CLIMATE CHANGE: THE RELATIONSHIP OF RAINFALL WITH THE ECOLOGICAL FOOTPRINT AND THE URBAN HEAT ISLAND

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Abstract

The greenhouse effect and the consequent changes in weather conditions lead to extreme climate change. In this study we will present a summary of studies, regarding precipitation and how it affects the precipitation of greenhouse gases in the soil, agricultural production, ecological footprint and urban heat island (UHI). The greenhouse effect and the corresponding changes in weather conditions have led to extreme climate change. The theoretical framework of this paper includes a summary of studies regarding rainfall and how it affects the precipitation of greenhouse gases in the soil, agricultural production, ecological footprint and the urban heat island (UHI). The aim of this paper is to highlight how bio-capacity interacts with population and respectively, ecological footprint with GDP, in the 28 countries of the European Union. In addition, the change of Gini index in each country was examined in order to draw useful conclusions about its influence on the aforementioned factors and in particular on GDP and population by taking into account three decades with a base year of 1997. Specifically, data were collected and analyzed for each decade i.e. taking values for years 1997, 2007 and 2017 before the final conclusions were drawn. The paper attempts to show how Gini index has changed over the years in EU countries, compared to changes in GDP and population of each country.

Keywords: *Bio-capacity, Ecological Footprint, Rainfall, GDP, Population Growth, Gini Index*

1. INTRODUCTION

Since the 19th century, there has been an unprecedented increase in carbon footprint and a surge in greenhouse gas emissions (GHGs), which have caused radical climate change. Climate change comprises rising temperatures and the occurrence of intense and extreme events, such as storms, rainfall and drought (Mani et al. 2018). The effects of climate change vary from place to place, but also among different groups in each community (Frieler et al. 2011). In Europe there will be extreme rainfalls combined with droughts in the 21st century, while more severe effects may occur in southern Europe. In particular, there will be a reduced amount of available water which will affect agricultural production and economic activities (industrial production, etc.). It is anticipated that more and more intense forest fires will occur, due to the increase in wind intensity coupled with drought and severe floods (Kundzewicz, Radziejewski & Pinskwar 2006). Consequently, rainfall increases humidity and thus plants will absorb larger amounts of CO_2 (Paravantis et al. 2021). As known, the increase in global temperature is mainly caused by three gases, carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O) (IPPC 2013). There is a differentiation in greenhouse gas flow rates (CO_2, N_2O and CH_4) depending on the altitude of each area (Fatumah, Munishi & Ndakidemi 2019). Therefore, there will be an increase in the production of greenhouse gases.

The aim of this paper is to highlight at European level the correlation of Gini Index with biocapacity, ecological footprint, UHI, GDP and population. In particular, at EU level, ecological footprint per capita in 1997 was 5.02 global hectares in 1997, 5.52 global hectares in 2007 and 4.74 global hectares in 2017. At the same time, the biocapacity per capita (biocapacity, GHA per person) was 3.07 world hectares in 1997 and 3.00 world hectares in 2007 and 2017 (York University 2021). The ecological footprint caused by UHI, increases about 1.5 – 2 times every year. Given that all buildings are air-conditioned, approximately 110,000 hectares of land are needed to compensate for the CO2 produced (Santamouris, Paraponiaris & Mihalakakou 2005). UHI has effects on environment, air pollution and

energy, such as climate change at local level (Lin et al. 2008), visibility degradation and air pollution (Lin et al. 2008), the energy consumption of buildings (Mihalakakou et al. 2004) and effects in the population (Makrogiannis et al. 1998) and in health (Doik & Hutchings 2013).

This article is structured as follows: The next Chapter - Chapter 2 - examines the bibliography and the correlation between greenhouse gases and rainfall. In Chapter 3 is being examined the relationship between ecological footprint and UHI. Chapter 4 outlines the results of the analysis. Finally, in chapter 5 come the conclusions and some directions for further research.

2. GREENHOUSE GASES AND PRECIPITATION

2.1. Greenhouse gases

The local increase in greenhouse gases is associated with augmented occurrence of extreme weather conditions, heavy precipitations and increased lightning production during precipitations (Wang et al. 2011). Additionally, greenhouse gases are correlated with increase in cardiopulmonary diseases and carcinogenesis. The total financial cost for the treatment of these diseases represents about 1% of a city's GDP. Agricultural production is also likely to be reduced by 2.5-9.2% (Huang et al. 2012). During periods of high temperatures, the main causes of death are respiratory and cardiovascular diseases. People over the age of 65, with underlying diseases, pregnant women and children up to 4 years old are at high risk (Doik & Hutchings 2013).

The flows of greenhouse gases through precipitation increase soil temperature and their concentration in soil is also enhanced by the increasing precipitations. The aforementioned fact affects the soil's microbes, its PH, its volume in terms of density and its pores. Soil microbes increase their activity and thus enhance their respiration by emitting larger amounts of greenhouse gases, amplifying the production of CO_2 and N_2O. These results affect crop production (Fatumah, Munishi & Ndakidemi 2019).

For every 2^oC increase in soil temperature, carbon dioxide emissions increase by 13% (Zhou et al. 2006). The amount of CO_2 flow in the soil depends on soil moisture and temperature, resulting in accelerated decomposition of organic matter by microbes, thus affecting greenhouse gas emission rates (Fatumah, Munishi & Ndakidemi 2019). Various studies have shown that the effect of soil temperature on CO_2 and CH_4 flows varies in different types of ecosystems (Liu et al. 2015). Furthermore, the higher the temperature, the more likely it is that air pollution will increase, followed by increased smog, with negative effects both on the natural environment and human health (Mihalakakou et al. 2004; Santamouris et al. 2001; Livada et al. 2002).

The atmosphere, however, does not function as an isolated system but as an interactive one, in which energy flows take place between it and other elements of the climate system, with the most important of these occurring in the oceans. The oceans absorb much more heat than the atmosphere, which results in the evaporation of their surface water. Another important function of the oceans is to move this heat through moisture and ocean currents from the equator to the earth's poles. Therefore, energy flows between the oceans and the atmosphere can have a decisive effect on the existing climate. Conversely, ice removes heat from the atmosphere in two ways: a) because of its low temperature and b) because of its white color. The earth, otherwise, would absorb more energy from the sun as we would not have a reflection of a large amount of light due to the white color of the ice. Global temperature without ice would be higher (Schneider, Rosencranz & Niles 2002).

The earth through oceans and the biosphere can control significantly the greenhouse effect and consequently its temperature through the control of carbon dioxide CO_2. Plants capture CO_2 for photosynthesis and in the oceans CO_2 dissolves in large quantities and is then used by various marine organisms for photosynthesis or other physiological processes. Energy exchange control mechanisms are vitally important because without them the atmosphere would contain four times more CO_2 and such an increase would lead to a substantial rise in temperature (Schneider, Rosencranz & Niles 2002).

2.2. Precipitation

Vegetation and especially trees have effective mechanisms for the reduction of temperature and consequently the reduction of UHI. The type and especially the allocation strategy of plants affect the reduction of UHI. Temperature is balanced through evaporation, respiration, reflection and shading. Through these four ways temperature can be reduced from 15^{o}C - 20^{o}C in the built environment and from 2^{o}C - 8^{o}C in the atmosphere. Plants, through evaporation, absorb energy to convert the water in their leaves, into their trunks and roots, into steam which is expelled through respiration. Hence, part of the energy is captured from the environment while reducing the temperature. Shading on the other hand contributes to the reduction of UHI by mitigating the penetration of sunlight on the surfaces. Aquatic zones function effectively in reducing UHI because water acts as a mirror and reflects most of the incident sunlight during the day. Part of this energy is used for evaporation, while during the night water releases the heat it has stored (Doik & Hutchings 2013).

Precipitation increases proportionally with altitude in an area, while there is an inverse relationship with soil temperature (Fatumah, Munishi & Ndakidemi 2019). The relationship between precipitation and runoff on green roofs depends on the amount of soil (soil). Rainwater retention is lower in winter than in summer. In Brussels, a 10% increase in green roofs resulted in a reduction in runoff of 2.7% per year and 54% in individual buildings (Mentens, Raes & Hermy 2006).

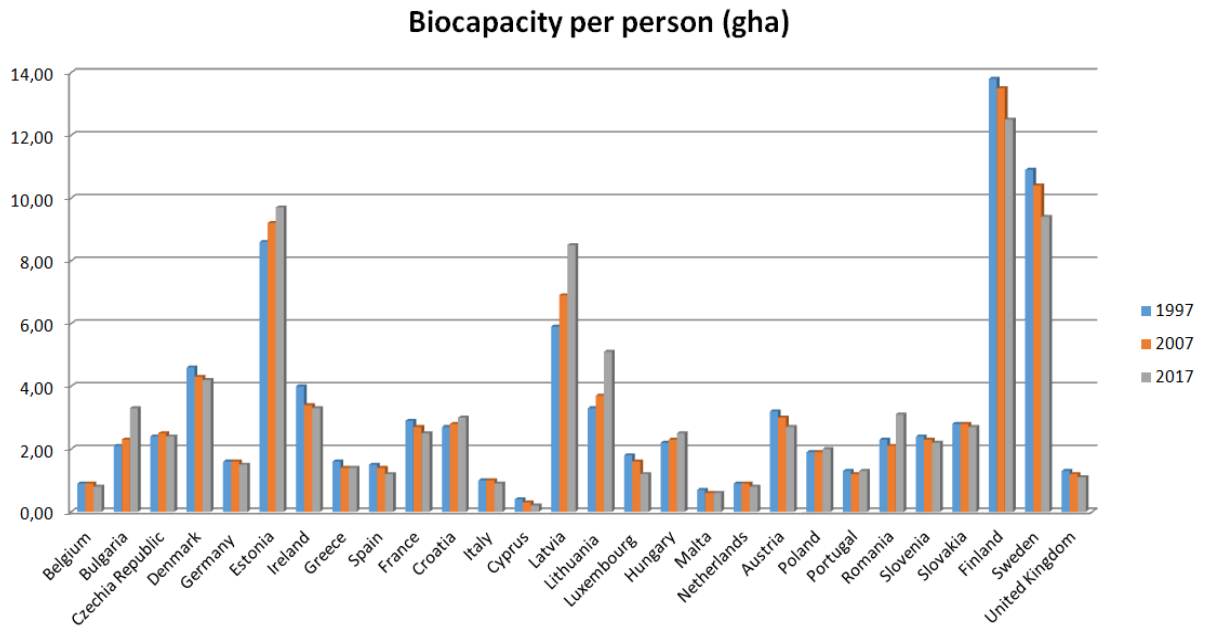
Niarchou et al. (2001) suggested that the most common way is green roofs but without much efficiency in terms of their energy benefit. According to an analysis regarding thermal efficiency from the properties of planted, green roofs, with temperature measurements on the roof surface of buildings and indoors, it was found that a well-insulated building with a green roof had an energy benefit of 2%. Areas with Mediterranean climate will face several challenges as their water resources will be reduced, the intensity of precipitation will be increased with an increased risk of floods and intense drought (Bates et al. 2008).

3. THE ECOLOGICAL FOOTPRINT AND THE URBAN HEAT ISLAND

3.1. Ecological footprint

The environmental changes that occur as a result of deforestation, overfishing, change in the use of land and CO_2 accumulation in the atmosphere indicate that hum demand may exceed the regenerative and absorbent capacity of the biosphere. The necessity to examine the exact condition of each country has led to the introduction of sustainability indicators (Chambers, Simmons & Wackernagel 2010). Anthropogenic climate change over time affects natural evolution through climate change. This is mainly reflected in the climatic cycles of fifty and one hundred years. It is mainly due to natural processes but also to anthropogenic causes that affect the climate since they modify the atmosphere (Stern 1992). In order to measure the planetary limits and their degree of viability, a dynamic tool is used which is the ecological footprint. With this tool we measure the production of human resources, by estimating the biological production of land and sea required for consumption as well as the absorption of the corresponding waste based on existing technology (Chambers, Simmons & Wackernagel 2010).

In the graphic below (Graphic 1), one can see how bio-capacity is captured for different decades in the countries of the European Union. For instance, extreme changes in Latvia, Lithuania, Finland and Sweden are depicted.



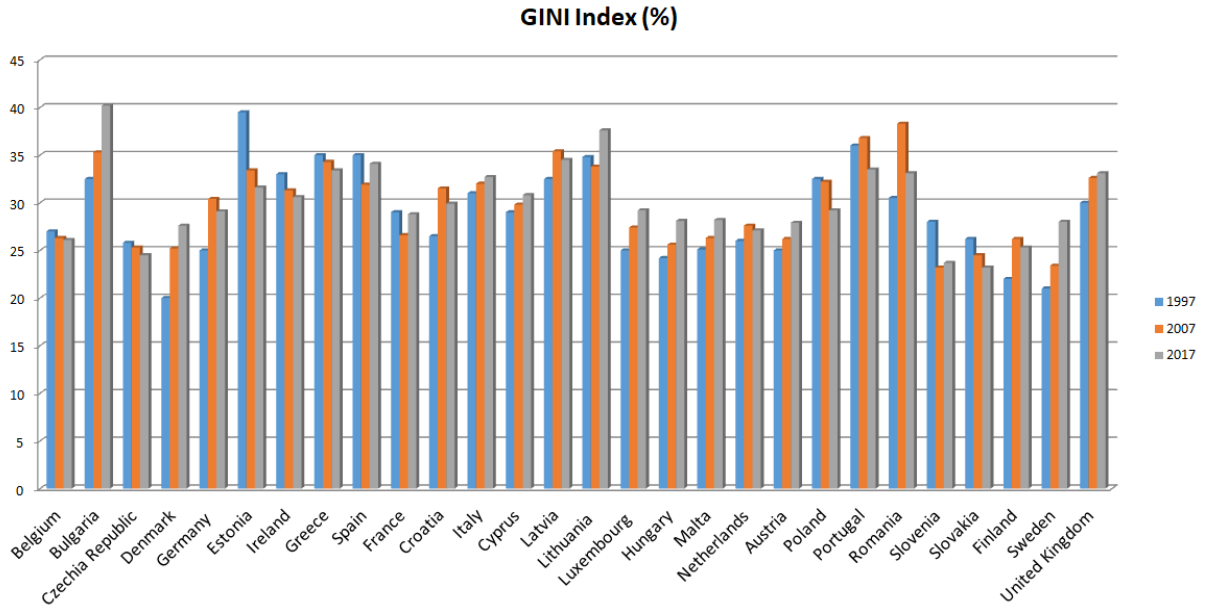
Graphic 1. Biocapacity per person (GHA), in 1997, 2007 and 2017 in European Union

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

Indicators are powerful tools for simplifying, quantifying and extracting results. They provide information about processes such as the nature-society interaction which are too complex to be immediately perceptible. Their aim is to contribute to information and to induce discussions on sustainability, land use and economic policies in a way that enhances the solution of problems (Hammond et al. 1995).

One of the indicators, Gini index, increases by about 1.5 respectively every five years, mainly after major epidemics. Throughout the 19th and 20th century, Gini index had a steady increase according to the World Bank. It is possible a low -income country to have the same Gini index with a high-income country. However, Gini index may overestimate income inequality and be inaccurate due to the limitations of reliable GDP data. The aforementioned fact can have economic or political consequences in a country's GDP.(World Population Review 2021). In most of OECD countries recently, Gini Index has been associated with increased inequalities even with a proportional growth of GDP (Organisation for Economic Co-operation and Development n.d.).

In the graphic below (Graphic 2), one can see the differentiation of Gini Index over decades in the countries of the European Union.

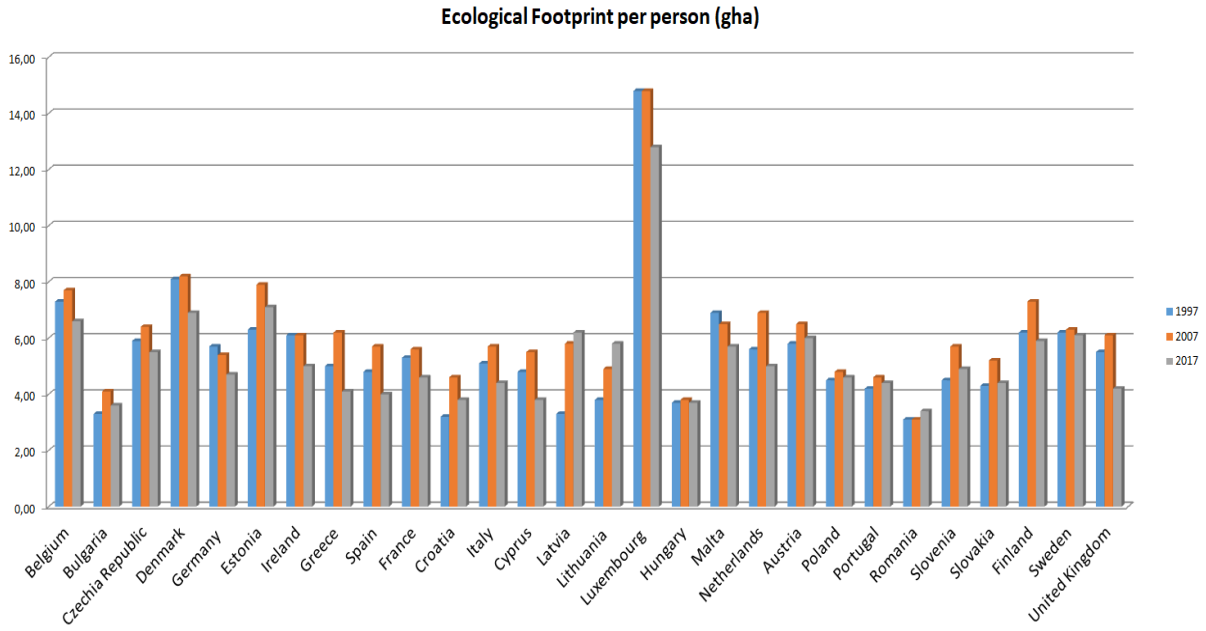


Graphic 2. Gini Index (%), in 1997, 2007 and 2017 in European Union

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

Another important indicator is the ecological footprint. Estimating the ecological footprint of a defined population is a multi-stage process. The calculation of land requirements includes areas which are required for the production and distribution of energy. The main idea is that the production of any kind of material or energy consumption corresponds to one or more regions of land. These areas are related to resources, energy flows and waste generated from material production or energy consumption. Hence, in order to determine the total area of land required for energy production or consumption, the land which is used and its effects on each important consumption category must be measured. This must be calculated in a specific pattern of consumption. It is appropriate to distinguish consumption into five main categories: 1) food, 2) housing, 3) transportation, 4) consumer goods, and 5) services (Chambers et al. 2010; Lewan 2000; Wackernagel & Rees 1996). The ecological footprint of UHI increases about 1.5-2 times every year. Provided that all buildings are air-conditioned, about 110,000 hectares of land are needed to compensate for the CO_2 produced (Santamouris, Paraponiaris & Mihalakakou 2005).

In the Graphic below (Graphic 3), we can see the fluctuation of Ecological Footprint, for different periods in the countries of the European Union. As we can see Luxembourg stands out.

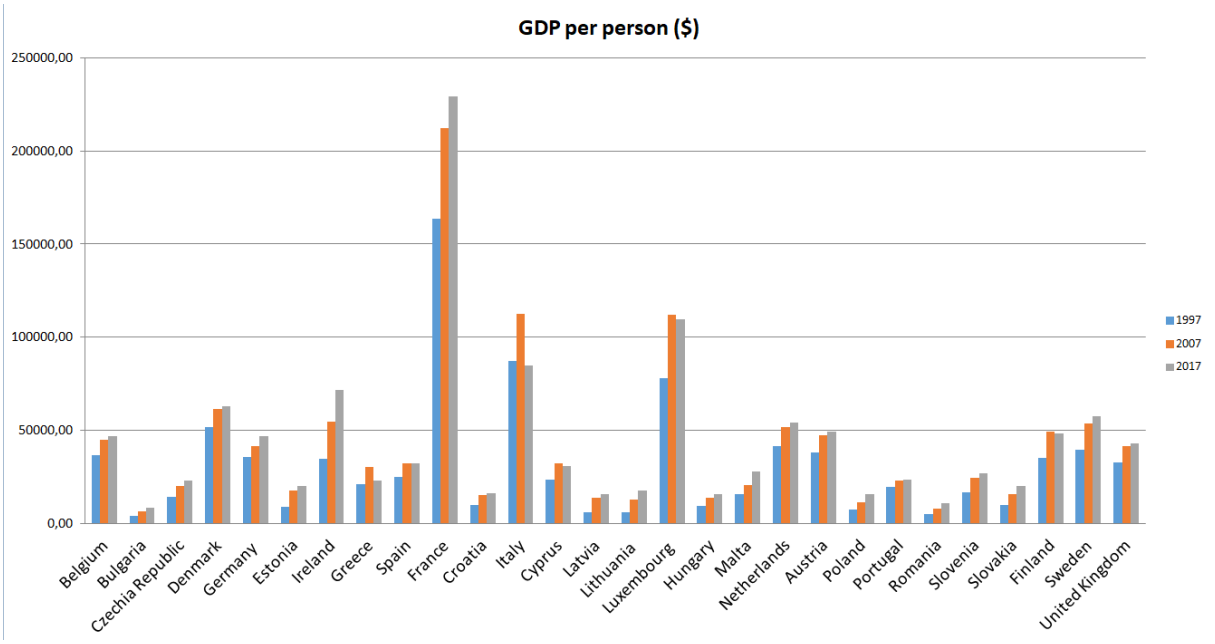


Graphic 3. Ecological Footprint per person (GHA) in 1997, 2007 and 2017 in EU

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

Urbanization affects CO_2 production proportionately to the level of income. The higher the GDP per capita, the higher the CO_2 production is due to higher and more intense consumption of electricity and fossil fuels irrespective of countries' development levels (Paravantis et al. 2021).

The graphic below (Graphic 4) illustrates values of GDP per person for the countries of the European Union in dollars. The increase of GDP in France is remarkable.



Graphic 4. GDP per person ($), in 1997, 2007 and 2017 in EU

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

3.2. Urban Heat Island

The Urban Heat Island (UHI) phenomenon is primarily caused by different thermal characteristics of the natural environment. Specifically, UHI is the outcome of structural differences between urban and rural environments related to the thermal properties of urban materials, urban spatial planning, air pollution and anthropogenic heat (Park 1989a). UHI occurs both during day and night. Its magnitude as well as its duration depends on the local characteristics of each urban area. The intensity of UHI can be quantified by measuring the temperature difference between urban and rural areas and depends on the meteorological conditions, the climate, the size of the area, the population, its industrial development, its topography and its natural layout (Oke et al. 1991). However, there are other factors that affect the development and intensity of the phenomenon such as the amount of cloud cover and wind speed. The intensity of the phenomenon increases is enhanced by the lack of cloud cover as well as anticyclonic conditions (Morris & Simmonds 2001).

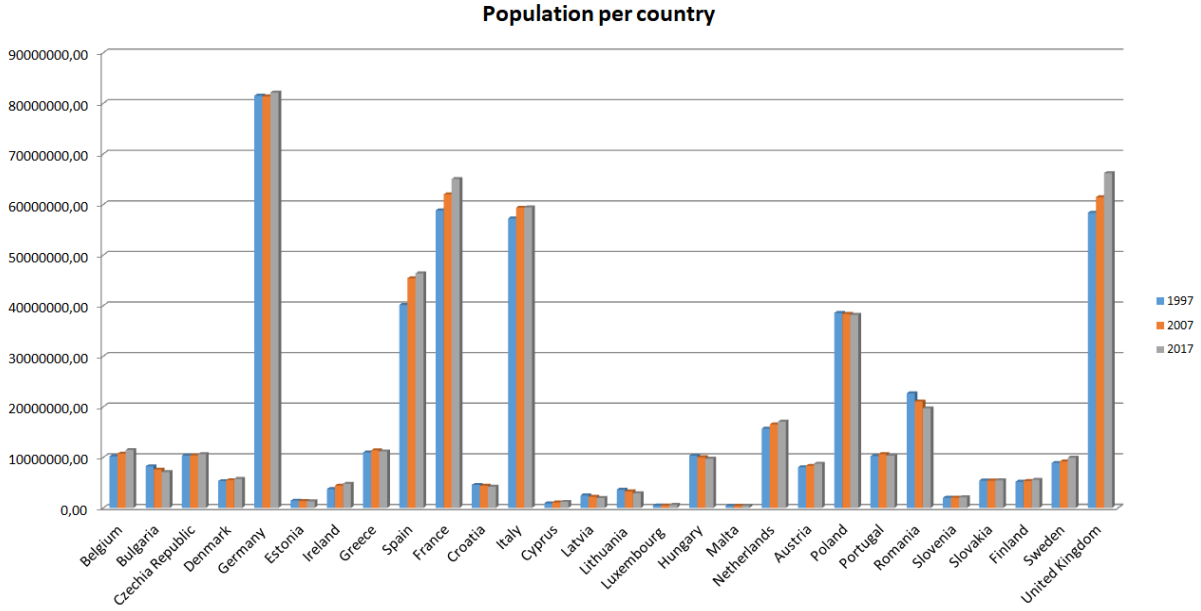
Materials that are mainly used in cities such as asphalt and cement have different thermal and reflective properties compared to the natural environment. These materials modify the energy balance because they absorb more solar radiation than they reflect resulting in an increase in temperature. The reduction of vegetation negatively affects the energy balance because it constrains evaporation and consequently the cooling caused by this phenomenon. Other factors that contribute to the further development of UHI are the geometric features of the city, air pollution, poor ventilation and anthropogenic heat (Mihalakakou et al. 2004; Santamouris et al. 2001; Livada et al. 2002).

Vegetation deficit in urban areas affects the energy balance, as the natural cooling of the urban surface through evapotranspiration is minimized (Taha 1997). The energy balance of an urban surface is altered by urban materials since they absorb incoming solar radiation instead of reflecting it, thus causing an increase in surface temperature and the environment (Stathopoulou & Cartalis 2007).

Urbanization results in very high energy consumption. An increase of 1% of GDP per capita leads to an almost equal (1.03) increase in energy consumption. However, an increase of the urban population by 1% leads to an increase in energy consumption by 2.2% i.e. the rate of change of energy use is

twice the rate of change of urbanization. The correlation between urbanization and energy consumption is obvious. Increased urban temperatures have a direct impact on the energy consumption of buildings, especially during summer. It is found that higher urban temperatures increase the demand for electricity for cooling during summer and therefore the production of CO_2 as well as other pollutants (Makrogiannis et al. 1998).

The graphic below (Graphic 5) depicts the population changes in the countries of the European Union. The most significant variations correspond to the United Kingdom and France.



Graphic 5. Population per Country in 1997, 2007 and 2017n EU

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

4. DISCUSSION

Conventional building materials have a small reflection of solar radiation, reaching an absorption capability of almost 95%. Such materials are cement, asphalt, bricks and iron. Asphalt covers about 1/3 of the surfaces of cities and in order to be insulated it needs to improve its stability and grind its surfaces. It has high energy absorption of over 95% so it heats up even when there is no high temperature in the air. Its temperature reaches 68^{o}C with an average air temperature of 35^{o}C (Doik & Hutchings 2013).

Modern construction technologies provide materials with a high degree of reflectivity of up to 85% of the incident radiation and provide pigments that offer increased whiteness. During summer months their temperature exceeds 45^{o}C – 46^{o}C. They excel, compared to conventional materials in which the temperature can exceed 75^{o}C. Approximately 25% of the total built space covers the roofs of the buildings and their temperature can reach 80^{o}C. They heat the interior air inside the buildings and increase the need for mechanical cooling. In buildings, the main roofing material is usually of asphalt origin. However, there are techniques which improve the whiteness of the roofs by up to 65%. The selection of material and color is not always effective. There are white metals that retain most of the energy they receive despite their high reflectivity. Materials which increase whiteness and reflectivity, although relatively inexpensive, tend to lose some of their efficiency over time (Doik & Hutchings 2013).

The construction of the urban fabric geometrically affects the cooling of the buildings as a whole by creating the urban ravine and constrains the view to the sky (Giridharan, Ganesan & Lau 2004). Additionally, a large percentage of infrared radiation from buildings, sidewalks and asphalt, has no possibility of releasing it into the atmosphere and is trapped between buildings. Multiple reflections of solar radiation between buildings increase its absorption and energy balance of all external surfaces (Santamouris et al. 1997). However, the development of photovoltaic systems increases the temperature locally by 3-4^{o}C and despite the fact they provide shading in the underlying spaces, they prevent the growth of vegetation and the corresponding benefit from cooling, through perspiration (Barron-Gafford et al. 2016). At the same time, the temperature in underlying areas can be increased depending on the incline (without slope, horizontal) of photovoltaic systems (Wang, Wang & Liu 2017).

Stathopoulou et al. (2004) suggested that buildings and artificial surfaces cover 77% of a city's area, 19% correspond to the road network and only 4% of the area are green open spaces. The consequences of removing the earth's natural cover and replacing it with materials of high thermal capacity and low solar reflectivity e.g. concrete, asphalt, stone, brick and metal affect the environment, especially when combined with lessened evaporation. They increase surface runoff, store and transfer detectable heat and degrade the quality of ambient air and water (Kardinal et al. 2007; Taha, Akbari & Rosenfeld 1991; Mallick & Rahman 2012).

Urbanization, coupled with anthropogenic activities, intensifies extreme precipitation and extreme weather events. The aforementioned fact poses a significant concern because by 2030, 60% of the global population is expected to join cities. Cities are vulnerable to heavy and extreme precipitation due to the lack of sufficient infrastructure for runoff because they are expensive and therefore pose a major threat to life in urban areas. Urban precipitation is associated with an increase in soil surface temperature, which enhances the development of the urban thermal island phenomenon (Marelle et al. 2020).

Climate-reduced buildings have the highest energy consumption in Europe, about 30% higher than in Spain and almost twice as high as in Portugal, and significantly higher than countries with colder climates such as Belgium and the Nordic countries (Elias et al. 2013).

Approximately 30-40% of the consumption of natural resources used by industrialized countries comes from the construction industry. Almost 50% of this energy flow is used for air conditioning in buildings (heating and cooling). Approximately 40% of the global consumption of natural materials is converted into a structured environment and about 30% from the use of energy consumed in housing. In the USA, for instance, 35-60% of total energy is used to maintain buildings. About 75% of the electricity supply in the United States is consumed through the thermoelectric effect. A large amount of CO_2 emissions comes from the building of houses and consequently their use and maintenance. In the European Union, energy consumption for housing and services was 371.4 Mtoes (Million Tonnes of Oil Equivalent) for the year 2000, which is higher than other sectors such as transportation and industry (Roodman & Lenssen 1995). Reducing energy consumption can be achieved by changing the shell of an old building in relation to district heating (Andric et al. 2017).

Pavan Sukhdev, an economist at Deutsche Bank in Germany who led a European study on ecosystems, claimed that natural capital between $2 trillion and $5 trillion is lost annually from deforestation alone. By the time survey was concluded, financial losses were estimated between $ 1 and $1.5 trillion (Black 2008). The former cash flows were calculated on the basis of the services produced by the various ecosystems that are lost annually, such as the value of the amount of precipitation for crops or the limitation of their protection due to floods.

5. RESULTS

As regards the 28 countries of the European Union, all the data under consideration (Biocapacity, Ecological Footprint, GDP, Population and Gini index) have been captured in the table below and will be analyzed right after.

Table 1. Values: GDP per person ($), Ecological footprint per person (GHA), Biocapacity per person (GHA), population and Gini Index (%) in European Union at different times.

TOTAL ECOLOGICAL FOOTPRINT							
A/A	**Country EE (28)**	**Years**	**Biocapacity per person (gha)**	**Ecological Footprint per person (gha)**	**GDP per perason ($)**	**Country population**	**GINI Index (%)**
1	**Belgium**	**1997**	0.9	7.3	36.403	10.198.700	27
		2007	=	+	+	+	-
		2017	-	-	+	+	-
2	**Bulgaria**	1997	2.1	3.3	3.908	8.211.730	32,5
		2007	+	+	+	-	+
		2017	+	-	+	-	+
3	**Czech Republic**	1997	2.4	5.9	13.979	10.338.600	25,8
		2007	+	+	+	+	-
		2017	-	-	+	+	-
4	**Denmark**	1997	4.6	8.1	51.686	5.277.710	20
		2007	-	+	+	+	+
		2017	-	-	+	+	+
5	**Germany**	1997	1.6	5.7	35.539	81.499.896	25
		2007	=	-	+	-	+
		2017	-	-	+	+	-
6	**Estonia**	1997	8.6	6.3	8.779	1.409.670	39,5
		2007	+	+	+	-	-
		2017	+	-	+	-	-
7	**Ireland**	1997	4.0	6.1	34.745	3.712.460	33
		2007	-	=	+	+	-
		2017	-	-	+	+	-
8	**Greece**	1997	1.6	5.0	21.199	10.961.100	35
		2007	-	+	+	+	-
		2017	=	-	-	-	-
9	**Spain**	1997	1.5	4.8	25.061	40.131.600	35
		2007	-	+	+	+	-
		2017	-	-	-	+	+
10	**France**	1997	2.9	5.3	163.375	58.794.600	29
		2007	-	+	+	+	-
		2017	-	-	+	+	+
11	**Croatia**	1997	2.7	3.2	9.862	4.532.400	26,5
		2007	+	+	+	-	+
		2017	+	-	+	-	-
12	**Italy**	1997	1.0	5.1	87.387	57.212.200	31
		2007	=	+	+	+	+
		2017	-	-	-	+	+
13	**Cyprus**	1997	0.4	4.8	23.388	891.192	29
		2007	-	+	+	+	+
		2017	-	-	-	+	+
14	**Latvia**	1997	5.9	3.3	5.866	2.453.300	32,5
		2007	+	+	+	-	+
		2017	+	+	+	-	-

15	**Lithuania**	1997	3.3	3.8	6.147	3.579.900	34,8
		2007	+	+	+	-	-
		2017	+	+	+	-	+
16	**Luxembourg**	1997	1.8	14.8	78.076	445.106	25
		2007	-	=	+	+	+
		2017	-	-	-	+	+
17	**Hungary**	1997	2.2	3.7	9.281	10.309.000	24,2
		2007	+	+	+	-	+
		2017	+	-	+	-	+
18	**Malta**	1997	0.7	6.9	15.886	387.184	25,1
		2007	-	-	+	+	+
		2017	=	-	+	+	+
19	**Netherlands**	1997	0.9	5.6	41.356	15.655.500	26
		2007	=	+	+	+	+
		2017	-	-	+	+	-
20	**Austria**	1997	3.2	5.8	38.085	8.032.880	25
		2007	-	+	+	+	+
		2017	-	-	+	+	+
21	**Poland**	1997	1.9	4.5	7.374	38.538.700	32,5
		2007	=	+	+	-	-
		2017	+	-	+	-	-
22	**Portugal**	1997	1.3	4.2	19.355	10.232.900	36
		2007	-	+	+	+	+
		2017	+	-	+	-	-
23	**Romania**	1997	2.3	3.1	4.872	22.632.800	30,5
		2007	-	=	+	-	+
		2017	+	+	+	-	-
24	**Slovenia**	1997	2.4	4.5	16.448	1.987.950	28
		2007	-	+	+	+	-
		2017	-	-	+	+	+
25	**Slovakia**	1997	2.8	4.3	9.823	5.391.200	26,2
		2007	=	+	+	+	-
		2017	-	-	+	+	-
26	**Finland**	1997	13.8	6.2	34.947	5.151.750	22
		2007	-	+	+	+	+
		2017	-	-	-	+	-
27	**Sweden**	1997	10.9	6.2	39.565	8.868.850	21
		2007	-	+	+	+	+
		2017	-	-	+	+	+
28	**United Kingdom**	1997	1.3	5.5	32.489	58.346.700	30
		2007	-	+	+	+	+
		2017	-	-	+	+	+

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

By observing table 1 and comparing GDP per person ($) and Ecological footprint per person (GHA), one can identify seven groups of Countries in the EU.

Specifically, in group A the countries which have positive (+) GDP and positive (+) Ecological footprint in 2007 and positive (+) GDP and negative (-) Ecological footprint in 2017, both compared to 1997, are the following: Belgium, Bulgaria, Czechia Republic, Denmark, Estonia, France, Croatia, Hungary, Netherlands, Austria, Poland, Portugal, Slovenia, Slovakia, Sweden and United Kingdom.

In group B, one can find countries which have positive (+) GDP and negative (-) Ecological footprint in 2007 and positive (+) GDP and negative (-) Ecological footprint in 2017, both compared to 1997. These countries are Germany and Malta.

In group C, Ireland in 2007, has positive (+) GDP and neutral Ecological footprint, while for 2017 it has positive (+) GDP and negative (-) Ecological footprint, both compared to 1997.

Group D includes countries like Greece, Spain, Italy, Cyprus and Finland which have positive (+) GDP and positive (+) Ecological footprint in 2007 and negative (-) GDP coupled with negative (-) Ecological footprint in 2017, both compared to 1997.

Latvia and Lithuania in group E, have positive (+) GDP combined with positive (+) Ecological footprint in 2007 and positive (+) GDP with positive (+) Ecological footprint in 2017, both compared to 1997.

Additionally, in Group F, Luxembourg in 2007 has positive (+) GDP and neutral (=) Ecological footprint, while in 2017 it has negative (-) GDP and negative (-) Ecological footprint, both compared to 1997.

Lastly, in group G, Romania has positive (+) GDP and neutral (=) Ecological footprint compared to 2007 and positive (+) GDP combined with positive (+) Ecological footprint in 2017, both compared to 1997.

Comparing Biocapacity per person (GHA) with countries' population, 10 distinguished groups can be identified.

In group A one can find Belgium, Italy, Netherlands and Slovakia. Compared to the base year (1997), in 2007 the population in aforementioned countries increased (+) while the biocapacity was neutral (=) in 2007. Moreover, in 2017 the population increased (+) and the biocapacity reduced (-).

Additionally, in group B, countries like Bulgaria, Estonia, Croatia, Latvia, Lithuania, Hungary has a decreased (-) population and increased (+) biocapacity in 2007. The same results were found in 2017.

As regards group C, in 2007 Czech Republic increased (+) its population and its biocapacity compared to 1997. However, in 2017 the population increased (+) and biocapacity decreased.

Denmark, Ireland, Spain, France, Cyprus, Luxembourg, Austria, Slovenia, Finland, Sweden and United Kingdom in group D has an increasing (+) population and neutral (=) biocapacity in 2007 compared to 1997 (paradox). In 2017, the population increased and the biocapacity decreased.

Regarding group E, Germany had a decreased (-) population and a neutral (=) biocapacity in 2007 compared to 1997. In 2017, the population increased (+) and the biocapacity decreased (-).

Group F includes Greece which increased (+) its population and decreased (-) its biocapacity in 2007 compared to 1997. In 2017, the population increased (+) and the biocapacity decreased.

Malta, in group G, increased (+) its population and decreased (-) its biocapacity in 2007 compared to 1997. In 2017, its population increased (+) and the biocapacity was neutral (=).

Poland, the only country in group H, has a decreased (-) population and neutral (=) biocapacity in 2007 compared to 1997. In 2017, the population decreased (-) and the biocapacity increased (+).

In addition, in group I, Portugal increased (+) its population and decreased (-) its biocapacity in 2007 compared to 1997. In 2017, the population decreased (-) and the biocapacity increased (+).

Lastly, in group J, Romania had decreased (-) population and biocapacity in 2007 compared to 1997. In 2017, the population decreased (-) and the biocapacity increased (+).

Consequently, we analyze the change in Gini index for 2007 and 2017, compared to 1997, in countries of the EU.

Table 2. Change of Gini Index in comparison with 1997, 2007 and 2017

1	Belgium, Czech Republic, Estonia, Ireland, Greece, Poland, Slovakia	Decreased (both in 2007 and 2017)
2	Bulgaria, Denmark, Italy, Cyprus, Luxembourg, Hungary, Malta, Austria, Sweden, United Kingdom	Increased (both in 2007 and 2017)
3	Germany, Croatia, Latvia, Netherlands, Portugal, Romania, Finland	Initially increased (2007) and then decreased (2017)
4	Spain, France, Lithuania, Slovenia	Initially decreased (2007) and the increased (2017)

Source: York University, 'Global Footprint Network' web site, https://data.footprintnetwork.org/#/countryTrends?type=BCpc,EFCpc&cn=2002, accessed March 2021.

According to table 2, as regards the period 2007 – 2017, compared to 1997, Gini decreased in the following countries: Belgium, Czechia Republic, Estonia, Ireland, Greece, Poland and Slovakia. In other countries, as Bulgaria, Denmark, Italy, Cyprus, Luxembourg, Hungary, Malta, Austria, Sweden and United Kingdom, Gini index increased.

Additionally, in countries like Germany, Croatia, Latvia, Netherlands, Portugal, Romania and Finland one can notice an initial increase in Gini followed by a decrease. Conversely, in countries like Spain, France, Lithuania and Slovenia, Gini initially decreased before it increased again.

6. CONCLUSION

Rainfall through the precipitation of greenhouse gases degrades the soil and raises its temperature while draining it into the sea. Conversely, it enhances the growth of plants and thus reduces CO2, thereby reducing the urban heat island and the ecological footprint, mainly due to the reduced use of cooling systems.

Based on above analysis, one can see that 16 out of 28 countries in the EU (Belgium, Bulgaria, Czech Republic, Denmark, Estonia, France, Croatia, Hungary, Netherlands, Austria, Poland, Portugal, Slovenia, Slovakia, Sweden and United Kingdom), compared with base year 1997, had an increasing GDP and Ecological footprint. Moreover, in the next decade (2007 – 2017) their GDP increased and their Ecological footprint decreased. In 12 out of 28 countries (Denmark, Ireland, Spain, France, Cyprus, Luxembourg, Austria, Slovenia, Finland, Sweden, Sweden, United Kingdom), in comparison with 2017, the population increased and the biocapacity decreased in the next two decades (1997-2017). Increase of bio-capacity can be achieved through policies which reduce the ecological footprint by establishing a more reasonable use of land. Additionally, a wider use of Renewable Energy Sources (RES) is expected to mitigate the negative effects of climate change. The data analysis showed that in 4 out of 28 EU countries, while the Gini index increased, the population also increased and biocapacity decreased (Denmark, Austria, Sweden, United Kingdom).

Correlation of the change in population and GDP with the Gini index showed that in 4 of the 28 EU countries (Belgium, Czech Republic, Ireland and Slovakia), while the Gini index was decreasing, the population and GDP was increasing. In 5 of the 28 EU countries (Denmark, Malta, Austria, Sweden,

and the United Kingdom), an increasing Gini index was combined with increasing population and GDP. Lastly, in 2 countries (Bulgaria and Hungary), an increasing Gini index was coupled with decreasing population and increasing GDP. The paradox in these results is that no country in the EU had a decreasing Gini Index in conjunction with increasing population and declining GDP. The analysis of the data outlined that there is no uniform distribution of Gini index in comparison with population and GDP. We suspect that there may be one or more variables which had influenced the values of the data we examined and thus needs to be further examined.

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