Meteorological parameters and land use changes in the industrial area of Thriasio Plain – Greece

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Abstract
This paper investigates the relationship between Air Temperature, Precipitation and Relative Humidity, as well as the E de Martonne climatic aridity index, and land use changes in the industrial area of Thriasio Plain – Greece, using 53 years of meteorological data (from 1958 to 2011). In order to examine the growth of the number of established activities over time and the consequent change in land use, a Verhulst equation model and two simple regression models were applied. Models results for established activities in the area were marked by a continuous growth, although the rate of growth varied among the different local authorities. In addition, what appears to a decisive factor in the evolution of activities and residential zones of the area is the land surface availability in each one of the local authorities. The results for the climatic index showed a trend towards characterizing the climate as warmer and drier. The latter conclusion is consistent with the intense land use change in the area of interest.

Keywords: Established Activities, Meteorological Parameters, Thriasio Plain

1 Introduction
In Greece the industrial development of the country was followed by nature's destruction to a large or small extent, depending on the type of industries, the size of the cities, the local climate, etc. Among other consequences, plant mortality, pollution of surface and ground waters, as well as dramatic depletion of flora and fauna species and populations were recorded in industrially developed countries of the West and East Europe. The constant population growth and the concentration of activities in the urban agglomeration of the capital during the post–war period were spatially expressed as a continuous expansion of the built–up agglomeration towards the periphery. This led to the occupation of a large part of the urban as well as the greater regional area of the prefecture of Attica due to land use and activities directly or indirectly linked to urban operations. Consequently, the borders between urban and suburban areas become indiscernible, suburban areas lack a consistent character (either urban or rural) and are characterized by diffusion and interference of frequently incompatible land uses, leading to the alteration as well as degradation of natural environment and, furthermore, to wasting space, infrastructures and investments. In the case of Attica, the urban development model was extremely destructive, due to the rapid development rate mainly occurring during the post-war period. In the last 20 years the aforementioned phenomena are rather intense within the suburban area of the metropolitan conglomeration, with the intensity rising in the area of Mesogeia (East Attica), Thriasio Plain (West Attica) and alongside the coastline. This development is attracted and supported by the existence or potential construction of large infrastructure facilities within the region of Attica (ports, a new airport, transport axes), however, at the same time creating the need to build more infrastructures to serve these new facilities. The pressure for building development and for finding areas for establishing production activities impedes efforts for a consistent urban planning. Since the end of the 18th century, West Attica has been associated with the history of development of the industrial sector in Greece. Situated in Thriasio Plain, with a population of about 80,000 residents and an

important concentration of manufacturing and logistics units, are some of the most advanced industrial units of great economic interest of the country, (Christofakis & Tsampra 2012; Mavrakis, 2012; Mavrakis & Papavasileiou, 2013a & 2013b).
In this paper an attempt is made to conjunct the meteorological parameter of Air Temperature, Relative Humidity, Precipitation and E. de Martonne climatic aridity index with the growth of the number of established activities over time and the consequent change in land use, especially during long hot dry Greek summer (Melendez-Pastor et al, 2010; Mavrakis et al., 2012)

2 Data and Methodology

The data used refers to Elefsis station (LGEL) covering the period from 1958 to 2011 and were provided from Hellenic National Meteorological Service. Data included monthly and annual average values of air temperature, relative humidity and precipitation. The de Martonne index calculates the dryness of a region and highlights the current circumstances basin.
It is estimated by the formula: $I = \frac{P}{T+10}$,
where: P–annual rainfall and T–Average Annual Rate of air temperature [^{o}C], (de Martonne, 1941).
In order to examine the growth of the number of established activities over time and the consequent change in land use a Verhulst equation model and two simple regretion models (R–1 & R–3) were used. Also Rate Growth was calculated. For the aforementioned research, census data were used (Stamatiadis, 1993 & 2000).

3 Results

The meteorological data set was divided in two new set. A climatologically set from 1960 – 1990 and a new set from 1991 – 2011 in order to examine the evolution of the meteorological parameters. Then we calculate the relative frequency between those two data sets categories. The average monthly Air Temperatures (Fig. 1a) show an increase of values above of 32 ^{o}C or below 8 to 14 ^{o}C. That's mean that Temperature has an increase of extreme values. The RH shows a clear continuous decline during the last 20 years (Fig. 1b). There is a significant shift to lower monthly and annual values of RH, especially during last 20 years. The average monthly Precipitation (Fig. 1c) shows an increase of monthly values, but total precipitation remain almost the same. That's mean that precipitation rate increase. The de Martonne aridity climate index (Fig. 1d) shows a normal volatility with the absence of extreme fluctuations. But what seems clear is that the average index is calculated for lower values. During two years is calculated above 10 while precipitation is less than 200 mm and 150 mm, suggesting significant dryness of the area, to such an extent as to reach the stage of desertification. Furthermore a very impressive result is that the climate is characterized as "Mediterranean" only during two years, while in one case the climate is classified as "semi-humid".
The industrialization of the area and the transformation of land from rural into industrial resulted in changes in the land uses, as it occurred without any previous planning, through a series of constant classification and declassification of minor and major areas as industrial zones and vice versa. Thriasio Plain is characterized by an unregulated development of various activities, since residence, agriculture, industry and port facilities co-exist within the same environment with the road network crossing the cities. The establishment of these activities in the area took place without any prior construction of necessary infrastructures. In addition, establishment of these activities taking place in the entire plain area was unregulated and arbitrary. More than half of the industries are located outside the statutory industrial zones. As a result, production units are scattered across the area, lacking a service network, whereas at the same time resident quality of life is gradually degrading. This phenomenon led to the emergence of environmental problems, overall degradation of the quality of life of residents and their gradual long-term deterioration (Tassopoulos et al., 2003; Helmi 2007).

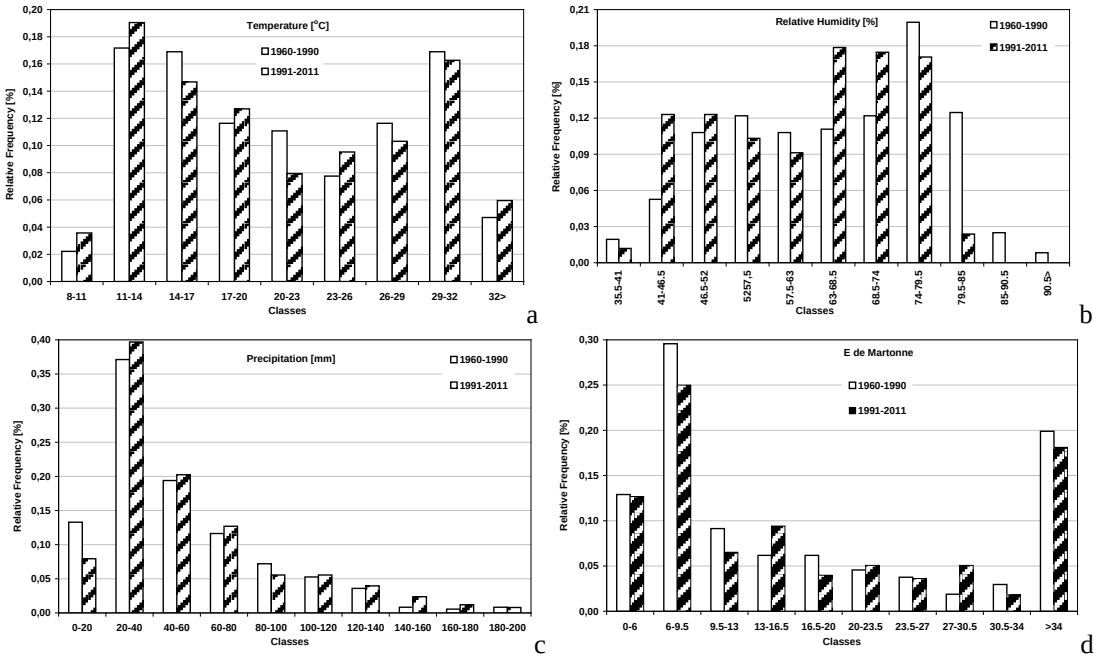

Fig. 1. Relative Frequency [%] of: a) Air Temperature, b) Relative Humidity, c) Precipitation and d) E. de Martonne Index for two times intervals (1960 – 1990 and 1991 – 2011).

The study of time evolution of the number of activities in the area is of particular interest. Because available data on activities refer to only five time points, all of them before economic crisis, it is necessary to approach time evolution of these figures using a mathematical relation, enabling calculations on any time point. This evolution can be described via a second–order multinomial relation (R–1 & R–3). Model results are displayed in Figure 2. Based on these results, it is estimated that the number of activities will reached 10000 in 2015.

Results show that the evolution of activities has not been consistent in all LARs, presenting significant differences. The LAR which received the largest number of established activities was Aspropyrgos, following a change of land uses (e.g. change from rural or agriculture to urban / industrial use). This happened due to the fact that the specific area provided the necessary land surface, contrary to other LARs, in which no similar surface was available, or the land was not suitable for establishing activities, such as the land of Mandra. Elefsis appears to have reached its limits, whereas Magoula also presents limited options for development. Until the middle 80s, the three initially smallest LARs presented similar change rates of activities. Thereafter, however, the LAR of Aspropyrgos has shown more significant change rates. Elefsis experienced the most abrupt rate increase, whereas the greatest rate increase was observed in Aspropyrgos. The sector currently thriving is the warehousing facilities and transit centers. Warehouses are rapidly replacing rural land. What is worse is the fact that although the actual surface in use is e.g. 20%, the remaining 80% is “cemented” in order to serve as a parking space for the vehicles, loading and unloading of goods etc. As a result, the area cannot “breathe”, temperature is rising and rain water cannot be absorbed. Although most industrial areas are zoned, no urban plan was applied, which means that no industrial parks were built that included greenery and other facilities (Stohlgren et al., 1998; Tassopoulos et al., 2003; Christofakis & Tsampra, 2012).

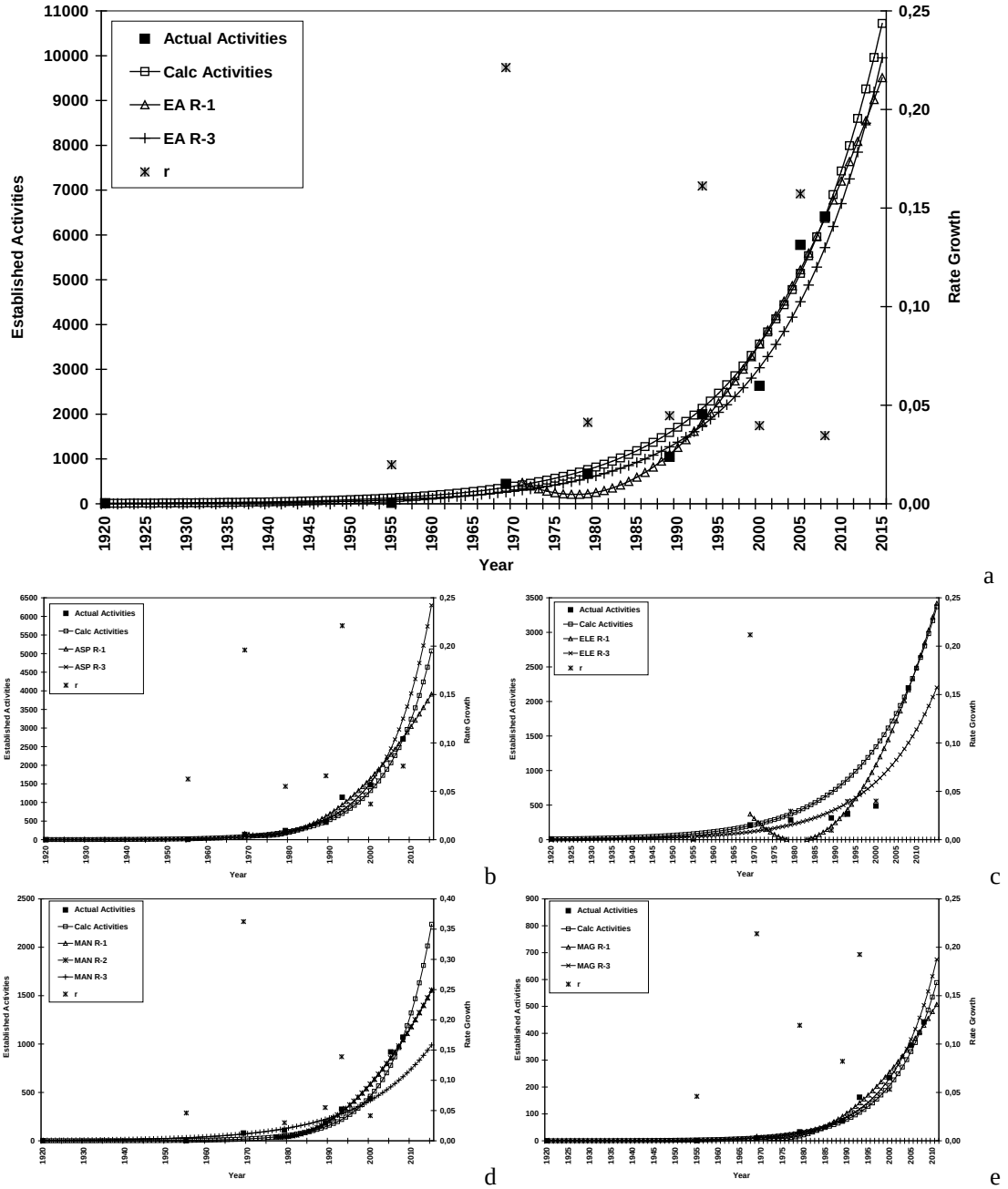

Fig. 2. Models results for Established Activities evolution: a) Thriasio Plain, b) Aspropyrgos, c) Elefsis d) Mandra, e) Magoula, for the times intervals 1920 – 2015

Using findings from Mavrakis 2012, we have made the Table 1 & 2, assigning rate growth of Established Activities during census years for Thriasio Plain with suggested turn point years for climatological parameters according to non-parametric Mann–Kendall test results, adopted from Mavrakis, 2012. It seems that there changes in meteorological parameters follow changes in land use changes.

Table 1. Variation of meteorological average values versus rate growth of Established Activities (A) and Population (B)

A	Year	Temperature	Precipitation	Relative Humidity	de Martonne	r growth [%]
Established Activities	1955					
	1969					
	1979	-0,7	5,5	-6,5	6,5	51
	1989	0,0	-16,3	0,4	-16,5	56
	1993	0,1	-5,1	-4,2	-5,0	91
	2000	-1,0	13,5	-0,4	14,1	32
	2005	1,8	6,9	1,9	5,7	120
	2008	-2,2	12,3	-3,5	13,7	144
B						
Population	1951					
	1961					40
	1971	-0,2	3,5	2,4	3,8	30
	1981	-0,5	3,0	-3,1	3,8	12
	1991	0,2	-16,0	-7,0	-16,1	21
	2001	-0,6	0,6	-2,1	0,8	33
	2011	0,0	12,0	7,7	11,5	11

Table 2. Suggested turn point years for climatological parameters: non parametric Mann–Kendall test results, adopted from Mavrakis, 2012.

	Man Kendall		Turn Point Years					
Temperature	-1,186		1970	1977	1990	1994	1998	2004
Precipitation	-0,471	1966	1972					2007
Relative Humidity	-3,623		1972	1977				
de Martonne	0,162		1972					2007

4 Conclusions

An overview of the findings leads us to the following conclusions:

By applying the de Martonne index the climate of Thriasio Plain began warmer and drier and characterized as a semi–arid. The latter conclusion is consistent with intense land use change in the area of interest. The results for the relative humidity demonstrate a very significant reduction. The rapid establishment of new production units, wholesale units as well as logistics centers resulted in the shift in land use, in many cases occurring arbitrarily with no previous planning thus leading to the degradation of natural environment and quality of life of the area's residents. Also, degradation of agriculture and irrigation affect relative humidity (Lobell & Bonfils 2008).

Both decrease of Relative Humidity and increase of Established Activities in the area, seems to have a common start point. From all the above results, it is reasonable to wonder about whether desertification is becoming a major problem of the area or not.

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