EU-LUPA
European Land Use Patterns

Applied Research 2013/1/8

VOLUME III

Regional Land Use Performance and Land Use Efficiency: approaches for evaluation

Part C Scientific report |

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This report presents the final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

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This basic report exists only in an electronic version.

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1. Introduction to the Land Use Efficiency approach in EU-LUPA

How to measure if the on-going trends of land use change in the European regions are sustainable or whether they are compromising future development has been one of the key challenges of the EU-LUPA project research.

These questions have been approached by analysing performance and efficiency.

> ***Land Use Performance*** *was defined within EU-LUPA as the degree in which the land is used to comply with a specific policy target.*
>
> ***Efficiency*** *has a wide variation in meaning for different disciplines. In general terms, efficiency describes the extent to which time or effort is well used for the intended task or purpose. In the case of land use science, this definition could be translated as the extent to which land is well used for the intended function considered. Efficiency can be understood as the amount of resource needed to obtain certain output (benefit). In the case of EU-LUPA the resource is the land and it involve an understanding of the quantity and quality.*

To date, several analyses have been undertaken in EU-LUPA project to assess Land Use Performance (LU Performance) and Land Use Efficiency (LU Efficiency) at regional level in Europe. However, from the results achieved so far it has been very difficult to extract any clear conclusion due to several constraints and conceptual limitations.

The first exercise for the evaluation of LU Performance and LU Efficiency at regional and it is fully explained in chapter 6 of Volume II. In this chapter the concept of Land Use Functions (LUFs) is further applied to define LU Performance and LU Efficiency.

By assessing the individual performance and efficiency of the six LUFs, a deeper insight is reached in the depiction of the multi-functionality of a region. LU performance was defined here as the degree in which the land that is used for a specific function complies with a related policy target. In EU LUPA these policy targets and goals were identified and after analysing the information available we conclude that it is not feasible to use them as reference to calculate the LU Performance (see Annex 6 of Volume II). The reason was that only few policy targets were found that were quantifiable and could be therefore linked to the values of the LUFs indicators. Considering that policy goals were not be directly available, it was decided to use the EU or national averages or other statistical measures as reference for the analysis.

The second attempt to assess LU Performance and evaluate the LU Efficiency in EU-LUPA project concluded in the connection of Land Use Change Typologies (see Volume I) to changing LUFs (see Volume II).

The idea is showing regions where changing LUFs are taking place. From a socio-economic perspective – where the Land Use Change typology has incorporated the notion of land use intensity – it is particularly interesting to compare the typology results to the LUF analysis of land use for provision of work. This seeks to further extend the analysis of the drivers of land use change by analysing land use changes vis-à-vis changing socio-economic and activities taking place within European regions. A cornerstone in the LUFs categorization is the connection between the performance of European regions in relation to the functions under consideration. Furthermore, the ability to measure the performance across the same time

series as the most recent Corine Land Cover data allows us to analyse changes in LUFs in relation to changes in land cover. This is an opportunity to significantly expand the manner in which socio-economic and environmental activities are analysed in relation to land cover data. It becomes possible to compare the numerical distribution of the performance for all outputs of the distribution of the LUF analysis (based on the matrix of performance values for each LUF) with the Land use change types for each region.

The results of the exercise undertaken are explained in chapter 2 of the present document.

Finally, a broad evaluation of the potential relationship between certain socioeconomic indicators particularly those set in the EU2020 Strategy and Cohesion Policy and the land take at NUTS2 level, based on CLC data, and by means of a scatter plot exercise, was undertaken.

Then, two kind of analysis have been carried out:

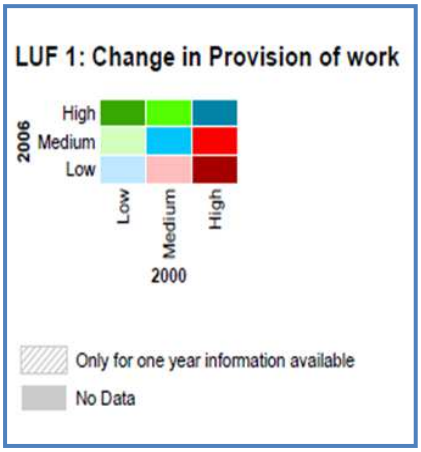
- Static analysis comparing the state of the selected indicators in 2006 and land in take in the same year at NUTS2 level.
- Dynamic analysis comparing the average progress of the selected indicators for the period 2000-2006 and the average annual growth rate of land take (Land take 2000-06. LCF2 Changes 00-06: Urban residential sprawl +LCF3 Changes 00-06: Sprawl of economic sites and infrastructures)

Although statistically speaking there is a weak correlation between the variables analysed there are several outliers that could provide relevant insights on how land consumption in certain regions explain socioeconomic behaviour and vice versa that are included in chapter 3 of the present document.

2. Connecting Land Use Change typologies to changing Land Use Functions

An exercise to assess the connection of Land Use Change typologies to Land Use Functions has been undertaken. The idea is showing regions where changing land use functions are taking place. From a socio-economic perspective – where the Land use change typology has incorporated the notion of land use intensity – it is particularly interesting to compare the typology results to the LUF analysis of land use for provision of work. This seeks to further extend the analysis of the drivers of land use change by analysing land use changes vis-à-vis changing socio-economic and activities taking place within European regions.

A cornerstone in the LUF categorization is the connection between the performance of European regions in relation to the functions under consideration. Furthermore, the ability to measure the performance across the same time series as the most recent CLC data allows us to analyse changes in land use functions in relation to changes in land cover - as presented by the land change typology. This is an opportunity that allows us to significantly expand the manner in which socio-economic and environmental activities are analysed in relation to land cover data.



LUF performance 2006				
	High	31	32	33
	Med	21	22	23
	Low	11	12	13
		Low	Med	High
		LUF performance 2000		

Figure 1 LUF 3x3 performance matrix generated during the LUFs analysis

The 3x3 matrix in figure 1 shows the different levels of change used in the LUFS analysis; going from low/low in the lower left corner to high/high in the upper right corner, indicated by a color scale with increasing intensity of change. According to this matrix, there is an increase in the performance related to the given land use function along the two axes respectively. To identify each of these groups as a unique performance attribute, the reference table bellow allocates a unique index number for each of the nine LUF changes within each land use function.

With a numerical distribution of the performance for all outputs of the LUF analysis it becomes possible to compare the distribution of the LUF analysis (based on the matrix of performance values for each LUF) with the Land use change types for each region. As such, table 1 compares the 2000-2006 Land Use Change Typology and LUF 1 – Provision of work. The left-hand column in the lists the 10 Land use change types for 2000-2006 and to the right this the 9 LUF categories are listed according to the three situations: categories showing a neutral performance over time (categories 11, 22 and 33), those showing decreasing performance (categories 12, 13 and 23); and those showing an increase in performance (categories 21, 31, and 32).

The number of regions characterized by the different Land use change types is shown on the right hand side of the table and the number of regions in each LUF class is shown on the lowest row of the table. A total of 580 regions in Europe are able to contribute to the analysis as this is the maximum number of regions where data for both the LUFs and the typology is available. The number of regions is therefore fixed for the entire analysis, as is the amount of total land change, which is 6.439% for these regions.

The main body of Table 1 distributes this change among the LUF rankings and the Land use change types. For example, at 4.41% (out of a total of 6.439%) the neutral-neutral score for LUF 1 (score 22 in the table) dominates the coverage.

The use of color ramps highlights “hotspots” where large contributions are included in relation to specific land use change types. This allows an immediate interpretation of the role of the different land use change types in describing the LUF categories. For example, it is very easy to see that at 2.16% (out of the 6.439% total), a majority of land changes (calculated by area of change) are taking place in regions where extensification is taking place due to agricultural and forest change. And where this is taking place, a vast majority of the regions are characterized as having a neutral performance in terms of provision of work in both 2000 and 2006.

However, the most interesting element of comparing the LUFs to the typology is to see where changes in relation to each LUF (either increases or decreases) match up against the Land use change types. Therefore as another example, it is clear that decreasing functionality in terms of provision of work is most likely to take place in regions that falling under the “Extensification due to agricultural processes and forest changes”. In fact this supports the notion of both the typologies and the LUFs (where extensification can often lead to a loss of job opportunities), which is a very common trend for instance in the rural and sparsely populated parts of the Nordic countries. This seems to show that land use patterns are indicative of the economic processes taking place in these regions.

When it comes to increases in performance (LUF 21, 31 and 32) it is obvious that types 4 and 5 (High intensification due to residential and economic sprawl combined with forest conversions, and Medium-high intensification due to diverse urban processes) are characteristic of regions undergoing an increase in provision of work.

Table 1 Overview of relations between LUF1- Provision of Works- and the type of flows

LUF1 - Provision of work													
Land Use Change Types		Neutral			Decrease			Increase					
		LUF11	LUF22	LUF33	LUF12	LUF13	LUF23	LUF21	LUF31	LUF32	Sum	Intensity	Regions
Very high intensification with artificial surfaces mainly replacing natural areas	10	0,0000	-	-	-	-	-	-	-	-	0,000	4,375	1
Very high intensification due to specific areas of residential and economic sprawl	9	-	0,0395	0,0053	-	-	-	-	-	-	0,045	2,910	6
High intensification due to residential and economic sprawl surrounding urban internal conversions	7	0,0001	0,0181	-	0,0215	-	0,0135	-	-	0,0122	0,065	2,077	9
High intensification due to residential and economic sprawl combined with forest conversions	5	-	0,1639	0,0344	-	-	0,0052	-	-	0,0456	0,249	1,756	41
Medium-high intensification due to diverse urban processes	6	0,0074	0,3395	0,2186	0,0266	-	0,0256	0,0018	-	0,0477	0,667	1,309	83
Medium intensification due to some urban sprawl combined mainly with forest conversions	4	0,0018	0,2264	0,1909	0,0092	-	0,0091	0,0008	-	0,0077	0,446	0,957	59
Medium intensification - dynamic mix between agricultural and forest changes with urban sprawl	3	0,0156	0,5579	0,1709	0,1562	-	0,0267	0,0114	-	-	0,939	0,643	107
Low intensification mainly due to agriculture and forest changes	2	0,0375	0,7759	0,1038	0,0242	-	0,0586	0,0058	-	0,0170	1,023	0,319	86
Extensification due to agricultural processes and forest changes	1	0,1231	2,1613	0,0500	0,3250	-	0,0218	0,0506	-	0,0058	2,738	0,052	171
High extensification due to forest and agricultural changes but specifically the withdrawal of farming	8	0,0980	0,1298	0,0009	0,0212	-	0,0166	-	-	-	0,267	(0,350)	17
Sum		0,28360	4,41232	0,77496	0,58404	-	0,17724	0,07044	-	0,13604	6,439		580
Average Intensity		0,3275	0,6354	0,8775	0,3357	-	0,9222	0,4429	-	1,1819			
Number of Regions		46	348	100	39	-	18	15	-	14	580		

3. Land taken in relation to certain socioeconomic Indicators

A broad evaluation of the potential relationship between certain socioeconomic indicators particularly those set in the EU2020 Strategy and Cohesion Policy and the land take at NUTS2 level, based on CLC data, and by means of a scatter plot exercise, has been undertaken. EU2020 Strategy is the one for the EU's growth for the coming decade for a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and the Member States deliver high levels of employment, productivity and social cohesion. Five ambitious objectives - on employment, innovation, education, social inclusion and climate/energy have been established.

Ideally we should have been able to assess the potential relationship between those objectives and land use patterns observed in Europe but we have identified two major handicaps:

- Data availability. Most of the indicators set by the EU2020 strategy are available at NUTS2 level and even at national level for certain indicators on Climate and Energy.
- On the other hand, from the 5 objectives set by the EU2020 it is very difficult to find a coherent link with land use patterns, particularly those on education and social inclusion

That is why we have selected a set of indicators to be analysed where we could identify some kind of policy relevance directly or indirectly to land use: Population growth; Employment rates 15-64; Long term unemployment rates; Gross Domestic Product at current market prices; Share of renewal energy in final energy consumption; RTD expenditure (as percentage of GDP). Then, two kind of analysis have been carried out:

- **Static analysis** comparing the state of the indicators in 2006 and land in take in the same year at NUTS2 level. Land take assumes changes, therefore we have two options: a) Compare built-up area 2006 with state indicators; b) Land take in the immediately previous period and the static indicator.
- **Dynamic analysis** comparing the average progress of those indicators for the period 2000-2006 and the average annual growth rate of land take (Land take 2000-06. LCF2 Changes 00-06: Urban residential sprawl +LCF3 Changes 00-06: Sprawl of economic sites and infrastructures)

Although statistically speaking there is a weak correlation between the variables analysed there are several outliers that could provide relevant insights on how land consumption in certain regions explain socioeconomic behaviour and viceversa.

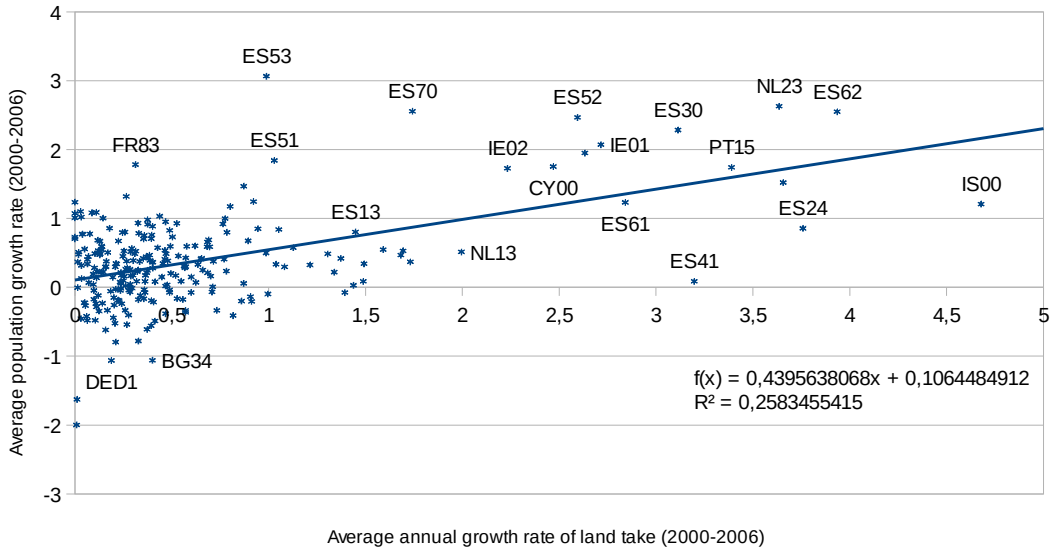
The linear regression represents:

- General trend assuming that there is a linear process
- When there are strong deviations we should see if they are systematic (e.g. all regions for a certain country) and if the assumption of linearility is correct

Land take by the expansion of residential areas and construction sites is the main cause of the increase in the coverage of urban land at the European level. Agricultural zones and, to a lesser extent, forests and semi-natural and natural areas, are disappearing in favour of the development of artificial surfaces. (EEA, Land Take GDI 5 March 2012)

At the European level, housing, services and recreation made up a third of the overall increase in urban and other artificial area between 2000 and 2006. (LEAC Database (based on Corine Land Cover 2000-2006 changes, version 13, 02/2010), ETC/LUSI)

Figure 2. Correlation between population growth rates and land take (2000-2006) - demo_r_d2jan over AV_LT



In most regions the pattern has been that the increase in the average population growth has gone together with an increase in the average annual growth rate of land take.

It is interesting to see that the slope of the regression is not 1 (growing at the same rate). **Land take is growing faster than population**.

Maybe changing the scale of X to log is better to see the relationship. However in certain regions mainly of Spain, The Netherlands and Ireland, the urban development has been a fast phenomenon particularly during the analysed period with irrelevant population growth At the European level, housing, services and recreation made up a third of the overall increase in urban and other artificial area between 2000 and 2006. (LEAC Database (based on Corine Land Cover 2000-2006 changes, version 13, 02/2010), ETC/LUSI, (EEA, Land Take GDI 5 March 2012)

In western European countries but in particular in Spain, Ireland, Portugal suffered an unsustainable rise in the price of real state from the 1990s to 2008, commonly known as **property bubble**. House ownership in Spain is above 80%. The desire to own one's own home was encouraged by governments in the 60s and 70s, and has thus become part of the Spanish psyche. In addition, tax regulation encourages ownership: 15% of mortgage payments are deductible from personal income taxes.

Static analysis

Figure 3 Correlation between total population and built-up area (artificial surfaces, 2006) - demo_r_d2jan_2006 over LC_2006_data

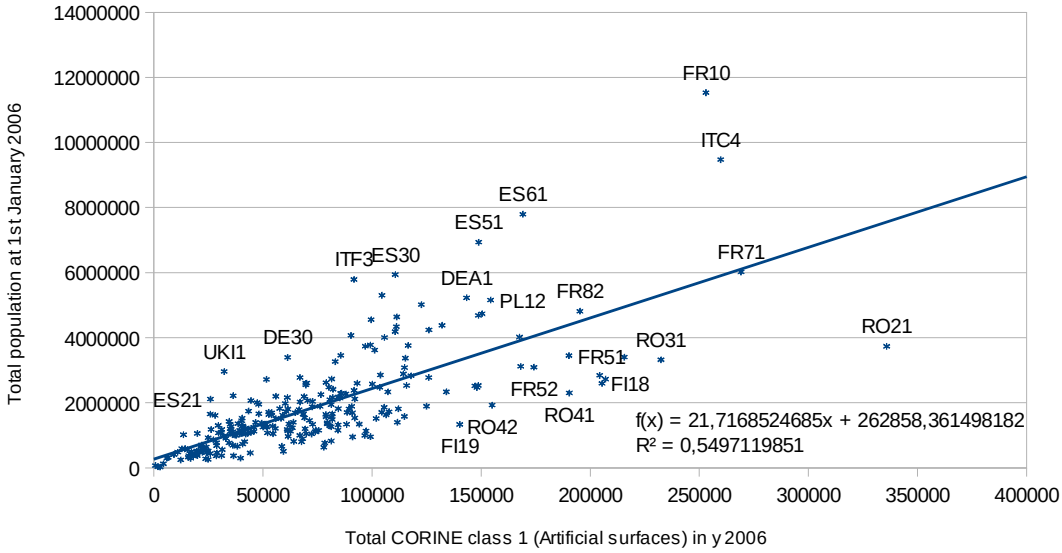
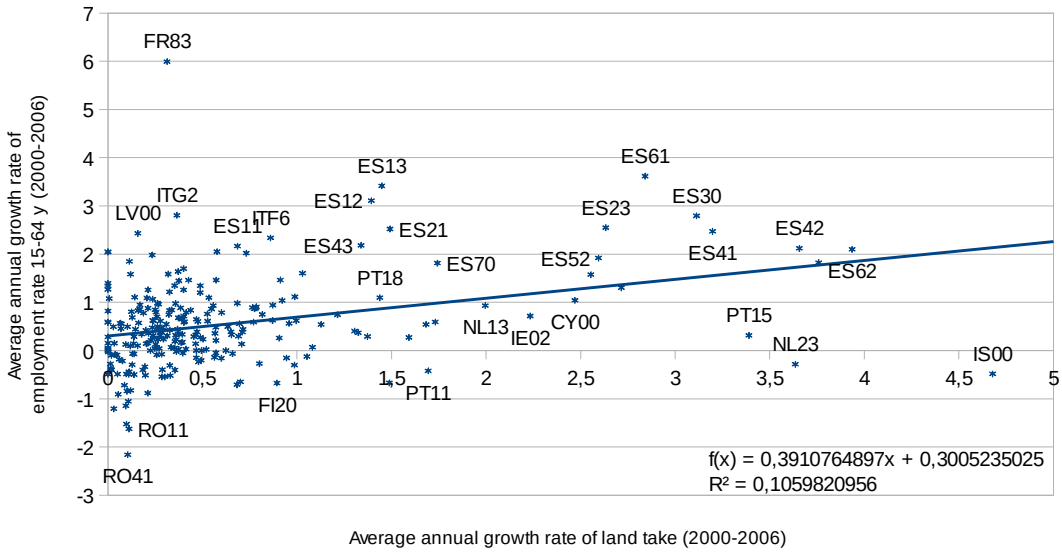


Figure 4 Labour efficiency of land take (2000-2006) - lfst_r_lfe2emprt over AV_LT



Certain parallelisms between increase in employment rates and land artificialization could be seen in several Spanish, Irish and Portuguese regions.

Again this could be explained due to those countries dependency on construction/building sector.

Static analysis

Figure 5 Correlation between employment rates and land take (artificial surfaces, 2006) - lfst_r_lfe2emprt_data_2006 over LC_2006_data

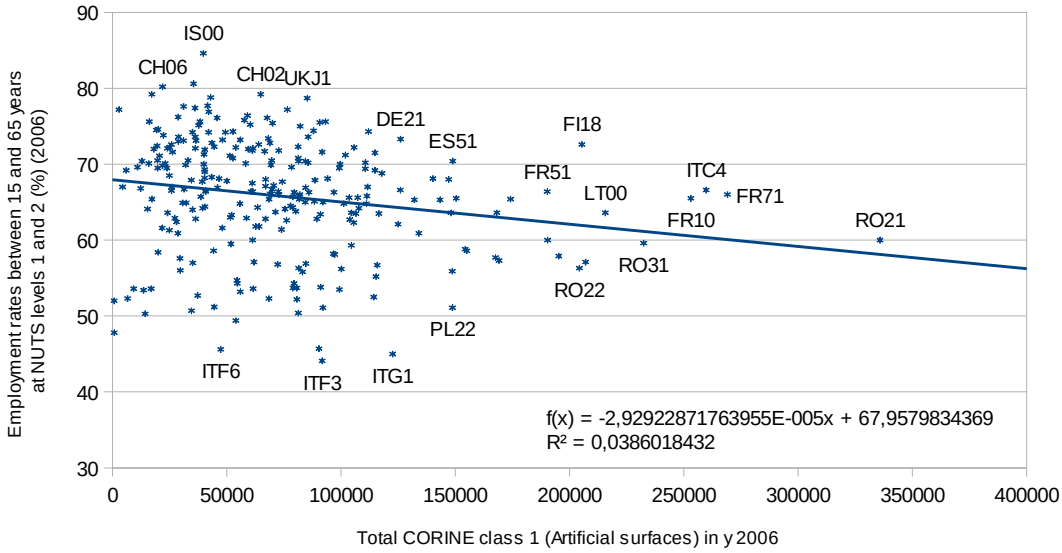
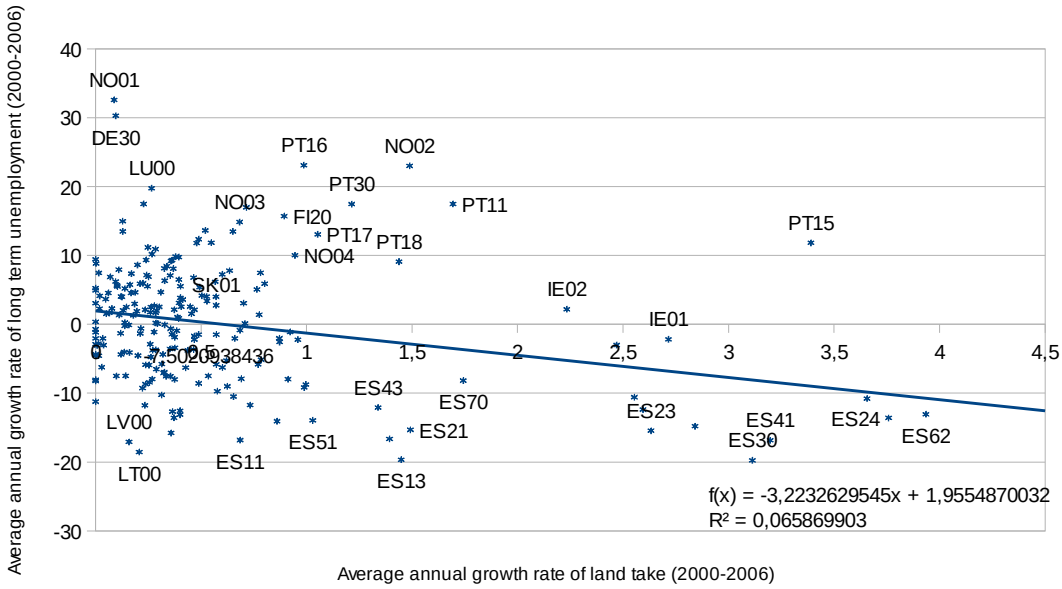


Figure 6 Correlation between long term unemployment and land take (2000-2006) - lfst_r_lfu2ltu_NBR over AV_LT



Looking at long term unemployment rates, a negative correlation is identified with respect to land take.

Figure 7 Correlation between absolute GDP growth and land take (2000-2006) - nama_r_e2gdp_mio_pps over AV_LT

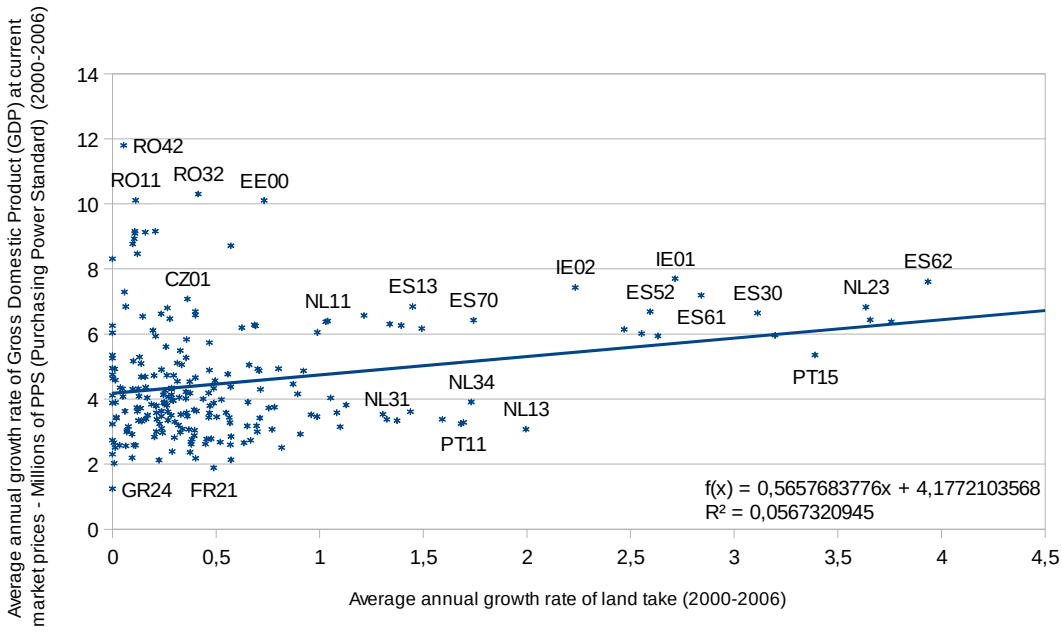
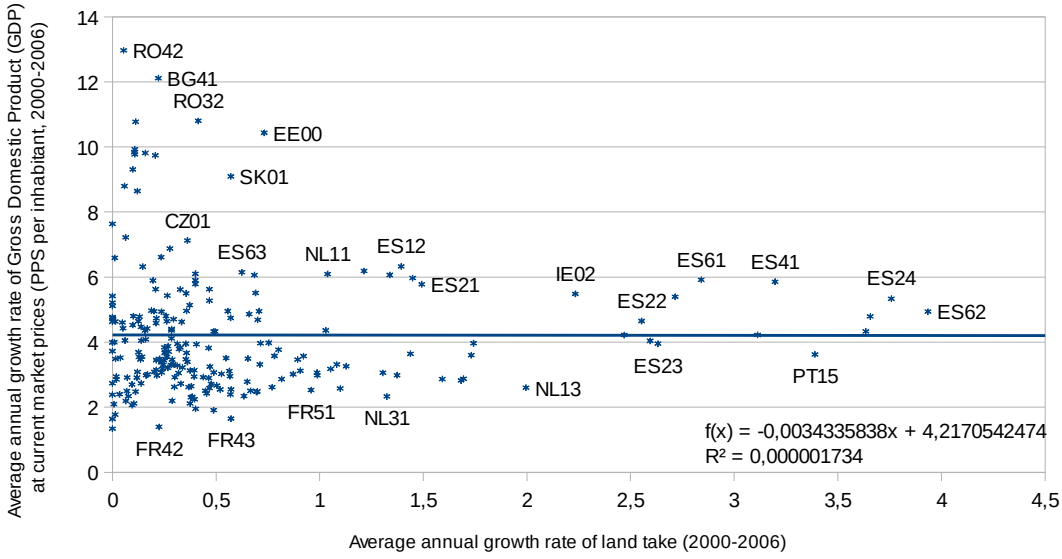


Figure 8 Correlation between GDP per capita growth rates and land take (2000-2006) - nama_r_e2gdp_pps_hab over AV_LT



Static analysis

Figure 9 Correlation between GDP and land take (artificial surfaces, 2006) - nama_r_e2gdp_mio_pps_2006 over LC_2006_data

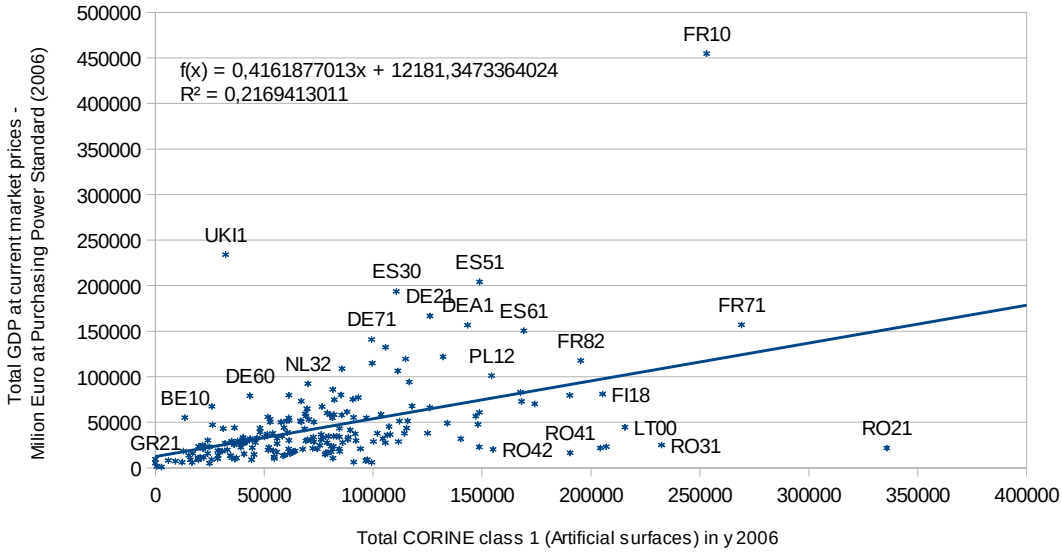


Figure 10 Correlation between GDP per inhabitant and land take (artificial surfaces, 2006) - nama_r_e2gdp_pps_hab_2006 over LC_2006_data

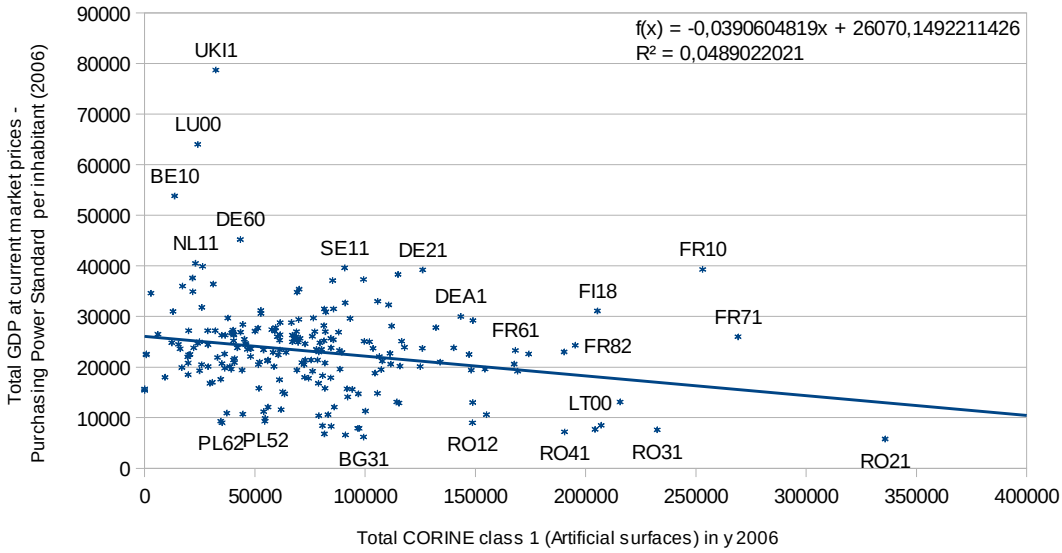


Figure 11 Correlation between energy efficiency and land take (2000-2006) - env_rfec over AV_LT

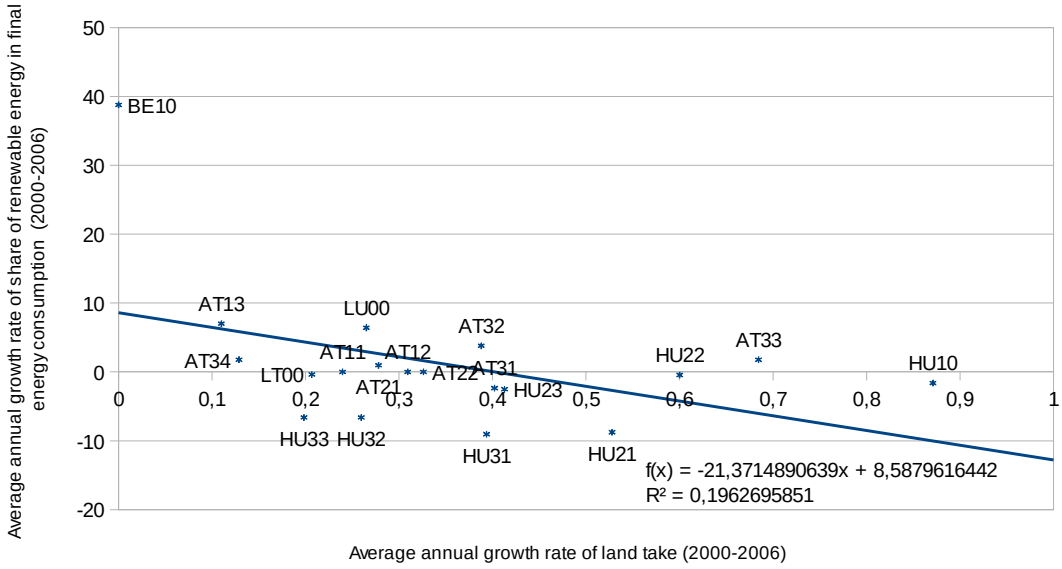
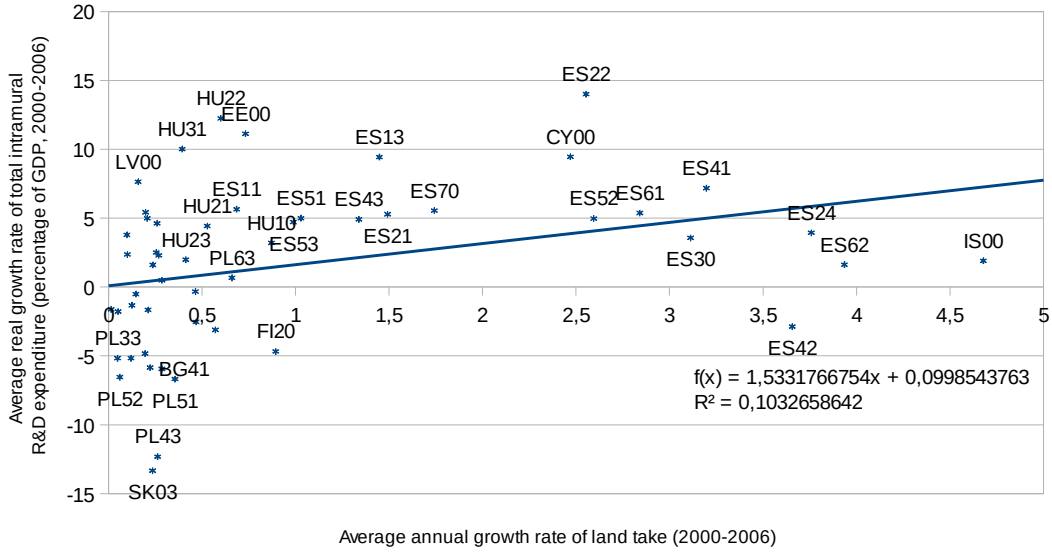


Figure 12 Correlation between R&D growth rates and land take (2000-2006) - rd_e_gerdreg over AV_LT



4. Conclusions, constraints and conceptual limitations

Most policy targets are territorially blind

One of the difficulties to understand the performance of European territories in relation to land use is that most of the policy targets do not have a direct translation on land use. Even that polices that have a more direct relationship with the land (e.g. Biodiversity, CAP) there are no specific targets on percentage of land that should fulfil certain requirements. This is strongly related to the fact that Europe has not any legal mandate on land planning. On the other side, the relevance of cities and the phenomena of sprawl have raised many concerns and the recommendation to limit urban sprawl appears in many documents. Moreover, land reclamation is strongly promoted by different means of funding and even a potential threshold in soil sealing is currently proposed in the EU2020 Strategy.

EU2020 Strategy is the one for the EU's growth for the coming decade for a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and the Member States deliver high levels of employment, productivity and social cohesion. Five ambitious objectives - on employment, innovation, education, social inclusion and climate/energy have been established.

Ideally we should have been able to assess the potential relationship between those objectives and land use patterns observed in Europe but we have identified two major handicaps:

- Data availability at NUTS3 in order to evaluate the potential correlation between land use dynamics observed in the Land Cover Characterization and typologies and the distance to the headline targets set in the EU2020 Strategy and Cohesion Policy at NUTS2/3 level. Most of the indicators set by the EU2020 strategy are available at NUTS2 level and even at national level for certain indicators on Climate and Energy.

- On the other hand, from the 5 objectives set by the EU2020 it is very difficult to find a coherent link with land use patterns, particularly those on education and social inclusion

Besides as highlighted by the ESPON SIESTA Spatial Indicators for a “Europe 2020 Strategy” Territorial Analysis[1] the spatial dimension of the strategy is not obvious. Indeed, the report pointed out that, scholars such as Böhme *et al.* (2011)[2] have recently stated that the spatial derivative of the EU2020S is territorially blind.

[1] ESPON SIESTA Spatial Indicators for a “Europe 2020 Strategy” Territorial Analysis. Draft Final Report 10/08/12.

[2] Böhme, K. et al (2011): How to Strenghthen the Territorial Dimension of Europe 2020 and the EU cohesion policy. Warsaw. Ministry of Regional development.

Narrow timeframe

The consideration of only 6 years to measure environmental, social and economic changes is considered insufficient timeframe to extract a coherent conclusion on performance and efficiency in connection to land use changes.

Although CLC data covers 16 years, indicators available with European coverage and therefore used in EU-LUPA for the assessment of the performance covered the last 6 years. It would have been a bit pretentious and not scientifically sound making any statement on land use efficiency based on these results.

Land Use functions approach to assess LU efficiency is in principle quite coarse.

However the approach helps to show how relatively efficient works out multi-functionality in each region. For example, the land of a region can be used very efficiently to provide food, while at the same time being inefficient in providing housing and abiotic resources (e.g. some North provinces of the Netherlands). The LU efficiency approach also helps to find out the degree of current use regarding the maximum (e.g. provision of food and bioenergy) or the potential use (e.g. in provision of abiotic resources).

Limitations in the results visualization

Visualisation of the LU performance results with maps and spider diagrams brings complementary information. The maps show the spatial distribution of the calculated values and help to identify hot spots; however it is difficult to get the full picture (i.e. addition of all the LUFS and indicator maps) for one region. The spider diagrams provide this by visualising at once all the indicators or the LUFs for a single region, displaying their distance to the EU average. Being able to analyse simultaneously the spider diagrams of the indicators and the LUFs, also helps to understand the role that the indicators play in underpinning the values of the LUFs. The spider diagrams show as well the large differences between the Nuts 2/3 regions and highlight their main functional specificities.

Working with aggregated data

In the attempt to link certain socio-economic benefits with the land needed to produce these benefits, one of the main difficulties that have been found is the degree of aggregation of socioeconomic data. There are two types of aggregations that need to be considered: one is related to the administrative unit at which the data is provided; the other type of aggregation relates to the typology of the data itself. For example employment by sector can be disaggregated down to several sectors and subsectors. However, to link the level of employment to certain land uses one would require a level of detail of sectors which is not available at European level.

Scale and complexity of the issues analysed

There are different drivers that act at different scale; consequently there is a need to identify the appropriate level for analysis. This is also connected to different resolution of original data sources.

There are therefore several challenges and questions that remain unresolved or in need for further explanation and rationalization.

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