DIFFERENTIAL PHOTOMETRIC STUDY OF THE EUROPEAN LIGHT EMISSION TO THE SPACE

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In the comparison of light pollution between two countries, there are some difficulties because of geographical, cultural and economical differences. The trouble is even worse considering all different systems of outdoor lighting.

As first step, to contrast light pollution between countries, a group of close nations have been chosen with different population densities, size, built surface, etc.

As a parameter to compare the emission of each country, the NOAA's images (DMSP Satellite, OLS "VIS" band 0.40-1.10 um) flux were used and NASA's software World Wind were employed to solve distortion problem of the Mercator projection.

This software allow to draw frontiers over countries, so it is possible to make a particular study of them. In these images all illuminated regions are saturated, so the number of counts don't represent the flux emitted from that region, although that number is proportional to region's area.

As it is known the area of each country it is possible to calculate the density of illuminated area per person and proportion of illuminated territory. These parameters allow to compare the aspect of the country from space.

This parameter is very influenced by population's density, so it is interesting to compare it with other parameters as urban surface, population density, street lamp density, etc.

In this study we show some conclusions of the possible roots of the differences found between countries' illumination.

Data acquisition

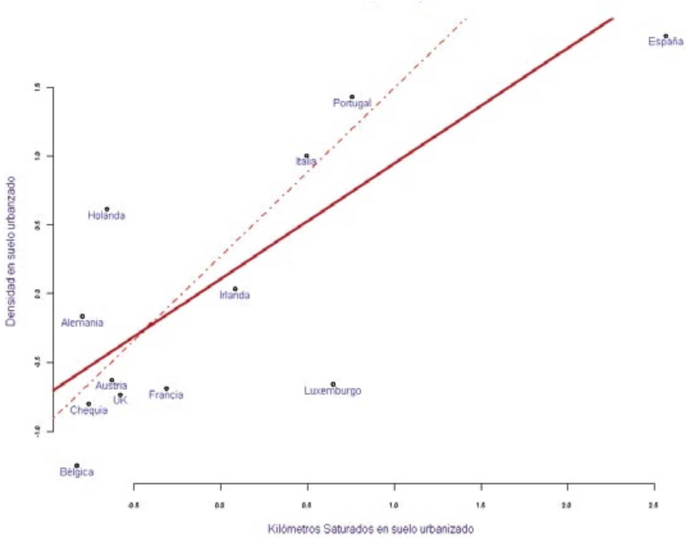
NASA´s software World Wind were used for the image visualization using the NOAA add-on of the Nightlights layer[1].

To discriminate the countries contribution the frontiers layer were employed. Then, countries night images were captured as closer as it was possible to minimise the perspective effect. Then, using MaxIm DL, the tree components of the image were split and the red one were chosen because they are the most representative of the surface illuminated. PhotoShop were used to remove other countries from the image to make the measure of the counts from each country.

Image analyses

These images are not raw images. They have been removed from the lowest level of illumination and they have a bit less resolution. The intensity of bright points is almost always saturated level too.

Figure 1. Saturated Km²/Density



As result, the flux measured is not proportional to the real flux, but it is proportional to the affected area. In sea area there are not significant signal.

Geographic data

To compare the light polluted area between countries some geographic data are needed to calculate the intensive values.

For general data, the CIA The World FactBook, the EEA (European Environment Agency) and in some cases the government data were used.

Data analyses

There are some studies about the relationship between the population density and the light pollution[2], although they are only a first approximation and if the deviations of this relationship are estimated, it is possible to extract political and quality effects of the illumination models. Twelve European countries have been chosen because they are the most uniform group of countries, as a consequence of the convergence European program.

As it is possible to infer of the correlation between the density of population in built area, versus saturated area per built area, there is a significant correlation between these magnitudes. There are some points more difficult to be explained because of geographic effect. These countries are Luxemburg, Netherlands, and Spain.

Luxemburg is a very small country and because of this it has a very high error. On the other cases more data are needed to get conclusions, but a group statistical analyses show that Spain is a outlier.

To find the roots of this out rule value, a compilation of the Ministerio de Industria y Turismo de España[3] data, some energetic waste values from different countries and

Figure 2. CLUSPLOT (x)

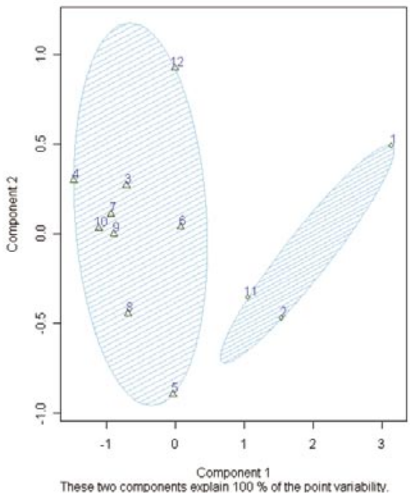
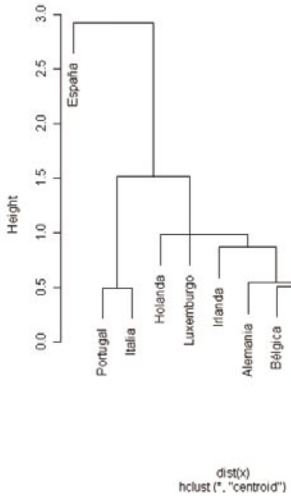


Figure 3. Dendrogram



Final Report Lot 9: Public street lighting(RPSL)[4] were made. These data let infer that pain has almost 50% more installed power peer light point. In this case CELMA[7], data were used, because IDAE's data are more pessimistic.[7] In other values, as power peer squared meter or light points per square kilometre (always using built area) Spain have a excess value.

In Netherlands case, they have the lowest installed power of all studied countries, that could explain the deviation of the rule.

This data show a relationship between latitude-culture and the number of light points per square kilometre too. Italy, Portugal and Spain have the highest values.

Figure 4. Km^2 sat vs km^2 built

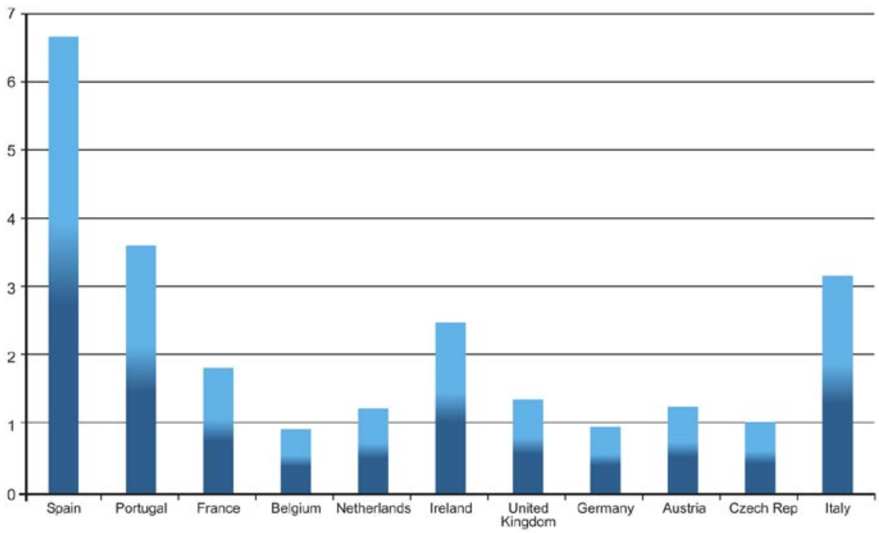


Figure 5. Watts by Luminaries

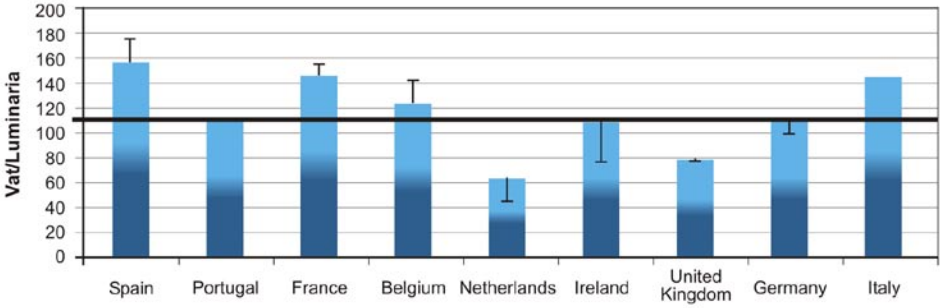


Figure 6. Light Points by km^2 built

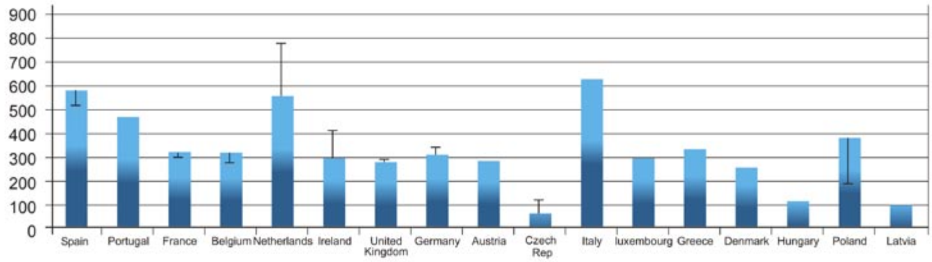
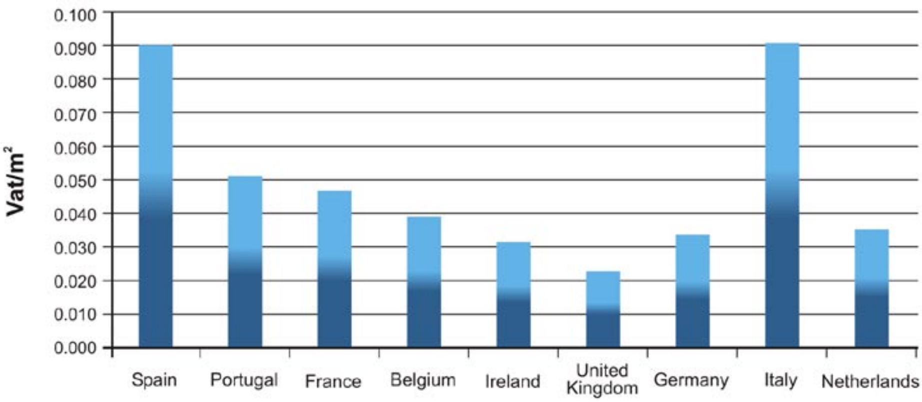


Figure 7. Watts by square meter



Conclusions and future work

- With the present data Spanish illumination can not be explained by demographic causes.
- There is important evidence of excessive waste in Italy.
- The population density in built land as intensive data is the best global parameter in order to represent the saturation of a country.
- An appropriate illumination can be shown in satellite images.
- It is needed further data of all the countries considered in the study.
- Extend this study to all European countries, EEUU and Japan.
- Search of an illumination model useful to countries in development.
- Discussion of hypothesis about the type of light polluting sources.

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Notes and References

1. Sensor DMSP/DMSP Visualization Date 2000-10-23 Credit Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC.
2. P. CINZANO , F. FALCHI , C.D. ELVIDGE, *Monthly Notices of the Royal Astronomical Society*, 328, 689-707 (2001)
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6. G HAZEU, F PARAMO & J-L WEBER, June 2005. *National statistics Form Land Cover Accounts (LEAC/CLC)* (Source: EEA - Provisional results).
7. CELMA 4700000, IDAE(2005) 4200000
8. Wikipedia
9. PINDAR, A., PAPETTI, M., *Public Procurement of Energy Saving Technologies in Europe (PROST) Report on the Country Study for Italy:Task 2a - Current Public Sector Purchasing, Building, and Replacement Practices Task 4b - PICO Feasibility Study.* February 2002, Politecnico di Milano
10. Average power of luminaries at Vila do Gaia (EnLight).
11. Energy Efficiency Index(IEE)=(W/m^2)*(100/10 lux).

	Spain	Portugal	France	Belgium	Irland	UK	Germany	Austria	Czeck Rep.	Italy	Netherlans	Luxenburg
Total Area Km^2 (5)	499542	91951	545630	30278	68890	241590	349223	82444	77276	294020	33883	2586
Built area(%)	2%	3%	5%	21%	2%	11%	8%	4%	6%	5%	13%	8%
Population(6)	40397842	10605870	60876136	10379067	4062235	60609153	82422299	8192880	10235455	58133509	16491461	474413
Density of population	80.87	115.34	111.57	342.79	58.97	250.88	236.02	99.38	132.45	197.72	486.72	183.45
Density of population built area	4986	4511	2256	1659	3026	2210	2814	2325	2137	4060	3644	2289
Light points(4)	4700000	1100000	8570000	2005000	401000	7851000	9120000	1000000	300000	9000000	2500000	61000
Light points per inhabitant	0.12	0.10	0.14	0.19	0.10	0.13	0.11	0.12	0.03	0.15	0.15	0.13
L P/km^2 built	580	468	318	321	299	286	311	284	63	629	552	32
Km^2/L P	0.011	0.008	0.006	0.003	0.008	0.005	0.003	0.004	0.017	0.005	0.002	0.012
Km^2 built	0.0013	0.0008	0.0008	0.0006	0.0008	0.0006	0.0003	0.0005	0.0005	0.0008	0.0003	0.0015
Saturated Area	53766	8456	48693	5835	3312	37107	28832	4483	5021	45212	5536	708
Saturated Area % total	11%	9%	9%	19%	5%	15%	8%	5%	6%	15%	16%	27%
Km^2 sat/ Km^2 built	6.64	3.60	1.80	0.93	2.47	1.35	0.98	1.27	1.05	3.16	1.22	3.42
CO_2(8)	6.9	5.8	6	9.9	10.9	9.5	9.7	7.5	11.6	7.4	8.8	18.9
MW(4)	7383	120	1250	249	43	619	1000			1310	161	
watt per LP	157	111	145	124	108	76	110	No data	No data	145.6	61	No data
EEI(11)	0.911	0.510	0.463	0.398	0.320	0.226	0.341			0.915	0.356	
Wat/m^2	0.091	0.051	0.046	0.040	0.032	0.023	0.034			0.091	0.036	
Watt per inhabitant	18.27	11.31	20.53	23.99	10.59	10.21	12.13			22.53	9.76	