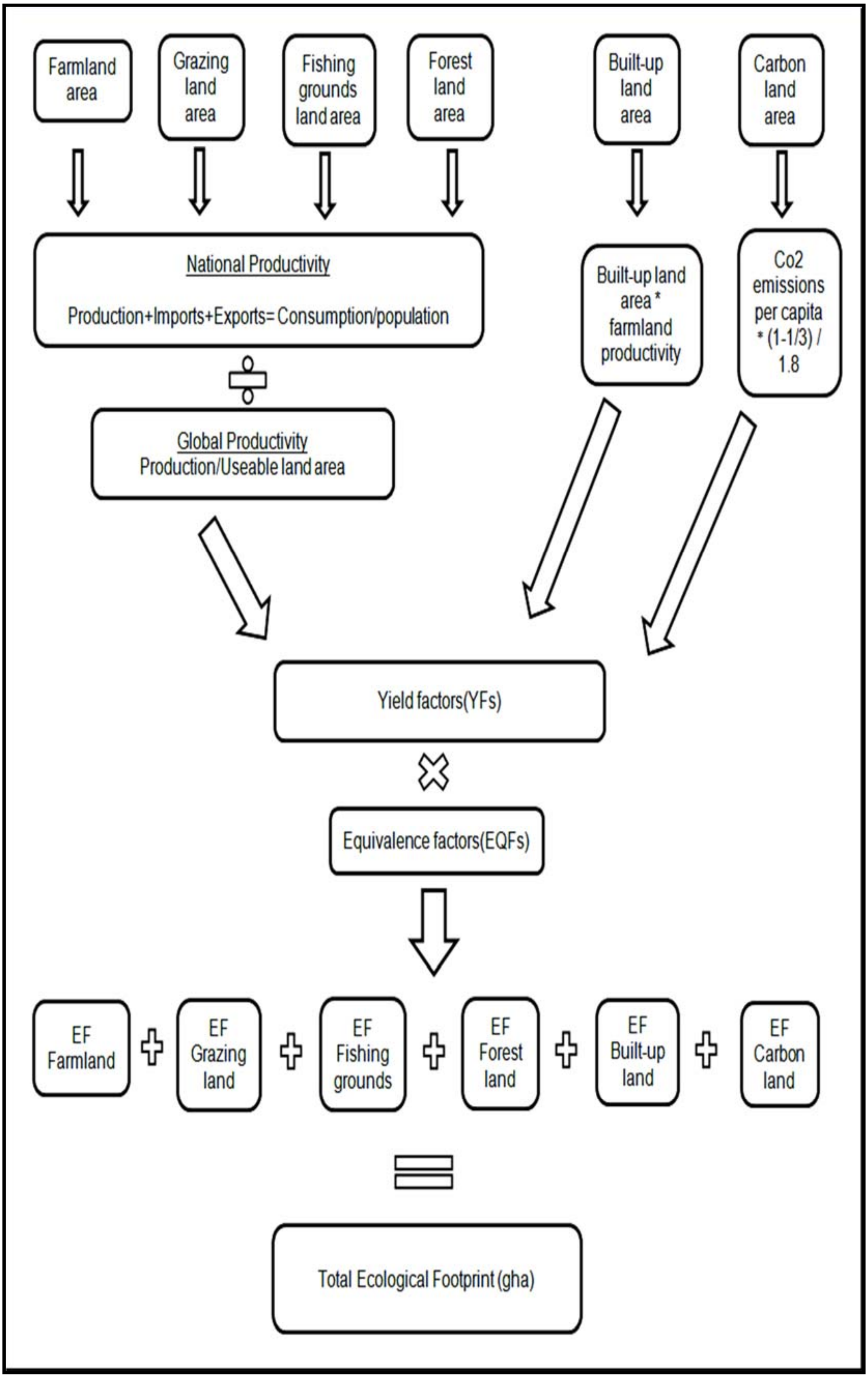

Figure 3.1. Ecological footprint calculation process flow chart

4. DATA ILLUSTRATION

4.1. Ecological Footprint of Turkey

This study calculates the EF of Turkey for the years 2002 till 2011 based on the calculation methodology analyzed at Chapter 2. Hence, the same selected indicators which Wang et al. (2012) used in their paper for the calculation of EF of Taiwan were used. However, this was not the only reason for their choise as they play a significant role in the economy of Turkey by being of the primary produced and consumed products. The statistics collected are based on databases and publications from governmental and international organizations. The site and publications of the official statistical institute of Turkey constituted the main source for data collection (TURKSTAT Turkish Statistical Institute Home Page, 2011), nevertheless, lack of data in some fields and in the values of some indicators for some years of the study forced to search for the appropriate information from other sources. In parallel, data concerning global information used for the calculation of the global bioproductivity of farmland, grazing land, fishing grounds and forest land were collected from the statistics division of food and agriculture organization of the United Nations (FAOSTAT Home page, 2011; FAO Statistical Yearbook Report 2004; 2005-2006; 2007-2008; 2009; 2010; 2012).

The following tables display the selected indicators that are needed for the calculation of the global average bioproductivity which in turn will provide the exchange rate that constitutes a critical factor for the EF calculation of Turkey. With the reference to the exchange rate, we mean the YFs that are responsible for the normalization of the bioproductivity of the regions that are analyzed according to the global average bioproductivity. Substantially, YFs balance the differences in bioproductivity of the different land area categories between different regions all over the world by converting the true area of a land area category into equivalent global one so as to be comparable for the EF calculation (Kitzes et al., 2008).

4.1.1. Farmland, Grazing Land and Fishing Ground Ecological Footprints

The year 2011 was taken as an example as being the last year of our study and the closest to the near future. The data for global bioproductivity (Table 4.1) were collected from the food and agriculture organization of the United Nations (FAO Statistical Yearbook Report 2004; 2005-2006; 2007-2008; 2009; 2010; 2012) and its statistics division (FAOSTAT Home page, 2011). Accordingly the data for the food ecological footprint of Turkey were provided by the Turkish statistical institute (TURKSTAT, Turkish Statistical Institute Home Page 2011) (Table 4.2). The data for the other years of the studied period are represented in Appendices A and B. Both for global average bioproductivity and Turkish average bioproductivity, the indicators that represented the food ecological footprint were the same. Hence, the categories of grains, potatoes, sugar & honey, nut & seed oils and fruits presented farmland, meat and fat & grease represented grazing land and last, seafood caught into the sea and inland waters stunt for fishing grounds. The indicators used were chosen so as to represent as much better as possible the picture of the Turkish market. However, they constitute only a representative sample as for being able to have an integral opinion, all the goods and services produced, consumed and traded within Turkish market should be comprised.

For the global average bioproductivity rate calculation, the global production quantity (tons) was divided by the area (ha) that is used for the food production. Then, in turn, for the calculation of the Turkish average bioproductivity rate the total consumption quantity was divided by the total population so as the average rate to be found. Lastly, through the division of the Turkish average bioproductivity by the global one, the YFs of each food category were found.

Table 4.1. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2011)

Farmland	Production Quanity (1000 metric tons)	Useable Farmland area (1000 ha)	Average Bioproductivity (kg / ha)
Grains	3,747,421.340	1,552,976.57	2413.060
Potato	478,642.260	1,552,976.57	308.210
Sugar&Honey	2,067,640.510	1,552,976.57	1331.400
Nut&Seed oils	498,851.070	1,552,976.57	321.220
Fruits	799,503.120	1,552,976.57	514.820
Grazing Land		Useable grazing land(1000 ha)	
Meat	296,044.687	3,359,864.00	88.110
Fat and Grease	28,523.712	3,359,864.00	8.490
Fishing Ground		Useable fishing area(1000 ha)	
Fishing Ground	178,303.426	1,900,000	93.840

Table 4.2. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2011)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	35,202.070	4780.540	4.122	39,978.490	74,724,269	535.014	0.222
Potatoes	4613.070	5.226	98.754	4519.543	74,724,269	60.483	0.196
Sugar & Honey	16,220.250	4.798	74.164	16,150.884	74,724,269	216.140	0.162
Nut &Seed Oils	3227.590	32.358	0.024	3259.922	74,724,269	43.626	0.136
Fruits	14,388.130	0.105	0.089	14,388.146	74,724,269	192.550	0.374
Total	73,651.110	4823.027	177.153	78,296.985	74,724,269	1047.812	1.090
Grazing Land							
Meat	2390.220	110.204	2.548	2497.880	74,724,269	33.428	0.379
Fat and Grease	640.600	103.013	0.523	743.090	74,724,269	9.944	1.171
Total	3030.820	213.217	3.071	3240.970	74,724,269	43.372	1.550
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor (gha
	703.550	65.6980	66.7380	702.505	74.724.269	9.401	0.100

4.1.2. Forest Ecological Footprint

For the calculation of global average bioproductivity of forest EF (Table 4.3) data were provided by the food and agriculture organization of the United Nations (FAO Statistical Yearbook Report 2004; 2005-2006; 2007-2008; 2009; 2010; 2012) and its statistics division (FAOSTAT Home Page, 2011). Respectively data for the forest EF of Turkey (Table 4.4) were collected by FAOSTAT for the years from 2002 to 2006 and by the Turkish statistic institute (TURKSTAT, Turkish Statistical Institute Home Page 2011) and Turkish directorate of Forestry (OGM, Turkish Directorate of Forestry Home Page, 2011) for the years 2007 till 2011. Based on the calculation method of Global Footprint Network in cooperation with Ewing B. et al. (2010b) the forest ecological footprint concerns the round wood EF.

Table 4.3. Global average bioproductivity for forest land from 2002 to 2011

Forest/Wood	Production quantity (1000 cubic meters)	Forestry dimensions (1000 ha)	Average Bioproductivity (m3/ha)
2002	3,401,549.066	4,075,487.040	0.835
2003	3,455,952.801	4,070,646.270	0.849
2004	3,512,560.130	4,065,805.450	0.864
2005	3,577,646.492	4,060,964.800	0.881
2006	3,537,316.289	4,055,383.240	0.872
2007	3,559,220.590	4,049,802.220	0.879
2008	3,442,772.855	4,044,221.590	0.851
2009	3,294,931.222	4,038,640.800	0.816
2010	3,405,675.862	4,033,049.100	0.844
2011	3,469,378.896	4,027,468.010	0.861

Table 4.4. Turkish average bioproductivity and yield factors for forest land from 2002 to 2011

Forest Wood	Production quantity (m3)	Import quantity (m3)	Export quantity (m3)	Total consumption quantity (m3)	Total population	Average Bio-productivity (m3/ person)	Yield Factors
2002	16,122,000	1,061,000	9002	17,173,998	65,446,165	0.262	0.314
2003	15,810,000	1,401,000	68,567	17,142,433	66,339,433	0.258	0.304
2004	16,503,000	2,052,888	36,509	18,519,379	67,235,927	0.275	0.319
2005	16,185,000	2,303,600	9693	18,478,907	68,143,186	0.271	0.308
2006	18,084,000	2,255,000	2781	20,336,219	69,063,538	0.294	0.338
2007	18,319,000	2,082,000	11,000	20,390,000	70,586,256	0.289	0.329
2008	19,420,000	1,349,000	4860	20,764,140	71,517,100	0.290	0.341
2009	19,300,000	987,000	13,017	20,273,983	72,561,312	0.279	0.342
2010	20,597,000	1,416,000	7412	22,005,588	73,722,988	0.298	0.354
2011	21,039,000	1,315,000	3800	22,350,200	74,724,269	0.299	0.347

Likewise, for the calculation of the YFs of food EF, as far as the average global bioproductivity (FAOSTAT Home Page, 2011; FAO Statistical Yearbook Report 2004; 2005-2006; 2007-2008; 2009; 2010; 2012) for each year was extracted, then by adjusting its values to the relevant Turkish forest average bioproductivity values (TURKSTAT, Turkish Statistical Institute Home Page 2011) the YFs of forest land area category were concluded. So, through the division of the global forest production quantity by the global forestry dimensions, the global exchange rate for the forest land area was found. Accordingly, for the calculation of the Turkish forest YFs rates for each year equation 3.15 was used:

$$\text{Forest YFs (gha)} = P + I - E \, / \, \text{global bioproductivity} \qquad (3.15)$$

As the total per capita consumption quantity was estimated through the summing up of domestically produced and imported quantities minus exported quantities, then by dividing their values by the relevant values of global average bioproductivity the forest YFs were reached (Wang et al., 2012; Wackernagel and Rees, 1996; Ewing et al., 2008a).

4.1.3. Carbon Footprint

Firstly, it must be clarified that while gathering the data for carbon footprint, in statistical calculation methodologies carbon land area category was called as “land used for fossil energy production” for the years 2002 and 2003. According to the calculation methodology that was followed, the carbon emissions per capita were the only indicator needed for the calculation of carbon footprint. Data for carbon emissions per capita in Turkey (Figure 4.1) were based on the International Energy Agency (IEA International Energy Agency, CO_2 Emissions from fuel combustion Report, 2007; 2012) and the Turkish statistical institute (TURKSTAT, Turkish Statistical Institute Home Page 2011). Thereafter, as carbon emissions per capita were the only data needed by adding their values in the equation 17 the YFs for carbon EF were extracted. It is important to mention that for the calculation of carbon footprint it is assumed that one third of the total carbon emissions are absorbed by the oceans (IPCC Intergovernmental Panel on Climate Change, 2001) and that forests absorption rate is 1.8 metric tons of CO_2 per hectare (Wackernagel and Rees, 1996).

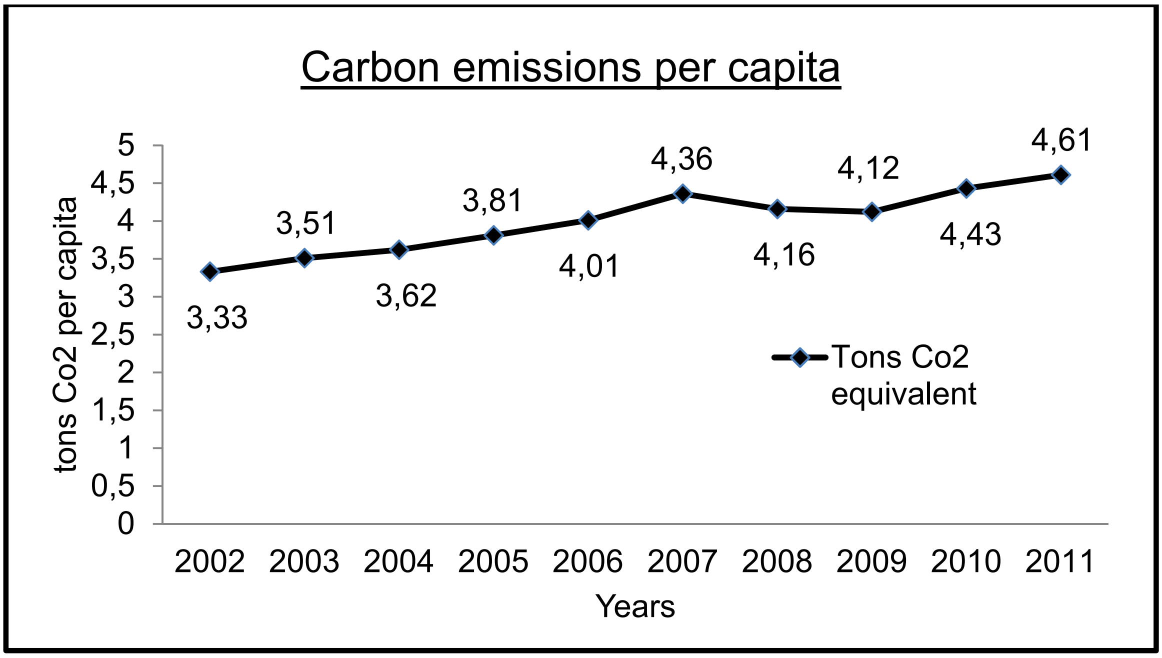

Figure 4.1. Carbon emissions per capita of Turkey from 2002 to 2011(IEA International Energy Agency, CO_2 Emissions from fuel combustion Report, 2007; 2012; TURKSTAT, Turkish Statistical Institute Home Page 2011)

4.1.4. Built-Up Land Footprint

Subsequently, data for built-up land area (Table 4.5, 4.6) were collected by the Turkish statistical institute (TURKSTAT Builiding Permit Statistics Report, 2010) and the electronic data delivery system of the central bank of the republic of Turkey (CBRT, Electronic Data Delivery System Home Page, 2011). The following tables show the land area which is covered and occupied by human infrastructure for transportation, housing, industrial structures and reservoirs for hydro-power measured in hectares and constituted the only data needed for the calculation of the yield factors. In Chapter five, by adding the data that were collected for the built-up area into the equation 16 the YFs for the built-up land area were found.

Table 4.5. Turkish built-up Land Area from 2002 to 2006

Year	2002	2003	2004	2005	2006
Residential Area	264,549.58	345,036.88	516,551.57	860,514.290	966,146.760
Commercial Area	14,013.020	15,033.240	14,763.840	23,682.950	45,748.760
Industrial Area	35,071.330	53,023.090	70,485.980	79,660.940	87,212.630
Public Institutional Area	20,674.070	12,101.790	20,330.540	36,060.220	45,592.130
Public Facility Land Area	1910.820	6309.320	5541.010	5341.270	8248.970
Transportation	1793.720	2,154.410	1323.840	3029.880	5841.270
Other Purpose Area	23,857.870	32,576.730	41,930.150	55,956.320	70,308.340
Total Area(ha)	361,870.38	466,235.46	670,926.93	106,4245.87	1,229,098.86

Table 4.6. Turkish built-up Land Area from 2007 to 2011

Year	2007	2008	2009	2010	2011
Residential Area	947,355.90	832,299.77	808,693.130	1,378,956.20	1,942,628.790
Commercial Area	47,681.110	41,150.980	34,837.420	47,273.770	49,387.500
Industrial Area	105,351.44	69,927.500	44,188.280	72,735.260	60,015.270
Public Institutional Area	50,080.510	52,123.240	51,320.420	66,460.060	61,129.880
Public Facility Land Area	7462.230	8184.490	9807.810	25,446.980	13,603.970
Transportation Area	8948.360	8107.990	6615.920	10,998.520	7037.270
Other Purpose Area	74,444.050	73,205.430	51,802.460	68,126.180	59,218.210
Total Area(ha)	1,241,323.6	1,084,999.4	1,007,265.44	1,669,996.97	2,193,020.890

4.2. Ecological Footprint of Bursa

The data collected for the calculation of EF of Bursa were taken from TURKSTAT (Turkish Statistical Institute Home Page, 2011) and by the provincial directorate of food, agriculture and animal husbandry of Bursa (Annual Report, 2011a; Selected Indicators Report, 2011b). However, because of lack of data in some categories of the study the use of different classification methods such as estimation of some indicators through other calculation methods were needed. Just like the case of Turkey, the same calculation methodology that was analyzed in Chapter three was followed for the case of Bursa too. As a result, based on the paper of Wang et al. (2012) the following tables include the same indicators that were used for the Taiwanese EF calculation. According to these indicators, the yield factors of all land categories of Bursa were calculated and after being multiplied by the EQFs the EF of Bursa for the year 2011 were found. The year of 2011 was chosen so as the comparison of the EF of Bursa with the respective results of EF of Turkey to be within the same time frame.

4.2.1. Food Ecological Footprint

As referred above, again for the case of Bursa the categories that indicated the food EF were the same with them of Turkey. Table 4.7 depicts the bioproductivity of farmland, grazing land and fishing grounds of Bursa which in turn, customized by the average global bioproductivity of 2011 provided the yield factors of food EF of Bursa. Hence, by calculating the per capita total consumption quantity for each indicator and then dividing its value by the global average bioproductivity of that year, the yield factors of food ecological footprint of Bursa were found. Data for food EF of Bursa were provided by the directorate of Food, Agriculture and Animal Husbandry of Bursa (BURSA Annual Report, 2011a).

Table 4.7. Bursa's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2011)

Farmland	Production Quantity (1000 tons)	Import Quantity (1000 tons)	Export Quantity (1000 tons)	Total Consumption quantity (1000 tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	446.073	60.578	30.983	475.668	2,652,126	179.353	0.074
Potatoes	38.459	0.000	0.124	38.335	2,652,126	14.454	0.047
Sugar & Honey	86.291	0.025	0.224	86.092	2,652,126	32.462	0.024
Nut & Seed Oils	26.829	0.270	0.305	26.794	2,652,126	10.103	0.032
Fruits	434.430	0.003	33.316	401.117	2,652,126	151.244	0.294
Total	1032.082	60.876	64.952	1028.006	2,652,126	387.616	0.471
Grazing Land							
Meat	18.022	0.220	0.288	17.954	2,652,126	6.770	0.077
Fat and Grease	16.736	3.656	0.020	20.372	2,652,126	7.681	0.905
Total	34.758	3.876	0.308	38.326	2,652,126	14.451	0.982
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor (gha)
	3943.487	6.546	1.057	3948.976	2,652,126	1.489	0.016

4.2.2. Forest Ecological Footprint

Again, like it was done for the calculation of forest EF of Turkey, since the global average bioproductivity of forest land area was found and was adjusted to the forest average bioproductivity of Bursa, their difference and consequently the yield factors of forest EF of Bursa were found. Hence, by calculating the per capita total consumption and divided it by the global forest exchange rate of 2011 the YF of forest for Bursa in 2011 was calculated. Table 4.8 depicts the average bioproductivity and the YFs of Bursa before being adjusted for the EQF and being converted to global hectares. Data provided for forest ecological footprint of Bursa were taken from Turkish Directorate of Forestry (OGM, Forestry Statistics Report, 2011) and from Food, Agriculture and Animal Husbandry Directorate of Bursa (BURSA Annual Report, 2011a).

Table 4.8. Bursa's average bioproductivity and yield factors of forest land (Year 2011)

Forest	Wood
Production quantity (m3)	606,719.640
Export quantity (m3)	134.870
Total consumption quantity (m3)	653,256.970
Total population	2,652,126
Average Bioroductivity (m3/person)	0.246
Yield Factor	0.286

4.2.3. Carbon Ecological Footprint

For carbon EF, by applying the per capita carbon emissions into the equation 3.17, the carbon yield factors before being adjusted for the EQF were taken. Therefore, by removing the quantity of carbon emissions absorbed by the oceans and consists the one third (IPCC Intergovernmental Panel on Climate Change, 2001) of total emissions from average per capita carbon emissions and in turn dividing it by the carbon absorption rate of the forest, the carbon yield factor was calculated to be 1.059. According to Wackernagel and Rees (1996) the carbon absorption rate of forest is 1.8 metric tons per hectare. Actually, the reference to the carbon EF is translated into how much bio-productive area should be forested so as being able to absorb the carbon emissions.

4.2.4. Built-Up Land Ecological Footprint

Data for land area covered and occupied by human infrastructure were provided by the regional directorate of Bursa (BURSA Selected Indicators Report, 2011b) and the Turkish statistical institute (TURKSTAT, Turkish Statistical Institute Home Page, 2011). The following figure (Fig. 4.2) represents the built-up land area of Bursa measured in hectares. Thereafter by adjusting this data into the equation 16, the YF of built-up land area of Bursa for 2011 was calculated.

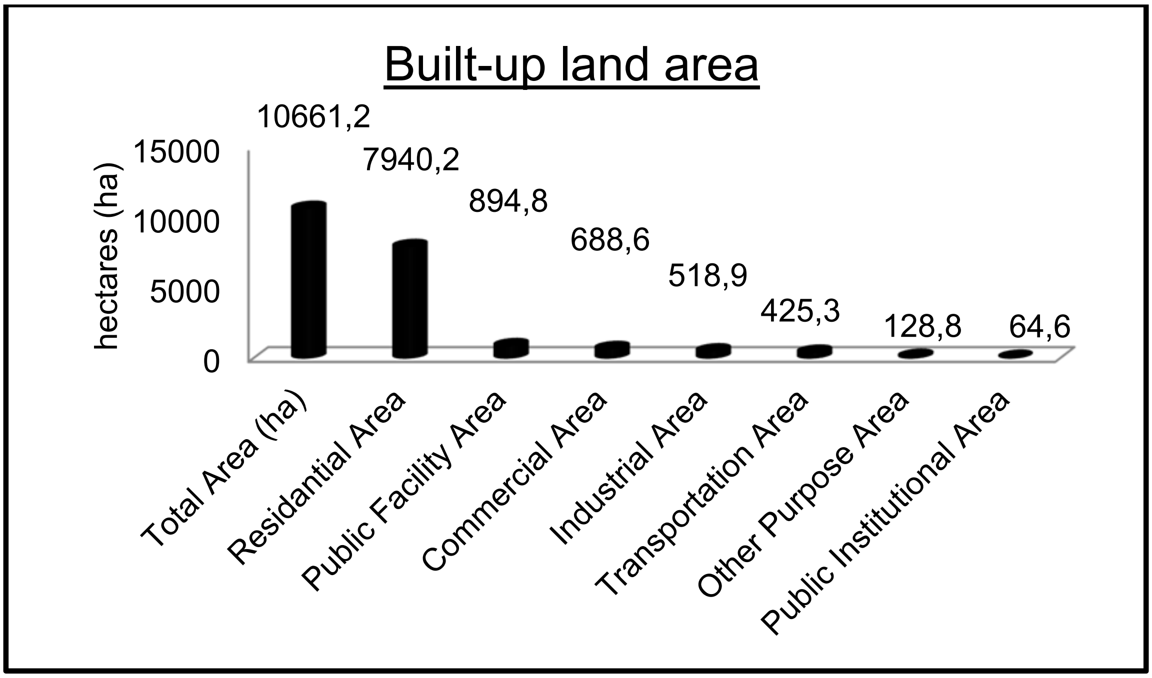

Figure 4.2. Built-up land area (ha) of Bursa in 2011(BURSA Selected Indicators Report, 2011b; TURKSTAT Turkish Statistical Institute Home Page, 2011).

4.3. Biocapacity

Biocapacity means the capacity of earth to produce regenerative resources, provide land for built-up land areas and to absorb waste such as carbon uptake. Biocapacity does not include only land area but sea area too and it is calculated by dividing the global hectares of biologically productive area by the total global population. Moreover, biocapacity, except from the available biologically productive areas globally, it considers also their productivity; so higher productivity and bio-productive area is translated into larger biocapacity. According to Wang et al. (2012), the Global Footprint Network in cooperation with Ewing et al. (2008b; 2009; 2010a) and the World Wildlife Fund (WWF, 2012 Living Planet Report), the global biologically productive area (available biocapacity) per person (Figure 4.3) between 2002 and 2011 was:

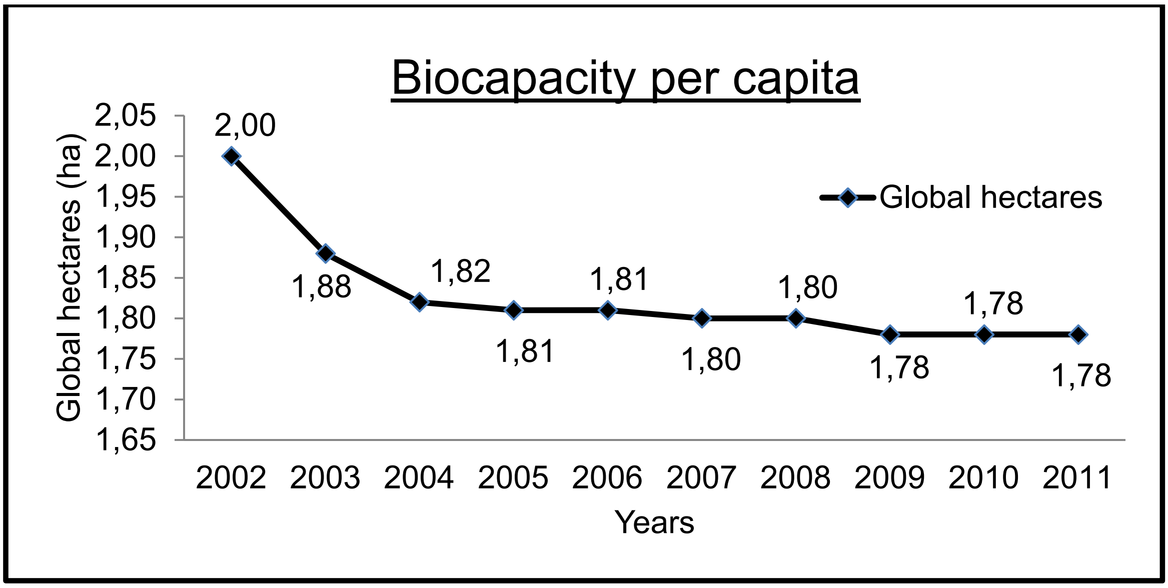

Figure 4.3. Global biocapacity per capita from 2002 to 2011

It is known that biocapacity is affected by natural events and human activities. In this study it is examined how the ecological footprint of Turkey influenced and in what degree the global biocapacity and whether an ecological deficit or reserve is created. Many nations including Turkey rely on the biocapacity of other countries to meet their domestic needs either through import of goods and services or through the dispersion of carbon emissions into the global atmosphere. So this constituted the reason to assess how Turkish people through their activities influence the global natural assets and the pressure that they exert on the environment worldwide. Through the comparison of biocapacity with EF, the difference created is called as ecological deficit or reserve. An ecological deficit is created when EF exceeds biocapacity while, an ecological overshoot occurs when biocapacity exceeds EF.

4.4. Equivalence Factors

At this point it is important to mention the importance of EQFs. As far as the bio-productive area (yield factor) of each land area is found, EQFs were used to yield the different dimensions in the productivity of land uses categories by relating the primary average bioproductivity of land uses categories to the global primary average bioproductivity. Substantially, EQFs are responsible to convert the area of different land categories which is measured in hectares into global hectares so as being able to make comparison between different regions. EQFs can vary according to the productivity of each land use which is determined from the management of the existing resources and the technologies that are used but it is constant for each year for all the regions globally. The data for EQFs concern 2001, 2003, 2005, 2006, 2007 years and were collected by the World Wildlife Fund for Nature (WWF, 2005 the ecological footprint report), the Global Footprint Network (GFN, 2006 Ecological Footprint and Biocapacity technical notes; Ewing et al., 2008a; Ewing et al., 2009; Ewing et al., 2010b) (Table 4.9). However, due to lack of data for the location or even the calculation of EQFs of some years, it is clarified that the equivalence factors of 2001 regard to the exchange rates of 2002 and the EQFs of 2003 regard to 2003 and 2004 exchange rates. Additionally, the EQFs of 2005 regard to the exchange rates of 2005, those of 2006 regard to 2006 exchange rates and lastly the EQFs of 2007 regard to the exchange rates of 2007, 2008, 2009, 2010 and 2011.

Table 4.9. Equivalence factors

Land Area Categories	2001	2003	2005	2006	2007
Farmland	2.190	2.210	2.640	2.390	2.510
Grazing Land	0.480	0.480	0.500	0.510	0.460
Forest land	1.380	1.350	1.330	1.240	1.260
Fishing Ground	0.360	0.360	0.400	0.410	0.370
Carbon Land	1.210	1.350	1.330	1.330	1.340
Built-up Land	2.190	2.210	2.640	2.390	2.510

4.5. Eco-Efficiency

By using the equation 18, the EE of Turkey and Bursa was calculated. According to the equation, GDP and ecological footprint constitute the key factors. For the values of GDP of Turkey data were collected from World Bank while data for Bursa were provided by the Chamber of Commerce of Bursa (BTSO, Chamber of Commerce of Bursa Home Page, 2011). Then by adding the values of EF that we calculated for Turkey and Bursa the respective EE values were found. For the case of Turkey its EE was calculated from 2002 to 2011 while for Bursa only that of 2011 was calculated. The data for both cases are represented in Chapter 5.

4.6. Carbon Ecological Footprint of Kadikoy

Following the same calculation methodology that took place for the cases of Turkey and Bursa and through the use of the equation 17, the carbon EF of Kadikoy was calculated by applying the data for the appropriate indicators. The data representing the carbon emissions of Kadikoy was based on different sources. Data for the building sector were taken from the database of Municipality of Kadikoy UKBS (Borough Info System); meanwhile data for electricity consumption and natural gas consumption were obtained from the Anatolian Side Electricity Distribution Company (AYEDAŞ Anatolian Side Electricity Distribution Company Home Page, 2010) and the Istanbul Gas Distribution Company (IGDAŞ Istanbul

Gas Distribution Company Home Page, 2011) respectively. Lastly Istanbul Metropolitan Municipality (IMM Istanbul Metropolitan Municipality Home Page, 2011) provided the data for the public lighting and public transportation. Figure 4.4 shows the total carbon emissions of Kadikoy and its sources of origin while figure 4.5 represents the values of carbon emissions generated from electricity consumption. All the indicators of the figures refer to the year 2010 as it was the only year able to provide the proper data.

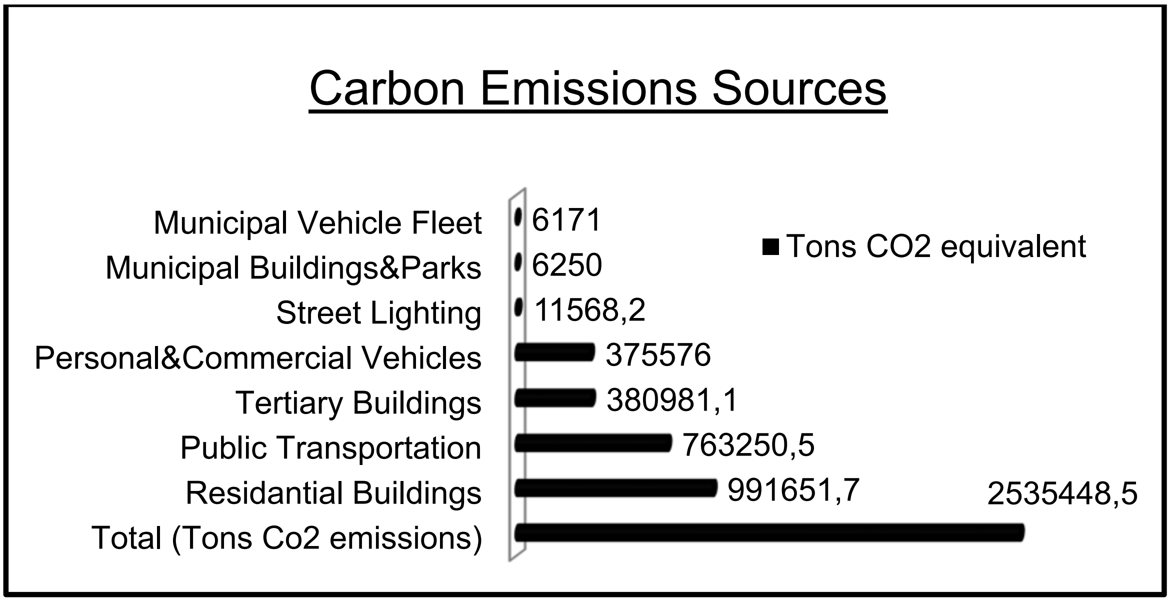

Figure 4.4. Carbon emissions sources of Kadikoy (Tons CO_2 equivalent) (2010) (AYEDAŞ Anatolian Side Electricity Distribution Company Home Page, 2010; IGDAŞ Istanbul Gas Distribution Company Home Page, 2011; IMM Istanbul Metropolitan Municipality Home Page, 2011)

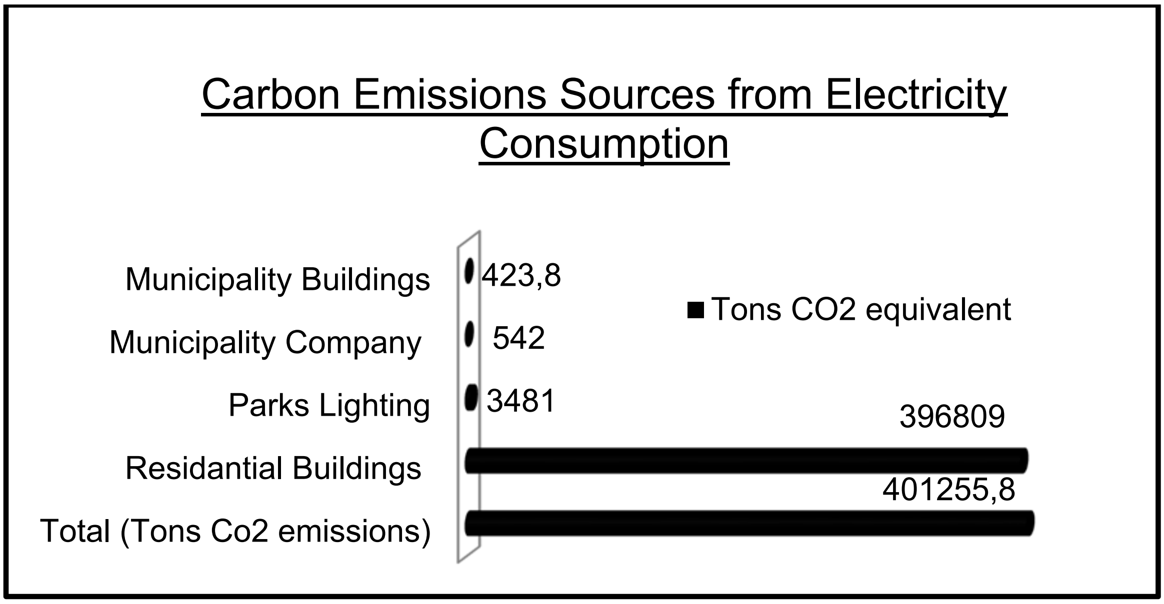

Figure 4.5. Kadikoy's CO_2 emissions from electricity consumption (Tons CO_2 equivalent) (2010) (AYEDAŞ Anatolian Side Electricity Distribution Company Home Page, 2010; IGDAŞ Istanbul Gas Distribution Company Home Page, 2011; IMM Istanbul Metropolitan Municipality Home Page, 2011.

5. RESULTS AND DISCUSSION

5.1. Results and Conclusions for Turkish Ecological Footprint

In Chapter 4 the data and its sources for Turkish EF were displayed and the YFs for farmland, grazing land fishing grounds and forest land area were extracted, before being adjusted for the EQFs. Additionally, in order to indicate the YFs of built-up land and carbon footprint, the formulas which Wang et al. (2012) used in their paper for Taiwan were used too. For built-up land area, according to the methodology of EF, built-up areas are considered to be productive farming areas and they are calculated according to the farming productivity that could have occurred. So, for the calculation of farmland bioproductivity the total global production quantity (tons) was divided by the global useable farmland area (hectares). Afterwards, as the whole built-up land area of Turkey was divided by the corresponding total population of each year the values of the per capita built-up land area were found which multiplied by the respective farmland bioproductivity of each year it was managed to calculate the YFs for built-up land EF (Table 5.1) of Turkey (equation 3.16):

$$\text{Built-up YFs (gha)} = \text{built-up lands} * \text{farmland bioproductivity} \qquad (3.16)$$

Correspondingly, for the calculation of YFs of carbon the equation 3.17 was used:

$$\text{CarbonYFs (gha)} = CO_2 \text{ emissions} * (1-1/3) / 1.8 \qquad (3.17)$$

By removing the CO_2 emissions absorbed by the oceans from the average per capita carbon emissions and dividing by the carbon absorption rate the carbon YFs were extracted before being adjusted for the EQFs (Table 5.1).

Table 5.1. Built-up land and carbon yield factors of Turkey from 2002 to 2011

Year	Built-up Land Yield Factors	Carbon Yield Factors
2002	0.022	1.233
2003	0.028	1.463
2004	0.042	1.341
2005	0.066	1.411
2006	0.075	1.485
2007	0.079	1.615
2008	0.072	1.541
2009	0.065	1.526
2010	0.106	1.641
2011	0.144	1.719

Therefore, as far as the YFs of each land area category for every year of the studied period were found; multiplying their values by the corresponding EQFs the EF of every land area of Turkey from 2002 till 2011 (Table 5.2) was calculated. Again, it must be noticed that because of lack of data, the EQFs of 2001 regard to the exchange rates of 2002 and the EQFs of 2003 regard to 2003 and 2004 exchange rates. Additionally, the EQFs of 2005 regard to the exchange rates of 2005, them of 2006 regard to 2006 exchange rates and lastly EQFs of 2007 regard to the exchange rates of 2007, 2008, 2009, 2010 and 2011.

Table 5.2. Turkish ecological footprint per land category from 2002 to 2011

Years	Farmland	Grazing Land	Fishing Grounds	Forest land	Carbon land	Built-up Land
2002	2.926	0.829	0.047	0.433	1.492	0.048
2003	2.935	0.882	0.045	0.410	1.975	0.062
2004	2.619	0.834	0.046	0.431	1.810	0.093
2005	3.200	0.929	0.041	0.410	1.877	0.174
2006	2.856	0.954	0.050	0.419	1.975	0.179
2007	2.909	0.802	0.050	0.415	2.164	0.198
2008	2.633	0.841	0.040	0.430	2.065	0.181
2009	2.841	0.857	0.038	0.431	2.045	0.163
2010	2.811	0.706	0.039	0.446	2.199	0.267
2011	2.736	0.713	0.037	0.437	2.304	0.361

Finally, after summarizing the above values of each land area category for every year, the total EF of Turkey from 2002 to 2011 was concluded (Figure 5.1). Correspondigly, it can also be revealed if an ecological deficit or an ecological reserve is created by removing the values of biocapacity of each year, represented in Chapter 4, from the respective values of EF. In the case of Turkey it is inferred that an ecological deficit is created (Figure 5.1). Ecological deficit reflects the amount by which the EF exceeds biocapacity and when it is present it means that ecological reserves are consumed faster than can be replenished.

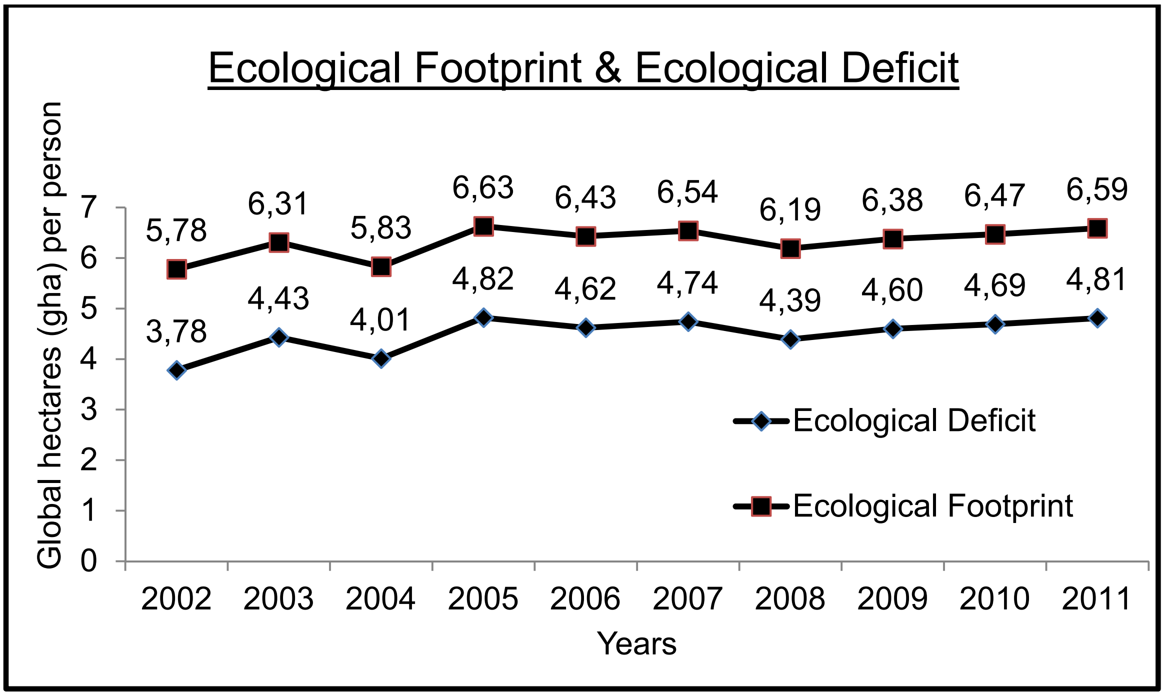

Figure 5.1. Ecological footprint & ecological deficit of Turkey from 2002 to 2011.

From a first view of the calculations, it is ascertained that 2005 constituted the peak year in total EF with 2011 and 2007 to follow respectively; with all of them to surpass the 6.5 global hectares. The first five years of the study, the EF was formed due to the high values of farmland, grazing land and fishing grounds, while the next five years the EF was formed due to the high values that were marked into carbon, forest land and built-up land EFs. More specifically, EF of 5.78 gha in 2002 was increased to 6.59 in 2011 which is translated into a 14 per cent increase. Through this period EF was increasing and decreasing respectively from 2002 till 2008, but from 2009 it started to increase continuously until it reached almost its highest value in 2011.

Accordingly, the ecological deficit had the same tendency just like the EF as it faced continuous fluctuations of its values from 2002 till 2009, when that year it started to increase up till 2011 when it noted its highest value after that of 2005 which was almost equal. Indeed, from 3.78 gha in 2002 it reached 4.81 gha in 2011 with an overall %27 increase. The value of 4.81 gha is translated into 359,423,733.89 ha and means that ecological deficit of that year according to the global biocapacity was 4.58 times the area of Turkey. Through that period, ecological deficit noted a bigger percentage of increase from EF because biocapacity was stable or it was slightly decreased. Additionally, according to the World Wide Fund for nature (WWF, 2012 Living Planet Report), the biocapacity of Turkey in 2008 was 1.31 global hectares. If it is assumed that in 2011 its value was stable then the ecological deficit that was formed was at 5.28 gha. So, it is clear that in Turkey the use of resources was not sustainable neither at global nor at national levels.

Furthermore, the increase of 0.80 gha of its EF value in 2005 from 2004, constituted the largest change from a year to the following year. This change coincided with the largest value of EF in the whole period that was studied and it fluctuated at 6.63 gha. The main reason for that large increase and high value of ecological footprint was the value of the farmland EF. Its value of 3.2 gha was by far the highest value of farmland in the whole period of the study and it constituted the 48 per cent of the whole EF of that year. In 2005, while the production and the consumption rates were not much higher or even lower in contrast to other years, the extreme climate and natural disasters that took place destroyed part of the production mainly in the farmland and had as a result the high value of EQF of farmland of that year. From the current analysis of data it is obvious that production and consumption in Turkey exceeded its own land capacity as Turkish people were overusing the resources that land could give them. It is of urgent matter to be noticed that if people of Turkey continue to consume under the current conditions and at the same pace, it will not be far in the future that their own land natural resources will not be able to serve them. It is known that natural resources depletion can result in various problems such as soil erosion, CO_2 accumulation, groundwater exhaustion but also increase of the prices and so inflation increase and other drawbacks such as threats to the human health. Therefore, EF and correspondingly ecological deficit depends on the population size, its natural resources consumption, its waste intensity, its living standards, the ecological productivity and the used technology (Wackernagel et al., 1997).

If the year 2011 is taken as an example, as it constitutes the second highest EF but the closest to the present, the population of Turkey was 74,724,269, which means that the EF was corresponding to 492,432,932.71 ha. As the total area of Turkey is 78,356,200 ha UN (2012), it means that the ecological footprint of Turkey was 6.29 times bigger than the area of Turkey, which means that for Turkey to meet its resource demands it needs 6.29 times the area of its own total land area. Moreover, in 2011 in comparison to 2002, farmland, grazing land and fishing grounds were decreased but there was an increase of EF in forest, carbon and built-up land area categories. Especially, carbon and built-up land noted the largest increases in the ten years period with that of carbon to increase from 1.492 gha in 2002 to 2.304 gha in 2011 and that of built-up land to rocket from 0.048 gha in 2002 to 0.361 gha in 2011. More specifically carbon footprint had an almost %55 increase whereas built-up land met an increase of an extraordinary 650 per cent. So the data indicated that although the per capita production and consumption did not increase and in fact it reduced, the increase of population forced the EF to higher values. The increase of almost 9 million of people resulted in the demand for housing and carbon both for the production and consumption of goods. However the growth of the population could not be considered as the main reason for EF increase as its percentage of increase is disproportional to that of ecological footprint. The huge increase of carbon and built-up land EFs can also be translated as an economic development. Over the recent years, from a financial perspective of view, Turkey constitutes one of the strongest developing economies. As a result, the increase of the production procedure and therefore the creation of new industrial zones are depicted as a parallel increase of carbon and built-up land area footprints. Apart from the EF and ecological deficit relationship, another concept which over the years is gaining ground is that of eco-efficiency.

5.2. Eco-Efficiency of Turkey

When it comes to investigate the economic wealth of a country or of a region the GDP rate is assumed as the most important indicator. However, in order to investigate further and have a better look of the general well-being, the term of environment must be introduced. Hence, by taking EF as an environmental indicator combined with GDP in a common equation the eco-efficiency term results. Wang et al. (2012) calculated the eco-efficiency of Taiwan in their paper by dividing the value of GDP by the value of EF through the equation 3.18:

$$\text{Eco-efficiency} = \text{GDP} / \text{Regional ecological footprint} \qquad (3.18)$$

According to the Organization of Economic Cooperation and Development (OECD) and the World Business Council for Sustainable Development (WBCSD) eco-efficiency is regarded as a universal concept for sustainable development (OECD 1998; WBCSD 2000). Eco-efficiency investigates the relationship between EF and economic growth through the index GDP. In general, GDP and ecological footprint are two correlated concepts, where, when there is economic prosperity through GDP growth there would be more pressure on the environment and which is expressed by increased ecological footprint (Bagliani et al., 2008). More concretely, eco-efficiency calculates how effectively the ecological resources are consumed to meet the demands of humanity. When the value of eco-efficiency is high it means that ecological resources correspond to larger human demand or fewer resources correspond to the same human demand. It is clear that eco-efficiency constitute an indicator that could investigate if a region is developing not only in financial terms but also in an eco-friendly way.

As far as GDP of Turkey is concerned as it is represented in figure 5.2 (World Bank Database Home Page, 2011) it is obvious that through the period from 2002 to 2011 the per capita GDP noted an overall increase of 6970.938 US $.

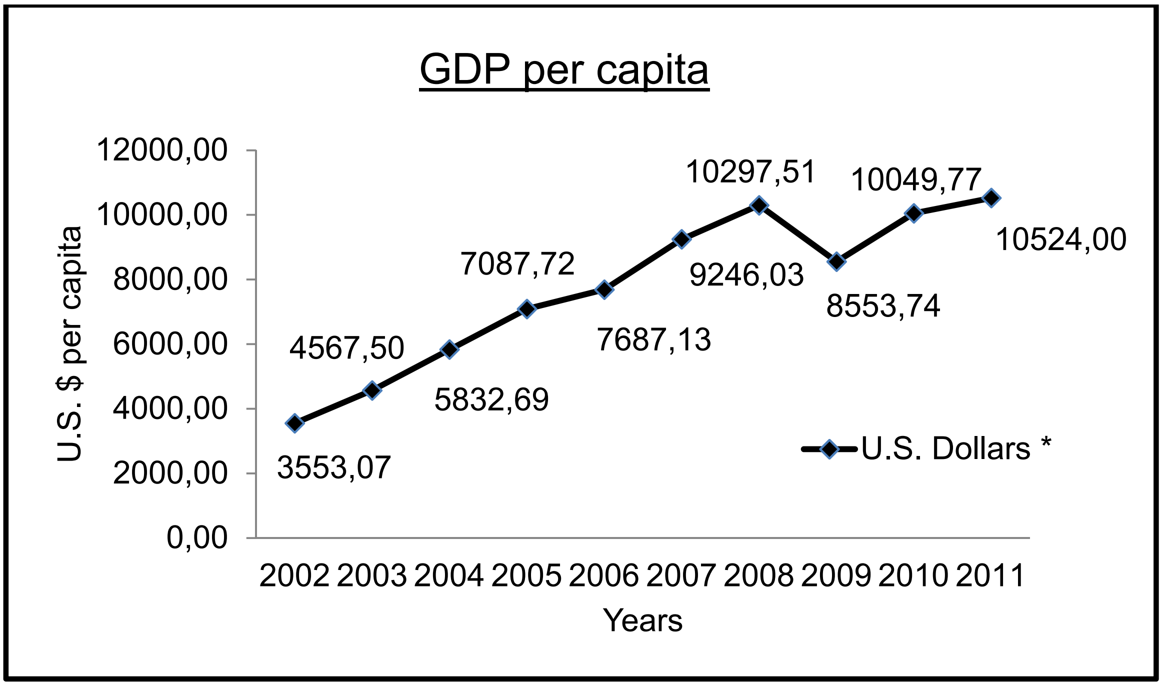

Figure 5.2. GDP per capita (US$) of Turkey from 2002 to 2011 (World Bank Database Home Page, 2011)

However, in 2009, a decrease of 1743.764 US $ was noted, before it begun to grow again until it reached its highest value of 10,524.004 US $ in 2011. This GDP reduction was the only one that was noted throughout the study period mostly because of the global economic crisis. GDP values divided by the values of EF of each corresponding year gave the eco-efficiency of Turkey for that period (Figure 5.3) (York et al., 2005). The GDP increase clearly shows that the improvement of living standards and well being forced the carbon and built-up land footprint to higher values as Turkish people searched for a better place to live.

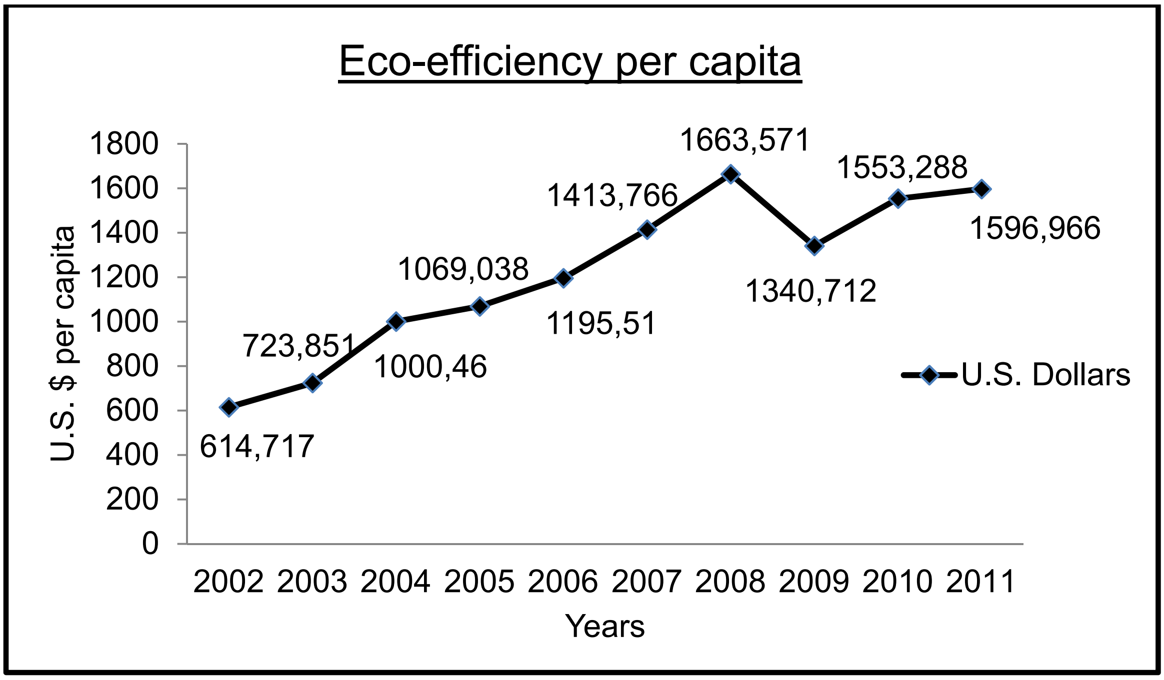

Figure 5.3. Eco-efficiency of Turkey from 2002 to 2011

By analyzing the results, it is ascertained that in 2002, year in which eco-efficiency noted its lowest value, the amount of 614.717 US $ increase of per capita GDP was needed for a global hectare of EF per person to be formed. On the other hand, 2008 constituted the year with the highest value in eco-efficiency. In that year, the formation of one global hectare of EF corresponded to an increase in GDP of 1663.571 US $ per person which means that eco-efficiency was performing in a much better way than previous years. Moreover, in 2011, while the per capita GDP of Turkey was at its highest value the eco-efficiency was not performing in the same way, as the high value of EF acted as a handicap to that direction.

Before continuing with the proposal of possible suggestions and solutions for the reduction of EF, a comparison between the Turkish and the E.F. of other countries is following. For example in the Taiwanese paper, Wang et al. (2012) found that the EF of Taiwan in 2007 was 6.54 global hectares which was exactly the same with that of Turkey for that year. Accordingly, in the year 2002, Taiwanese EF was 5.04 gha while that of Turkey was 5.78 gha. What can be inferred here is that Taiwan was performing more sustainable than Turkey in 2002, however, through the period till 2007 where they had the same value of EF Taiwan was performing worse as its E.F. increase rate was bigger than that of Turkey's. Moreover, another study on the ecological footprint of U.K. (Barret and Simmons, 2003) calculated that in 2002 the EF of U.K. was 5.45 gha. This means that U.K. was developing quite more sustainable than Turkey but compared to the global biocapacity again an ecological deficit bigger than 3 global hectares was created. In addition, another similar research study that took place (Dawkins et al., 2008) calculated the EF of Wales, which resulted to be 5.46 gha in 2003. Compared to the EF of Turkey of that year it was lower by 0.32 gha meaning a better sustainable development. In general, it is clear that Turkey had a larger EF than the study case-countries represented above, but none of them were using the global resources in a sustainable way.

5.3. Suggestions for Turkish Ecological Footprint

The calculations and subsequently their results clearly show that in the period between 2000 till 2011 Turkey was not developing in a sustainable way at all. Some people will wonder how Turkey could be sustainable developed when its population is growing almost per 1 million people by year; as this constant growing rate of population is translated in an increased need for food, shelter, energy and water. However, population growth should not be considered as the main reason for ecological footprint growth. Under no circumstances should Turkey apply a law like that of China and its “one-child policy”, where urban couples are restricted to have only one child. Such an anti-social law that deprives a family from having children must never be the solution for SD. Turkey should take some measures and make some implementations in all the categories of land uses. However, as farmland and carbon land areas constitute the biggest problems with the greatest negative contribution EF, they should be treated more carefully and analyzed more thoroughly. If Turkey continues to develop under the current tempo and the same practices, it will not be too far in the future when the highest value of EF of 2005 will be surpassed; putting the country in a more precarious situation.

5.3.1. Measures for Food Ecological Footprint Reduction

As farmland, grazing land and fishing grounds constitute two thirds of the EF of Turkey for every year of the study, it goes without saying that several changes should be made in these categories of land use. The improvement of the food production process looks and consist an inevitable measure for the reduction of food EF and the conservation of biophysical ecosystems. Better production practices more eco-friendly and technologically advanced could urge and evolve the existed bio-productive land areas to become more effective and consequently more productive. Nitrogen and phosphorus application in fertilizers and pesticides should be eliminated as their ability to increase the yields is disputed as it is counterbalanced by their diminishing returns. The fact that only a 30-50% of nitrogen and a 45% of phosphorus fertilizers is taken up by the crops means that the rest portion is lost from agricultural fields and pervading into coastal waters, lakes, rivers and streams by being able to pollute aquatic and terrestrials habitats, ground waters and lead to eutrophication, over-enrichment, soil erosion decrease and greenhouse gases emissions increase (David Tilman et al., 2002). Solutions to such problems require the use of organic nutrient sources and planting of crops with increased nutrient use efficiency. Moreover, water use efficiency must be increased through better technologies of irrigation and the construction of dams that will stock the rain water. Another measure for food EF reduction could be a balanced flow of goods between supply and demand as the huge quantities of food that end up in dumps bear witness that Turkey is producing and consuming more than the necessary.

In addition, overgrazing should be avoided through the frequent transfer of livestock between various pasture areas. In that case, the vegetation will have the ability to be naturally regenerated and the productivity of those areas to become more efficient which is translated in more food for the animals. Another suggestion is the handling and appropriate disposal of animal wastes that can be harmful and contaminate the surface area and water streams or ground waters. Through the controlled microbial degradation process of composting, organic waste can be converted into organic fertilizer for crops clear of pathogens and toxins. Lastly, an improved management of fisheries both to coastal zones and at open sea is critical. Over-fishing must be shrank so as the governance of marine ecosystems to be strengthened. Aquaculture could play a prime role to that direction. According to Guerry (2005), ecosystem-based management (EBM) is an approach of environmental management that takes into account all the interactions within an ecosystem. It is obvious that human activities negatively affect marine ecosystems through over-fishing, climate change and pollution by declining them. Subsequently, ecosystem-based management of marine fisheries could help to obtain sustainable marine ecosystems through the protection of the resources, goods and services that they provide. A successful ecosystem-based management of marine ecosystems and fisheries could be attained through the correct information about ecosystem and its interacted factors within it.

5.3.2. Recommendations for Forest Ecological Footprint Reduction

It is widely accepted that forests have the ability to prevent soil erosion, stabilize the climate, maintain the hydrological cycles, safeguard the livelihoods and protect biodiversity. In order to protect them and though decrease their EF, the most dominant and preferable measures and strategies are them involving recycling and regeneration. The development of a recycling and regeneration supply chain is of urgent matter. However, the implementation of such strategies into the sectors and industries that use wood as a raw material is the most critical. The government should take action, motivating these industries to show good behavior by awarding them with subsidies or conversely through the inflicting of large fines and strict measures for the non compliant enterprises. Furthermore, illegal logging and forest degradation that lead to carbon emissions increase in the short term and carbon sequestration capacity decrease in the long term must be banned and strictly punished for the governance improvement of forest systems. Another measure could be the installation of special recycling bins accessible to all citizens where they will be able to discard their recyclable wastes.

Moreover, under the supervision of the state forestry authorities, paper plantation and plantation for the production of forest products is assumed as an undisputable measure against the combating of EF. Lastly, every individual must become more educated and sensitive to such matters by learning the appropriate way of recycling and by promoting the companies that operate under such eco-friendly techniques and policies so that they become the preferred businesses in the market place.

5.3.3. Ideas for Built-Up Land and Carbon Ecological Footprint Reduction

The increase in population combined with economic development and better living standards had as a result the incredible growth of built-up land ecological footprint through 2002-2011 period. A solution that could reduce the built-up area EF is collective housing that is already a well-known and widely used technique. Especially in cities and urban areas there are unique opportunities for achieving efficiency gains in housing and infrastructures with taller buildings instead of wider that will save more land area in favor of green areas or farmlands. The concept of co-housing should also take place into governmental services and buildings by being under a unique roof instead of being segregated into separate and wasteful large buildings. Moreover, derelict residences and facilities should be re-utilized or demolished in favor of green open areas such as parks or groves through afforestation that would help to reduce the forest EF too. Last but not least, measures and laws should be adopted so that building permits are not issued for more buildings but for more green areas that will benefit the inhabitants and their quality of life.

As far as carbon EF is concerned, the constant growth of carbon emissions throughout the years might depict the economic development of Turkey, but on the other hand has inverse results on human health and on environment. It is indisputable that the planet cannot support such growing rates of carbon emissions. Turkey must adopt techniques and measures that reduce carbon emissions by promoting green energy and supporting renewable energy sources. Firstly, a step towards that direction should be the reduction and the gradually replacement of fossil fuels, especially in sectors with the biggest negative impact, such as industries by placing limits on the amount of carbon emissions that they are allowed to emit. Less dependence on fossil fuels can be succeeded through the transformation of energy systems to cleaner ones and through the implementation of effective both national and regional climate policies. In the sector of transportation, bio-fuels and electric cars should be promoted by the installation of electric charging stations and bio-fuels filling stations. Furthermore, public buildings and facilities should become self-sufficient as far as their energy needs are concerned, by being supplied with solar collectors and water and waste management services.

5.4. Ecological Footprint of Bursa

The idea behind the calculation of EF of Bursa was to find the way under which a province city like Bursa is developing (always according to the framework of SD) and compare it with that of all Turkey. One of the most interesting features of Bursa is that it cannot be characterized as a rural area as it constitutes the 4th most populated province of Turkey, but on the other hand, Bursa represents only a 3.55 per cent of the whole population of Turkey (Bursa Annual Report, 2011a). However, the most noticeable characteristic of Bursa is that its forest area runs up to 484,067 ha when its total land area is 1,088,638 ha. This means that 45 per cent of the land area of Bursa is covered with trees, hence the term “Green Bursa”.

5.4.1. Analysis of the Results of Ecological Footprint of Bursa

For the calculation of EF of Bursa the methodology of Global Footprint Network was followed in cooperation with Ewing et al. (2010a, 2010b) and Wang et al. (2012). In Chapter 4, after displaying the data and calculating the exchange rates for all EF areas, by multiplying their values with the EQFs, the EF of Bursa which is depicted at Table 5.4 per land area category was found.

Table 5.3. Ecological footprint of Bursa in 2011

Farmland	Grazing Land	Forest land	Fishing Ground	Energy Land	Built-up Land	Total
1.182	0.452	0.360	0.006	1.419	0.020	3.49

As it seems the EF of Bursa in 2011 was estimated to be 3.49 gha. If it is compared to that of all Turkey, it is inferred that it was lower by 3.10 gha. Therefore, it could be said that Bursa was developing in a much more sustainable way in 2011 in relation to Turkey. After a further investigation, it can be noted that all the values of EF land areas are lower in contrast to those of Turkish ecological footprint with large differences in their rates with that of fishing grounds area to dominate for its small value. Built-up land, farmland, grazing land and forest land follow respectively, with the lower difference noted in carbon footprint as carbon footprint of Bursa was 77 per cent lower than that of the average overall of Turkey. However, in both cases, farmland with carbon land area constituted the main reason for the EF to be elevated away to such a high value. In the Turkish EF, farmland is the land area with the highest value, whereas in Bursa's EF it was the carbon footprint that represented the higher EF of land use. Obviously, Bursa is developing more sustainably in contrast to Turkey without meaning that it cannot attribute better.

However, if the results of EF of Bursa are analyzed individually, it can be ascertained that Bursa too was not developing in a sustainable way. The ecological deficit of Bursa in 2011 amounted to be 1.69 gha, showing clearly that people of Bursa were overusing the natural resources. The carbon footprint was lower than the overall average of Turkey but it constituted the highest value of land area with 62 per cent of the overall EF of Bursa. In contrast, the EF of fishing grounds is the lowest in value land area with a minus contribution to the whole ecological footprint so it could be characterized ideal as an example of sustainable development. Another land area which is managed well is that of built-up land area where the value is the lowest after that of fishing grounds showing that in that the people of Bursa are moving forward in a correct sustainable direction.

5.4.2. Eco-Efficiency of Bursa

According to the Bursa Chamber of Commerce the per capita GDP of Bursa for 2011 was 11,673 US $ (BTSO, Chamber of Commerce of Bursa Home Page, 2011). Compared to the average per capita GDP of the whole Turkey in 2011 it is ascertained that GDP of Bursa that year was larger by 1149 US $. At a first approximation, it appears that the people of Bursa enjoy a higher GDP rate than the average of the whole Turkey. This is translated into a better quality of life from economic and social perspective and so makes the region one of the largest contributors to the Turkish economy. However, in order to investigate the simultaneous performance of Bursa both in financial and environmental terms the eco-efficiency of Bursa will be calculated and be compared to that of Turkey. So by adding the appropriate data into the equation 24 the eco-efficiency of Bursa for 2011 can be extracted. So the value of 3344.69 US $ resulted from equation 24 represented the eco-efficiency of Bursa. Eco-efficiency of Bursa was much higher than that of the whole Turkey and shows that in Bursa ecological resources were used more efficiently, in contrast to them of the whole Turkey. The total difference in the values of eco-efficiency reached the 1747.724 US $ and shows how much more US $ were needed in Bursa for the formation of a global hectare per person compared to that of Turkey. As referred to above, a GDP growth generally exerts more pressure on the environment and it is expressed by an increased EF. As the equation of eco-efficiency shows how much money are needed for the formation of a global hectare per person, the fact that in Bursa in 2011, there were needed more 1747.724 US $ than the average of Turkey means that eco-efficiency was performing much better.

5.4.3. Suggestions for Ecological Footprint of Bursa

The fact that EF of Bursa is almost half of all Turkey does not mean that measures should not be taken. Before mentioning some suggestions for the EF and ecological deficit reduction it must be clarified that the value of the biocapacity that was used for Bursa concerns the global one. Lack of data about its own biocapacity or even of data that could prompt an exact calculation makes a true report of biocapacity and the ecological deficit very sketchy. A better system of information collection in Bursa and an organized and systematic collection program of information are required. Therefore, just like the case of Turkey, Bursa was analyzed and compared to the global biocapacity so as to assess how its citizens influenced the global natural assets.

Firstly, as far as the carbon footprint is the land area with the highest value it would be logical to start with obstacles about this land area use. Bursa like Turkey had the same tendency in carbon emissions with a distinct increase from 2002 to 2011. According to Diler et al. (2008) the carbon emissions per capita in 2002 in Bursa were 1.3 million tones which is translated into a 120 per cent increase till 2011. The main reason for this increase was that in 2011 the total electric consumption for all Turkey was 2334 Kwh per capita while the respective rate for Bursa was 3291 Kwh (TURKSTAT, Turkish Statistical Institute Home Page 2011; Bursa Annual Report, 2011a). Hence, it can be assumed that households constituted the biggest source of carbon emissions. So a solution towards that direction could be the installation of solar collectors in the residences as in Bursa the annual average sunshine duration is 6.89 hours per day (TURKSTAT TR41Regional Indicators Report, 2010). But the best defense against this problem should be the general introduction of renewable energy sources. Obligatory installation of photovoltaic systems and the replacement of fossil fuels in industries, municipal buildings, facilities and transportation under the supervision of the municipality which will be in charge to put limits on the allowed carbon emissions and impose endorsements to the non-compliant ones could prevent the growth of carbon ecological footprint and bring it back at tolerable values for the humanity and the environment.

Furthermore, as far as farmland, grazing land and forest land are concerned, measures for their limitations should also be taken. The suggestions that were mentioned above for the case of Turkey can also be valid for Bursa. The unnecessary quantities of waste should be eliminated through the equal production and supply of goods according to their demand. The quantity of 857648 tons of waste in 2010 for Bursa (TURKSTAT TR41Regional Indicators Report, 2010) is not a reliable data to draw further conclusions about the quantities of food that end up in dumps; however it is unethical to dispose of unused food when other people in the world are starving. Additionally, the local government of Bursa should take initiatives in promoting new techniques of agriculture, animal husbandry and fishing; modernized and innovative techniques that would be able to increase the efficiency of land use and simultaneously the production yields. The use of organic nutrients fertilizers and pesticides looks necessary for the avoidance of side effects originated from the current methods such as soil erosion, eutrophication and over-enrichment. In addition, pasture areas should be treated in such a way that will have the chance and the time to be naturally regenerated. Another measure should be the appropriate handling and disposal of animal wastes through techniques such as composting. Lastly, related to the food ecological footprint, the people of Bursa should eat more organic and support the local farmers and markets but they must also realize the importance of rejecting goods produced in an unsustainable manner.

As far as forest EF is concerned, the fact that green and forest areas in Bursa constitute a 45 per cent of the total land area clearly shows that measures such as recycling and regeneration should be taken for the handling of wastes made up from wood. The distribution of recycling bins in every corner of Bursa both with the necessary information of the citizens about the importance of recycling could drive EF into lower levels. Lastly, fishing grounds and built-up land EFs were performing in a really sustainable way where there is no need to suggest any measures. If all the land areas could perform under the same or a similar way the total EF of Bursa will not exceeded not even the one global hectare.

In conclusion, the fact that the majority of citizens of Bursa were born and raised in Bursa can constitute an important factor in favor of SD. It is universally agreed on that a born and bred local will care more about the environment where he lives and the negative impact of his actions. Hence, through the proper information of the negative consequences on the environment and how they could be rectified, the people of Bursa would be made aware of protect their surroundings for them and their descendants.

So far, through the analysis of the data it is inferred that both for the case of Bursa and that of all Turkey, carbon constituted one of the main causes for the high values of EF. Therefore it was decided to include in the study the analysis of carbon emissions of Kadikoy so as to assess how an urban city is performing.

5.5. Carbon Emissions Analysis for Kadikoy

Kadikoy is one of the 32 districts of Istanbul and it is known as the center of the Anatolian side of Istanbul. In 2010, Kadikoy was one of the most crowded districts with a population of 532,835 citizens (ADNKS Address Based Population Registration System Home Page, 2011); a number that classified Kadikoy seventh place in rank. The total carbon emissions reached the 2,535,448.5 tons which divided by the population gave us the per capita carbon emissions of 4.76 tons. By taking this value and following the methodology that was used for Turkey´s and Bursa´s analysis, it was possible to find the carbon EF. Hence, according to Wackernagel and Rees (1996) and Global Footprint Network in cooperation with Ewing et al. (2008a) the YF for carbon was calculated through the equation 17. Then by multiplying its value which was found to be 1.763 with the EQF of carbon it was found that the carbon EF of Kadikoy for 2011 was 2.362 gha. The value of EQF of carbon used was that of 2007 because of lack of data. By comparing this value with those of Bursa and Turkey it is found that CO_2 emissions of Kadikoy were almost at the same levels of the whole Turkey. However, Kadikoy has the highest value of carbon EF among the regions that were studied and even larger than the total average of Turkey by 0.058 gha. So it is obvious that the sector of carbon EF in Kadikoy was not developing sustainable.

By taking the biocapacity of 1.78 gha of 2011 as a measure of comparison an ecological deficit of 0.582 gha was created only from the carbon footprint. For being able for biocapacity to be maintained at such levels and the ecological deficit to become zero the total EF should not exceed the 1.78 gha. If it is assumed that all the categories should have the same influence against EF, then the carbon footprint of Kadikoy in 2011 far exceeded the permissible limit as it should be no greater than 0.297 gha. However, the EF is calculated in total as one category and so a high value of a land area category can be counterbalanced by another one with a lower value, so it is impossible to draw clear conclusions from this comparison. Additionally, the 4.76 tons of CO_2 emissions per capita of Kadikoy is prohibitive both for the environment and for the citizens alike. Indeed, measures for the carbon footprint reduction should be taken immediately.

But for being able to propose a better solution and measures, a more in-depth analysis of CO_2 emissions of Kadikoy is taking place which analyzes the sources of carbon emissions of Kadikoy that were depicted in Chapter 4. From a first view on the data, it can be detected that residential buildings constitute the largest source of carbon emissions in Kadikoy followed by public transportation, tertiary buildings, personal & commercial vehicles, street lighting, municipal vehicle fleet and municipal buildings & parks. The value of 991,651.7 tons of CO_2 emissions of residential buildings is translated into a 39 per cent and both with the value of 763,250.5 tons of public transportation they constituted the 69 per cent of the overall CO_2 emissions of Kadikoy. Then tertiary buildings with a 15 per cent and personal & commercial vehicles with another % 15 are the main sources of CO_2 emissions while the remaining categories to contribute only for one per cent.

Moreover, the data that depict the sources for carbon emissions from electricity consumption showed that the total carbon emissions from electricity consumption constituted an almost 16 per cent of the total CO_2 emissions. However, the most prevalent source of carbon emissions is from residential buildings which were responsible for a 99 per cent and were followed by the electricity consumption of the municipality buildings, parks and municipality companies respectively.

5.5.1. Suggestions for Kadıkoy's Carbon Ecological Footprint

According to the Covenant of Mayors, Kadikoy has made an obligation to reduce the carbon emissions coming from its own activity by the year 2020. However, this does not seem feasible as its share to the total CO_2 emissions does not surpass the one per cent. So, even if the municipality of Kadikoy manages to reduce carbon emissions by % 20, its effect to the total would be minimal. Therefore, Kadikoy is one of the regions that decided to follow a different strategy and fight climate change in favor of SD. By having adopted 16 projects in that direction it is estimated that by 2020 total carbon emissions will reach 213,426.60 tons of CO_2 emissions.

For example, in the transport sector, apart from the transformation and replacement of municipal vehicles with electric and hybrid ones, electric charging stations will be setup in several points around the district to reduce the use of fossil-fuel consumption and so electric cars will be promoted. In the construction sector, renewable sources are promoted as 30 per cent of the apartment buildings constructed will use solar energy through solar panels for lighting of communal areas. Additionally, another %30 of existing buildings will switch to using renewable energy in an effort to reduce carbon emissions. Moreover, other projects and campaigns, that will manage to drag the attention and give more information about the advantages of renewable energy and the drawbacks of climate change, will be applied firstly in schools so that following generations will see the necessity of using alternative energy.

It is obvious that owing to the structure of the district of Kadikoy and the absence of heavy industries, agriculture and livestock activities combined with the fact that residential buildings constitute the biggest resource of carbon emissions, the CO_2 emissions reduction depends largely on the responsibility of the citizens. Under the constant support and the organization of the municipality, citizens of Kadikoy have to change their way of living by taking into account and realizing the importance of carbon emissions reduction. They must decide to change their behavior not only outdoors, by using the public transportation and bicycling or walking for short distances instead of using their private cars, but also indoors.

Firstly, good insulated and waterproofed buildings could save a lot of energy which otherwise could be lost such as heat leaking especially during the winter. The choice and use of energy-efficient appliances and electronics and energy-saving bulbs, not only could reduce the carbon emissions but also constitute a measure of retrenchment for the households. Another possible measure is the creation of small gardens on the terraces of the buildings or on available land areas which could both sequester more quantities of carbon emissions and constitute a source of goods. Moreover, the citizens of Kadikoy must try to amplify their impacts by changing their daily habits. Small steps like minimal use of power equipment, eat lower on the food chain, use of non-toxic products, recycling and purchase preferences of recycled and recyclable products might seem meaningless for an individual but it is vital and with a huge positive impact in reduction of carbon EF. In general, citizens of Kadikoy must become more sensitive and conscious of such matters by giving more thought before buying or consume something between their needs and their desires.

6. CONCLUSION

As noted in the introduction too, the concept of SD has attracted more attention in recent years and as a result the number of applications in different areas and regions has increased. Consequently, by using the methodology of EF as a core indicator for a SD measurement it was able to evaluate the sustainability of Turkey, Bursa and the sector of carbon for Kadikoy. The calculation methodology for EF proposed by the Global Footprint Network in cooperation with Ewing B. et al. (2010b) ensured the effectiveness and credibility of the analysis according to global standards.

According to the analysis, it was concluded that Turkey's development was not a viable path as biophysical ecosystems were in decline. Turkey must make improvements in the well being of its people by the simultaneous EF reduction and biocapacity maintenance or even its further expanding as climate change, ecosystem degradation and possible permanent losses of productivity are knocking the door. More specifically, EF is a continuous growth with periods of acceleration and deceleration. Hence, in 2002 the EF had the lowest value with 5.78 gha when in 2011 it reached the 6.59 gha. 2005 constituted the peak year as the EF reached its highest value of 6.63 gha. The destruction, part of the production in farmland because of the severe climate and natural disasters of that year drove the farmland EF to 3.2 gha which is translated into a % 48 of the total E.F. In 2011, while the population of Turkey was 74,724,269, the EF corresponded to 492,432,932.71 ha which equaled to 6.29 times the land area of Turkey. Subsequently, the ecological deficit noted continual fluctuations in its values with an overall increase through our research period that reached the 4.81 gha in 2011 which is translated to 4.58 times the area of Turkey. Throughout the research period, ecological deficit in some years noted greater increase to its values from EF as a result of the simultaneous decreasing of biocapacity of those years.

However, the main reason for the increase of EF and ecological deficit could be the simultaneous growth of GDP and eco-efficiency. Although, Turkey's population was increasing almost per 1 million every year, the consumption and production rates in farmland, grazing land and fishing grounds were either stable or slightly lower both with their EFs. In contrast, the economic development and economic prosperity that the Turkey citizens met through GDP growth became apparent by the large increase in the rates of EFs of carbon and built-up land. But, on the other hand the GDP growth drove the eco-efficiency of Turkey to have an overall better performance that have been reached 1596.966 US$ in 2011. The performance of eco-efficiency could be even bigger if the increase of EF and the economic crisis of 2009 that reduced the per capita GDP were not existed.

Thereafter, the analysis of the EF of Bursa shows up that Bursa clearly has developed in a more sustainable way than the rest Turkey; however its EF of 3.49 gha can still be improved so as to meet SD goals. The EF of Bursa was found to be lower by 3.10 gha than that of Turkey and carbon constituted the land area category with the highest value of 1.419 gha. Accordingly, the ecological deficit reached 1.69 gha equaled to 4,482,092.94 which translates to almost 4 times the size of Bursa. So this clearly shows that the people of Bursa are overusing the natural resources. However, most of the attention should be focused on the land area categories of farmland and carbon as both of them constituted a 74.5 per cent of the overall EF of Bursa. Moreover, the data for GDP and eco-efficiency of Bursa for 2011 showed again that Bursa had a better performance than that of all Turkey. Indeed, Bursa's GDP was 11673 US $ when its eco-efficiency that year was formed at 3344.69 US $. The people of Bursa enjoyed a much greater economic prosperity than the average Turkish citizen. The lower EF drove eco-efficiency to perform much better; therefore, the negative consequences that flow from economic prosperity were less for the environment at 1747.724, so more US $ were needed for a global hectare to be formed.

In the process of the study, Kadikoy is the second city of Turkey that was investigated and more specifically its carbon sector. The fact that it is an urban city on the center of Istanbul made it an ideal choice for analysis on how the citizens of a crowed city with no agricultural or industrial activities are managing and influencing the sector of carbon. In 2010, the carbon emissions of Kadikoy per capita were 4.76 tons which estimated to be 2.362 gha of carbon EF. This showed that among the regions that were studied Kadikoy had the highest value of carbon ecological footprint and it constituted one of the cities that impelled the overall average carbon EF of Turkey to higher values. Also, our data showed that the biggest carbon emitting source were the residential buildings with public transportation secondary.

Additionally, the suggestions and the solutions that were proposed were corresponding to the results of each region; but, most of them could be used in every case that was analyzed. Hence, a balanced flow of goods between supply and demand could reduce total consumption, the huge amount of food that ends up in dumps and therefore the EF. New energy-efficient techniques and practices could improve the production process and increase the yields. Also recycling and regeneration should be increased through the public information services. Moreover, the replacement of fossil fuels with renewable energy is extremely urgent. The promotion and use of more environmentally friendly fuels from renewable sources could constitute the solution for the high carbon EF. Separately for Kadikoy, as far as the sources of carbon emissions are known it is easier to take measures that focus on specific sectors.

There is no doubt that Turkey is a huge country with a diverse landscape and widely dispersed population. This makes the promotion of regional SD a considerably tough proposition. However, with the implementation of stricter controls combined with local compliance it looks feasible that success is possible. Turkey must aim to bring the values of EF and ecological deficit into more desired levels. Referred to the desired levels, as there are not specific or recommended values to define them, it is meant that Turkey must reduce its EF down to the levels of its biocapacity and therefore its ecological deficit to be eliminated or even be converted into an ecological reserve. As eco-efficiency is concerned, its desired value should climb at higher levels and perform even better so as a bigger amount of money, than the existing, to be needed for the formation of one global hectare.

Lastly, it should be stated that the measurement of future EFs depends on systematic recorded data which up until now has been vague and misleading. It goes without saying that without reliable data the progress of SD in this country will be compromised. Techniques such as estimation for missing values or imputation of data from a big variety of different sources should be eliminated. A trustworthy and reliable database could show the road to the true confrontation and solution of the problems.

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APPENDIX A: GLOBAL AVERAGE BIOPRODUCTIVITY OF FARMLAND, GRAZING LAND AND FISHING GROUND FROM 2002 TO 2010

Table A.1. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2002)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	2,919,417.120	1,515,345.240	1926.570
Potato	453,192.760	1,515,345.240	299.070
Sugar & Honey	1,595,815.720	1,515,345.24	1053.100
Nut & Seed oils	334,190.680	1,515,345.240	220.540
Fruits	627,184.550	1,515,345.240	413.890
Grazing Land		Useable grazing land(1000ha)	
Meat	243,947.016	3,409,783.600	71.540
Fat and Grease	27,667.114	3,409,783.600	8.110
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	139,246.396	1,900,000	73.290

Table A.2. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2003)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,036,573.180	1,522,211.500	1994.840
Potato	445,665.300	1,522,211.500	292.770
Sugar & Honey	1,612,542.810	1,522,211.500	1059.340
Nut & Seed oils	355,890.070	1,522,211.500	233.800
Fruits	639,632.540	1,522,211.500	420.200
Grazing Land		Useable grazing land(1000ha)	
Meat	249,102.220	3,386,684.300	73.550
Fat and Grease	27,810.464	3,386,684.300	8.210
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	139,486.192	1,900,000	73.410

Table A.3. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2004)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,320,746.450	1,533,076,780	2166.070
Potato	466,882.950	1,533,076,780	304.530
Sugar & Honey	1,593,849.840	1,533,076,780	1039.640
Nut & Seed oils	387,628.460	1,533,076,780	252.840
Fruits	667,942.100	1,533,076,780	435.690
Grazing Land		Useable grazing land(1000ha)	
Meat	254,305.712	3,395,852,650	74.890
Fat and Grease	28,639.756	3,395,852,650	8.430
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	148,191.799	1,900,000	78.000

Table A.4. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2005)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,276,217.270	1,536,268.360	2132.580
Potato	454,965.580	1,536,268.360	296.150
Sugar & Honey	1,577,100.190	1,536,268.360	102.580
Nut & Seed oils	408,490.880	1,536,268.360	265.900
Fruits	681,735.940	1,536,268.360	443.760
Grazing Land		Useable grazing land(1000ha)	
Meat	262,262.407	3,386,035.140	77.450
Fat and Grease	28,732.791	3,386,035.140	8.490
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	151,190.181	1,900,000	79.570

Table A.5. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2006)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,229,068.790	1,532,168.210	2107.520
Potato	414299.010	1,532,168.210	270.400
Sugar & Honey	1,677,844.150	1,532,168.210	1095.080
Nut & Seed oils	420,199.330	1,532,168.210	274.250
Fruits	708,006.880	1,532,168.210	462.090
Grazing Land		Useable grazing land(1000ha)	
Meat	268,002.472	3,384,761.360	79.180
Fat and Grease	28,351.094	3,384,761.360	8.380
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	152,331.773	1,900,000	80.180

Table A.6. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2007)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,440,787.240	1,525,180.580	2255.990
Potato	425,077.730	1,525,180.580	278.710
Sugar & Honey	1,864,127.980	1,525,180.580	1222.230
Nut & Seed oils	420,599.480	1,525,180.580	275.770
Fruits	717,179.610	1,525,180.580	470.230
Grazing Land		Useable grazing land(1000ha)	
Meat	273,697.822	3,378,194.530	81.020
Fat and Grease	28,940.756	3,378,194.530	8.570
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	156,212.918	1,900,000	82.220

Table A.7. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2008)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,681,079.810	1,534,989.860	2398.110
Potato	434,058.210	1,534,989.860	282.780
Sugar & Honey	1,956,810.570	1,534,989.860	1274.800
Nut & Seed oils	449,731.890	1,534,989.860	292.990
Fruits	741,420.330	1,534,989.860	483.010
Grazing Land		Useable grazing land(1000ha)	
Meat	282,525.446	3,374,411.790	83.730
Fat and Grease	29,021.725	3,374,411.790	8.600
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	159,491.361	1,900,000	83.940

Table A.8. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2009)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,620,310.010	1,537,897.240	2354.060
Potato	437,303.450	1,537,897.240	284.350
Sugar & Honey	1,916,595.480	1,537,897.240	124.240
Nut & Seed oils	443,391.480	1,537,897.240	288.310
Fruits	755,014.860	1,537,897.240	490.940
Grazing Land		Useable grazing land(1000ha)	
Meat	288,505.333	3,361,820.150	85.820
Fat and Grease	28,861.165	3,361,820.150	8.580
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	163,499.903	1,900,000	86.050

Table A.9. Global average bioproductivity of farmland, grazing land and fishing grounds (Year 2010)

Farmland	Production Quantity (1000 metric tons)	Useable Farmland area(1000 ha)	Average Bioproductivity (kg/ha)
Grains	3,598,348.520	1,541,099.250	2334.920
Potato	436,768.180	1,541,099.250	283.410
Sugar & Honey	1,924,808.670	1,541,099.250	1248.98
Nut & Seed oils	486,115.790	1,541,099.250	315.430
Fruits	765,073.020	1,541,099.250	496.450
Grazing Land		Useable grazing land(1000ha)	
Meat	296,035.594	3,354,656.490	88.250
Fat and Grease	29,001.698	3,354,656.490	8.650
Fishing Ground		Useable fishing area(1000ha)	
Fishing Ground	168,387.552	1,900,000	88.630

APPENDIX B: TURKEY'S AVERAGE BIOPRODUCTIVITY AND YIELD FACTORS OF FARMLAND, GRAZING LAND AND FISHING GROUNDS FROM 2002 TO 2010

Table B.1. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2002)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	30,830.65	2317.60	1.37	33,146.88	65,446,165	506.48	0.263
Potatoes	5200	0.92	32.04	5168.87	65,446,165	78.98	0.264
Sugar and Honey	16,597.72	1.08	123.27	16,475.52	65,446,165	251.74	0.239
Nut and Seed Oils	2514.83	37.04	4.31	2574.56	65,446,165	39.34	0.178
Fruits	10,630.35	0.01	0.10	10,630.26	65,446,165	162.43	0.392
Total	60,573.55	2356.63	161.09	67,996.09	65,446,165	1038.96	1.336
Grazing Land							
Meat	2142.14	0.003	0.218	2141.929	65,446,165	32.728	0.457
Fat and Grease	538.95	135.685	1.051	673.586	65,446,165	10.292	1.269
Total	26,841.1	135.688	1.269	28155.515	65,446,165	43.020	1.726
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	627,857	2532	26,860	623,529	65,446,165	9.58	0.130

Table B.2. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2003)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	30,806.80	3787.22	1.62	34,592.40	66,339,433	521.45	0.261
Potatoes	5300	0.96	158.47	5114.72	66,339,433	77.10	0.263
Sugar and Honey	16,692.47	1.07	186.35	16,507.19	66,339,433	248.83	0.235
Nut and Seed Oils	2387.93	41.80	3.58	2426.14	66,339,433	36.57	0.156
Fruits	11,502.37	0.03	0.42	11,501.95	66,339,433	173.38	0.413
Total	66,689.57	3831.08	350.45	67,142.39	66,339,433	1057.33	1.328
Grazing Land							
Meat	2413.74	0.00	0.10	2413.64	66,339,433	36.38	0.495
Fat and Grease	587.86	143.73	0.73	730.85	66,339,433	11.02	1.342
Total	3001.60	143.73	0.83	3144.49	66,339,433	47.40	1.837
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	587,725	45,616	29,947	603,384	66,339,433	9.10	0.124

Table B.3. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2004)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	34,153.91	2113.40	1.41	36,265.90	67,235,927	539.38	0.249
Potatoes	4770	1.25	132.72	4638.53	67,235,927	68.99	0.227
Sugar and Honey	13,591.17	0.65	132.67	13,459.15	67,235,927	200.18	0.193
Nut and Seed Oils	2501.42	23.19	0.20	2524.40	67,235,927	37.55	0.148
Fruits	10,773.45	0.02	0.12	10,773.34	67,235,927	160.23	0.368
Total	65,789.95	2138.48	267.11	6775.13	67,235,927	3006.33	1.185
Grazing Land							
Meat	2576.00	0.00	0.03	2575.98	67,235,927	39.49	0.512
Fat and Grease	578.83	115.60	0.18	694.24	67,235,927	10.33	1.225
Total	3236.59	115.60	0.21	3270.22	67,235,927	49.81	1.737
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	644,492	57,694	32,804	669,382	67,235,927	9.96	0.128

Table B.4. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2005)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	34,471.60	353.46	108.56	34,716.49	68,143,186	509.46	0.239
Potatoes	4060	3.53	72.56	3990.97	68,143,186	58.57	0.198
Sugar and Honey	15,263.58	3.86	7.44	15,259.99	68,143,186	223.94	0.218
Nut and Seed Oils	2421.34	73.76	0.00	2495.10	68,143,186	36.62	0.138
Fruits	12,680.48	0.02	0.32	12,680.16	68,143,186	828.59	0.419
Total							1.212
Grazing Land							
Meat	2616.89	0.00	0.39	2616.50	68,143,186	38.40	0.496
Fat and Grease	643.00	145.16	0.13	788.03	68,143,186	49.96	1.362
Total							1.858
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	544,773	47,676	37,655	554,794	68,143,186	8.14	0.102

Table B.5. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2006)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	34,642.97	312.77	442.43	34,513.31	69,063,538	499.73	0.237
Potatoes	4366.18	7.28	33.68	4,339.78	69,063,538	62.84	0.232
Sugar and Honey	14,536.00	7.20	125.58	14,417.62	69,063,538	208.76	0.191
Nut and Seed Oils	2789.15	88.73	0.20	2877.68	69,063,538	41.67	0.152
Fruits	12,226.21	0.009	0.24	12,225.98	69,063,538	177.03	0.383
Total	68,560.51	415.98	602.12	68,374.37	69,063,538	990.02	1.195
Grazing Land							
Meat	2628.69	0.004	1.40	2627.30	69,063,538	38.04	0.480
Fat and Grease	649.78	155.58	0.05	805.30	69,063,538	11.66	1.391
Total	3278.46	155.58	1.44	3432.60	69,063,538	49.70	1.871
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	661,991	53,563	41,973	673,581	69,063,538	9.75	0.122

Table B.6. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2007)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	29,256.99	21,226.61	4.96	50478.64	70,586,256	715.13	0.317
Potatoes	4227.73	4.19	221.21	4010.70	70,586,256	56.82	0.204
Sugar and Honey	12488.65	4.20	38.46	12454.38	70,586,256	176.44	0.144
Nut and Seed Oils	2352.38	25.59	0.02	2377.95	70,586,256	33.69	0.122
Fruits	12362.85	0.026	0.10	12361.93	70,586,256	175.13	0.372
Total	60,688.60	21,260.61	264.76	81,683.60	70,586,256	1157.22	1.159
Grazing Land							
Meat	2712.53	0.000	0.60	2711.93	70,586,256	38.42	0.474
Fat and Grease	623.44	144.275	0.10	767.61	70,586,256	10.88	1.269
Total	3335.97	144.275	0.70	3479.55	70,586,256	49.21	1.743
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	772,323	58,022	4214	783,131	70,586,256	11.95	0.135

Table B.7. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2008)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	29287.27	3653.42	14.05	32,926.64	71,517,100	460.40	0.192
Potatoes	4196.52	0.43	87.81	4109.14	71,517,100	57.46	0.203
Sugar and Honey	15,569.70	4.78	5.28	15,569.20	71,517,100	217.70	0.171
Nut and Seed Oils	2311.43	21.68	0.03	2289.75	71,517,100	32.02	0.109
Fruits	12,929.79	0.02	0.08	12,929.73	71,517,100	180.79	0.374
Total	64,294.71	3680.34	107.25	67,824.47	71,517,100	948.37	1.049
Grazing Land							
Meat	2657.82	0.00	4.04	2653.78	71,517,100	37.11	0.443
Fat and Grease	712.16	139.76	0.16	851.76	71,517,100	11.91	1.385
Total	3369.98	139.76	4.20	3505.54	71,517,100	49.02	1.828
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	646,310	63,222	54,526	655,006	71,517,100	9.16	0.109

Table B.8. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2009)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	33577.15	3388.91	201.97	36,764.10	72,561,312	506.66	0.215
Potatoe	4397.71	0.45	67.87	4330.29	72,561,312	59.68	0.210
Sugar and Honey	17,356.68	5.05	4.99	17,356.75	72,561,312	239.20	0.192
Nut and Seed Oils	2396.04	25.41	0.00	2421.46	72,561,312	33.37	0.116
Fruits	14,222.44	0.02	0.07	14,222.39	72,561,312	196.01	0.399
Total	71,950.03	3419.84	274.89	75,094.98	72,561,312	1034.92	1.132
Grazing Land							
Meat	2999.25	0.00	1.30	2997.95	72,561,312	41.32	0.481
Fat and Grease	720.45	139.51	0.13	859.83	72,561,312	11.84	1.381
Total	3719.70	139.51	1.43	3857.78	72,561,312	53.15	1.862
Fishing Grounds	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	622,962	72,686	54,354	641,294	72,561,312	8.34	0.103

Table B.9. Turkey's average bioproductivity and yield factors of farmland, grazing land and fishing grounds (Year 2010)

Farmland	Production Quantity (1000 metric tons)	Import Quantity (1000 metric tons)	Export Quantity (1000 metric tons)	Total Consumption quantity (1000 metric tons)	Total Population	Average Bio-productivity (kg/capita)	Yield Factors
Grains	32,772.55	2536.42	826.61	34,482.37	73,722,988	467.73	0.200
Potatoes	4513.45	0.80	83.63	4430.62	73,722,988	60.10	0.212
Sugar and Honey	18,023.23	4.10	77.25	17,950.97	73,722,988	243.49	0.195
Nut and Seed Oils	2969.48	44.90	0.05	3,014.33	73,722,988	40.89	0.130
Fruits	14,004.03	0.11	0.09	14,000.05	73,722,988	189.90	0.383
Total	72,282.74	2587.23	987.63	73,878.34	73,722,988	1002.11	1.120
Grazing Land							
Meat	2224.78	46.77	0.51	2271.04	73,722,988	30.81	0.349
Fat and Grease	617.28	138.40	0.25	755.43	73,722,988	10.25	1.185
Total	2842.06	185.17	0.76	3026.47	73,722,988	41.05	1.534
Fishing Ground	Production Quantity (1000 kg)	Import Quantity (1000 kg)	Export Quantity (1000 kg)	Total Consumption quanity (1000 kg)	Total Population	Average Bio-productivity (kg/capita)	Yield Factor
	653,080	80,726	55,109	678,697	73,722,988	9.21	0.104