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Land Use Characterization in Europe: Analysing land use patterns using typologies

Part C Scientific report |

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List of authors

NORDREGIO (Sweden)

Rasmus Ole Rasmussen

Ryan Weber

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1.1 Introduction

Europe's Resource Efficient Strategy sets the goal of no additional land consumption after 2020, yet this mandate will mostly likely work against the goals of a number of regions; particularly those seeking to ascend the socio-economic ranks toward the most established European nations. The fact that the magnitude of land change has been more or less maintained throughout the period from 1990 to 2006, and prospective new members of EU appear ready to make use of land change as a vehicle for economic progress, it seems that measures of compensating any limitations in this respect would be needed. Therefore, it is both an unlikely and unrealistic goal for a number of European regions.

Existing European policy regarding land use lacks a comprehensive and integrated approach that takes the inherently broad number of trade-offs between many sectoral, social and environmental issues. In particular, this includes activities relating to: industry, transport, energy, mining, forestry, agriculture (EEA, 2010), as well as recreation and environmental protection/conservation. According, to the EEA, "these trade-offs can be tackled through integrated planning for land use and territorial planning, sectoral policies, as well as targeted policy instruments, such as protected area networks." (EEA, 2010: 5). Similarly it is expected that the integration of the European Landscape Convention as a tool in territorial planning would become an important contribution to the planning process. Along these lines, institutional arrangements dictating land use policy in Europe include the EU objective for Territorial Cohesion – with which this project is closely connected to – the Water Framework Directive, Common Agricultural Policy (CAP), Natura 2000, and with an increasing importance, Energy 2020. Important tools for informing, monitoring and evaluating these policies and programmes are Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA), and most importantly, the advent of the Corine land cover inventory (EEA, 2010).

Within this context, it is increasingly understood that a more integrated, comprehensive and up-to-date policy approach is needed; one that can bolster sustainability through increased efficiency and a multi-functional approach. As such, this project seeks to provide evidence to support such a policy initiative by providing a new and insightful way of characterizing land use patterns and their dynamic relationship with socio-economic growth. For example, it emphasizes that we need land to grow, but our growth puts pressure on the social, economic and environmental services we can obtain from it. But it also shows that the drivers, the enablers and the ingredients of what we require for development are the very things pressuring the over-consumption of land. This pressure cannot continue to escalate as we continue to develop and it means that a growth model that is blind to the host of thresholds related to land and its resources cannot continue sustainably.

Land is one of the environmental conditions that, right alongside energy resources, water and climate, we need to use within a sustainable level in order not to endanger our continued development. But we could even go a step further to say that land is the most tangible of these conditions. Like many resources, we continue to be dependent on land and its resources. We rely on it in the sense that land type is one of the most integral components for determining how land is used. For example, one can't grow crops, raise cattle or tend to a forest on land that isn't suitable for farming plants, letting animals graze or growing trees. Just as one can’t build a ski resort without mountains, sell beach holidays without sand and ocean or construct buildings without wood and stone.

Yet its tangibility also rests on the fact that land is that which is at the interface of our existence. It is the space where we situate ourselves, interact with one another and move about space. But it is also the interface where we interact with a variety of other resources, such as water and climate. This perspective begins to highlight that while we are dependent on what land provides us, we also have an ability to manipulate it away from its natural landscape in order to meet our needs. It can be deforested through logging or by environmental pressures and relatively small disruptions to the balance of soil nutrients can hamper agricultural production. Perhaps more worrisome, the onset of negative impacts of pollution and overuse can develop very quickly and dramatically.

Another example is the extent with which we develop our built environment. With an almost unanimous interruption of natural land surface, cities for instance can be built almost anywhere - from the middle of deserts like in Dubai or Las Vegas to the shores of beaches and edges of lakes like in Barcelona or Geneva. All of these processes reflect how we cause change to the natural environment and invoke our existence on the land we consume.

It is strikingly clear that we have double-sided relationship between land and growth. We are dependent on land to provide the resources we need to grow, yet our ability to grow is inseparable from our need to conserve and protect land. With this in mind, the task of EU LUPA is to provide evidence on land use and its changes that can support policy; which in turn can support an improvement of land use performance and thus land use efficiency. To achieve this, the project outputs seek to characterize regional patterns and trends of land use in Europe. Parts of this process include research and analysis of the existing land or land-related policy, as well as the patterns and changes in land use functions, particularly in relation to the cause-effect relationships with economic, social and environmental changes.

But the tangibility, dependence and interconnectedness we share with land itself (in this case relating to the bio-physical perspective of what covers the land) puts emphasis on the importance of accounting for land patterns and attributing these patterns to the general conditions of socio-economic development. Accordingly, the focus of this report is on the development of a land use characterization for Europe - one which perceives land in relation to the drivers, effects, challenges, or put more plainly, the general conditions of regional development in Europe. This characterization is to take place primarily by the classification of patterns of land and the processes of land change through regional typologies with a European coverage.

The main input into this process will be Corine Land Cover (CLC) data that has been produced by the European Environment Agency (EEA) since 1990. This dataset will be used in three ways: as a means of characterizing land cover, as a means of characterizing land cover changes, and as a means to characterize the intensity of human intervention on the land. All three perspectives in the typologies of land and land change allow us to move towards evidence-based understandings on regional and patterns of land use in Europe.

Yet in the last two paragraphs alone, land characterizations have included land, land cover, land change, intensity of land intervention, and not least, land use. This shows a need for deciphering between these terms in order to clearly describe how CLC data can be used to characterize land use. Therefore, following a brief discussion on the use of typologies, a more detailed theoretical discussion will be provided on how we approach land use through the availability of CLC and socio economic data in this task. Following this, general methodological discussions will precede the presentation of both the method and results of each characterization of land use and land use changes in this report. This will include the use of typologies on prevailing characteristics of land use, hotspots of land use change and finally, a land use change typology.

1.2 Integrating land use information: typologies

The focus of this report is on a characterization of land use for Europe - one that can be used to interpret land cover in relation to the drivers, effects, challenges, or put more plainly, the general conditions of regional development. Through the use of regionalized land cover data, including the formation of regional typologies, this characterization aims to identify land patterns and dynamics in Europe and attribute these processes to shifting regional socio-economic characteristics. In turn, this can help to address major territorial challenges and political priorities in order to increase land use efficiency at the European, national and regional levels.

The use of typologies is meant to provide an analytical basis for characterizing and analysing patterns and processes of land use changes. This is centered on the aggregation and regionalization of CLC data, both in terms of the account on the prevailing characteristics of land use but also regarding land cover flows. Once completed, these land cover typologies will be placed in the context of land use in two ways. On one hand, they will be compared with the results of the land use functions (LUFs) exercise, which has also been completed in Task 2.2 of this project.

In parallel to this however, the objective of typologies has also been to find an innovative way of accounting for land use patterns and dynamics through the use of land cover data. As discussion will show, while land cover and land use are two terms that often get misused in place of each other, we have approached a means of investigating land use through CLC data by means of the intensity concept. Consequently, the typologies do not directly integrate data reflecting regional socio-economic conditions in Europe, but the intensity concept shows a clear correlation between the presence of land cover types and the characteristics of socio-economic development that takes place as a result.

1.3 Theory, hypothesis and approach

Distinction between land use and land cover

In the discussion of characteristics and changes in relation to land use a very common approach is to draw a direct connection between land cover and land use. This infers a direct implication of land cover on the way that land is used. An example of this approach, as done by Lambin et al (2003: 216) defines land use as “the purpose for which humans exploit the land cover”. The key element in this connection is *vegetation* as a productive resource, which implies that CLC classes show information related to vegetation as a basis for production.

Historically, there have been many reasons for choosing such an approach to defining land use. First and foremost, it enables an analysis based on what is immediately visible through the land cover, which in turn provides a rather direct connection between land cover information and economic activities (at least to the extent that land cover actually reflects such a relationship). This however, has been the situation in predominantly agrarian societies, just as in societies where forestry and other direct land cover uses provide the main economic activities.

Typically this approach is very common in relation to discussions in relation to *developing* countries where these types of direct connections between economic activities typify the mainstay of both society and economy (see Lepers et al (2002), Turner et al (2007), and more recently in a global scale by Lambin (2010)). Similarly, a tradition has developed in relation to *developed* countries emphasizing the historical use of land as a background for understanding the present characteristics of rural areas. This has been documented in a European setting by Dovring (1960) and followed up by Reenberg (2009) among others.

However, the parallel increase of urbanization and the development of non-land-based production (e.g. the service, financial sectors as well as many high-tech industrial developments) have significantly constrained the validity of such an assumed synergy between land use and land cover. As a result new territorial-based logics beyond land cover now have the predominant role in determining how land is used. Thus, some of the most important elements are now what characterizes land use in already built-up areas, connectedness through proximity to other cities, settlements and linking infrastructure, as well as increased demands for ownership, leisure and recreation.

In this case we have to look no further than the fact that, according to Turner et al. (2007) land change in Europe has increased to unprecedented levels over the past couple of decades. What's more, the fastest of these changes relate to the covering of land with artificial surfaces, which increased by 6 258km^2, or 3.4% of the European continent between 2000 and 2006 alone. Not only does this have to do with the fact that Europe's population is still increasing, but also the fact that people in Europe generally have the desire for increased living space per person.

In many ways, the increased pressures to develop sustainably have also increased the divergence between the two terms. For instance, there is increased demand for the production of energy from the landscape, which can involve a transition of land uses vis-à-vis land cover often remaining the same. In parallel, the role of improving land efficiency through increasing the functions that we can obtain from our land is also accentuated. These issues point to a major problem in this connection; namely that to base any land use analysis only on the Lambin et al (2003) definition of "the purpose for which humans exploit the land cover" is insufficient. By doing so it leaves out what tends to be an increasing part – if not the determining part – of what characterizes the use of the land resources in our current socio-economic setting.

Taking these present day conditions into consideration, the focus on the trends, dynamics and driving forces of European land use means that a clear land use definition is a critical issue in the EU LUPA project. In the following text we present some key elements in our understanding of the concept. But we do so with a specific focus on the fact that our analysis of *land use* is primarily based on the availability of data that comprehensively accounts for the characteristics of *land cover*. This necessitates a further discussion on the differences between land use and land cover, the implications and vulnerabilities of using land cover data to interpret land use, and as a result, our chosen method to navigate land use patterns using land cover information. Ultimately this will lead us through to the notion of intensity.

While it is easy to interchange the terms "land cover" and "land use" as terms describing overlapping or even identical perspectives to the way land exists or is consumed in time and space, the distinction between the two can be made very simply. *Land cover* is a term that reflects the bio-physical nature of the land surface. To determine the land cover is simply to ask one's self what they see when they look to the ground. Therefore, in its absolute sense it is void of human perception and be placed in zero-sum terms. Examples of land cover could be given in relational terms (i.e. natural or non-natural) or in absolute terms (i.e. grassland or bare rock).

In contrast, a *land use* is an adjective that is used to describe the manner in which the land is perceived or consumed by humans. For example, 'recreational', 'preserved' or 'waste' land uses are often legal entities but also speak to the human perception or valuation of land. Yet, describing land use also relates to describing the nature of human activities that use, exploit and consume land. For example, agriculture, industrial land, transport areas, pastures, agro-forestry, plantations and irrigated land all relate directly to the use of land in space. Here, human intervention does not operate in zero-sum terms and allows for the inclusion of multiple functions on a given piece of land. For instance, we often hear the term mixed land use within planning policy as a way of describing the conditions and benefits of over-lapping land uses.

Deciphering land cover and land use using Corine data

While the land cover land use distinction above is straightforward, the use of Corine land cover data adds a layer of complexity. The Corine Land Cover Programme was initiated in the mid-eighties as a voluntary agreement to provide researchers and policy makers in multiple fields with an inventory of land cover based on satellite images (Bossard et al., 2000). This valuable resource has now been developed for three time series' (1990, 2000 and 2006), with another expected in the coming few years. However, the diverse value of the resource – for economists, engineers, biologists, geographers or planners to just name a few – pressures on CLC data to account for the different land dimensions for different utilities. By the EEA's own record this has limited the ability for CLC nomenclature to strictly reflect land cover without introducing human usage into the nomenclature:

> *"…However, it should be emphasized that due to the physiographic nature of CLC classes, and to a limited extent the functional distinctions that are introduced in the nomenclature it is hardly imaginable to fully match the CLC nomenclature starting from an automated classification procedure, without additional human interpretation work." (Bossard et al. 2000, pp 6)*

The unavoidable consequence is that even though CLC data is often assumed to provide an 'objective' characterization of land cover, this actually isn't the case. Rather, human-related aspects (pertaining to human intervention on land) are used in conjunction with bio-physical (non-human) perspectives. Thus, the nomenclature of CLC classes is something between land cover and land use. In fact, in a majority of the 44 classes human interventions and perceptions are explicitly used to define land cover.

For example, the class Agricultural areas say very little about the bio-physical nature of the land surface, but says a great deal about planned or perceived use of the land. The Artificial surfaces class is also broken down to an entirely human perspective on use of land, which includes: Port Areas, Airports, Construction Sites, etc. This trend is taken a step even further with the EEA's production of land cover flow data. By including flow types such as Urban Land Management, Urban Residential Sprawl and Withdrawal of Farming the classification is almost entirely based on a the above notion of land use rather than land cover.

While it is clear that the CLC nomenclature is conflicted, it is most sensible to seek consistency with their approach. The EU LUPA notion of land cover is therefore synonymous with the definition that is inferred through the CLC and CLC flow nomenclature. And as such, CLC data is used to describe land cover conditions in the EU LUPA project, even though it is understood that underlying perceptions of land use and human functions are included in the characterization.

Responding to limitations in the traditional analysis

As indicated above, a traditional approach to land use does not sufficiently go beyond the uni-dimensional linkage between the "use" of land only for production. In this perspective, the land cover is directly part of one type of production, and this disregards the fact that land is actually an important part of many human activities. For example, the production of energy by means of windmills requires land for the situation of the tower and turbine, but its presence has an impact on the surrounding area in terms of human visibility, noise, danger to animals, etc. As such, other land activities such as hiking or other forms of recreation that could take place within proximity to the windmill are affected. Further, the "consumption" of land through these more discreet landscape qualities represents another way of perceiving land use characteristics; however they do not have a specific link to production activities and therefore cannot be appropriately recognized through such a uni-dimensional approach.

In order to overcome some of the major problems in the traditional approach to defining land use characteristics, at least four types of linkages would need to be emphasized and considered in connection with the definition of land use categories:

- ***The use of land as a means of production:*** This group of activities is similar to the definition by Lambin et al (2007), where qualities of the land itself becomes an important contributor in connection with questions regarding to land intensity and value.
- ***The use of land as locus standii for production purposes:*** This includes activities that are localized, but not necessarily directly linked to a "consumption" of the qualities and productive forces of the land itself. Instead, qualities such as the questions of accessibility, proximity, water, sewage disposal, etc. are important issues. In the case of windmills mentioned above several of these issues are at stake.

  Another example is evident with the CLC class Artificial surfaces, which is subdivided in classes where specific functional qualities have been used in determining the class qualities. However, while those activities connected to urbanized activities are directly reflected, while many other activities are still missing.
- ***The use of land as a means of recreation***: This group includes land areas where the consumption of land areas is important in relation to recreational purposes. Here, recreational purposes are seen in a dual perspective, both in terms of environmental functions for recreation in the current society but also in terms of recreating (preserving) the environment for future development. In this connection a number of sub-groups could include:
- ***Reproduction directly connected to socio-economic growth***: This group includes housing, recreational parks, amusement parks, sports facilities not only in near-urban areas, but also including summerhouses and second homes in rural areas. As such, a key issue in this connection is the transformation of areas into land cover characteristics defined by human activities or perceptions. Some of these activities are already included in the CLC classification Sports and Leisure Facilities, but this could be extended to rural areas in order to reflect, for instance, environmental protection. Protected areas are not included as the CLC class, but new types of protection are being implemented that were not foreseen when existing CLC classifications were decided.

Land use in the EU LUPA project

It is now clear that even though a CLC-prescribed notion of land cover can be used to infer land use such an approach leaves room for improvement for meeting the multiple elements of a comprehensive and up-to-date definition of land use. This would be a notion that simultaneously reflects direct and indirect uses, mono- and multi-functional uses, and especially, its contribution to socio-economic production which is not explicitly related to the consumption of land.

In fact, one may argue in line with Verburg et al (2008) that the term land functions would be a more suitable concept when referring to the goods and services provided by the land systems. Their view is that land functions "not only include the provision of goods and services related to the intended land use (e.g. production services such as food and wood production), but also include goods and services such as the provision of esthetic beauty, cultural heritage and preservation of biodiversity that are often unintended by the owner of the land.

Based on the need to approach these multiple perspectives of land use, the EU LUPA project has introduced the notion of Land Use Functions and has completed a comprehensive analysis of changing performance in relation to six individual land use functions:

1. LUF1: Provision of work
2. LUF2: Provision of leisure
3. LUF3: Provision of land-based products
4. LUF4: Provision of housing and infrastructure
5. LUF5: Provision of abiotic resources
6. LUF6: Provision of biotic resources

Synthesis of these functions also allows for the summaries of land use functions relating to:

1. Provision of societal functions
2. Provision of economical functions
3. Provision of environmental functions
4. Provision of total functions

However, the analysis of relationships between socio-economic development and land use remains as a cornerstone of this project. We must therefore take CLC data a step further to include a practical, relevant and informative notion of land use – one that includes the regional socio-economic patterns and dynamics of Europe.

Integrating the socio-economic and land cover dimensions – Intensity of land use

The concept of land use intensity is introduced into the LUPA project to acknowledge and respond to the understanding that while socio-economic development is less and less attributed to land-based production; it is an ever increasing driver of land changes. Seen from this perspective, it is not only important to know how much land is changing, but it is crucial to know if land changes reflect minor changes (which usually reflect on-going socio-economic processes) or if they reflect major shifts in land cover (which are often part and parcel with structural socio-economic changes or environmental impacts). Furthermore, it is important to consider that increased human landscape intervention is among the strongest pressures on biodiversity (Environment Council, 2010), and potentiating land use efficiency is a direct means of improving the sustainability of land use in general.

This aim is in direct relation to a key question of the project; namely, how and to what extent land cover changes interact with ongoing changes in the ways the land is *used* for socio-economic purposes. This in turn raises questions of how the typologies in the LUPA project can reflect on both the physical characteristics of land patterns and the socio-economic dynamics of land use that are behind these changes.

In light of this, land use intensity is defined as: the degree of human intervention caused by activities taking place on a given parcel of land - activities that, in most cases, do not have a direct and one-to-one implication on the characteristics of land cover. Therefore, the intensity is not related to the amount of input used – a driver that usually leads to an increase of production from a piece of land (cf. Gabrielsen, 2005). As described at length above, such a characterization would be reminiscent of what we are trying to avoid – land use characterization that is preferential the inputs and outputs of land-based production. But at the same time, land use intensity is not only related to the per capita use of artificial surfaces, for this is also too narrow a concept which tells more about the efficiency of land use than is doe about intensity (cf. Prokop et al. 2011).

In contrast, the quantitative assessment of land use intensity is created based on the inference that the ordering of the CLC classes – from CLC 34 – Glaciers and Perpetual Snow to CLC 1 – Continuous urban fabric – are representative of has an increasing level of land use intensity[1]. This ordering is based on a conservative set of guidelines and assumptions that are used to reinforce the plausibility of scoring land use intensity through the CLC classification hierarchy in lieu of additional validation.

We are aware that this relatively simplified approach may be criticized for being too simplistic. However, the structure of the CLC at an overall scale obviously shows tendencies towards the interpretation as indicated above. Thus, it is clear that when looking into details there are limitations to how much characterization and distinction can be incorporated into the scale of intensity reflected by the CLC classification.

Nevertheless, preliminary validation of the land use intensity concept uses indicators that can infer the value of land in relation to the range of socio-economic activities it provides (again, especially those which are not related to land-based production). Two indicators that best serve this purpose are population density and gross domestic product (GDP). As a result, regional statistics on both are compared to the results of the Land Use Intensity in Section 0 below. General Methodological Issues

1.4 Working with CORINE

Section 1.3 discusses the use of CLC data in the EU LUPA land use characterization at length, particularly in relation to the distinction between the concepts of land cover and land use. It was mentioned that the CORINE Land Cover Programme was initiated in the mid-eighties and has now been developed for three time series' (1990, 2000 and 2006). Consistency has been a key goal of the EEA and as a result each of the releases of CLC data uses the same classification scheme and nomenclature. Three scales of CLC land classification are available depending on the type of analysis being conducted. In the most general sense, land cover is classified into five classes, at the second level it is classified into 15 classes and at the third level into 44 classes. This consistent classification allows for the distinction between different types of land processes taking place at different scales and magnitudes. As discussed above, this is an important benefit in the classification of land use intensity.

[1] CLC 35 – 44 reflect Wetlands and Water bodies and have not been considered in the analysis due to uncertainty over the associated socio-economic activities that may take place on them.

One of the limitations however, is that the spatial coverage is not entirely consistent for each time series. This prevents full European coverage of the typologies for the entire 1990-2006 time series. As a result, the typologies are constructed at all three time scales to provide the fullest extent of European coverage possible. Yet, this is also advantageous for identifying changes in land patterns that have taken place through time; for instance based on trajectories of regional development related to entering EU membership. It also allows for the inclusion of analysis of socio-economic and environmental alongside CLC data that is not unanimously available back to 1990.

Aggregating CLC data to 1km^2 land types

One on the best assets of CLC data is its ability to produce very high resolution results for such a wide area. Land cover classification is available at both a 100m and 250m grid for each CLC in all three time series'. However, in some cases such a high resolution is not advantageous because it provides very fine, fragmented land cover results that fail to identify dominating land cover patterns. Here dominating land pattern is important to know because it starts to show the socio-economic uses of the land. This is especially crucial for identifying dominant land cover classes that are often relatively discrete in their distribution but have disproportionately high roles in a socio-economic perspective. The foremost example of this situation is that of artificial surfaces – areas that cover only 4% of Europe's land but accommodate an increasing majority of people and economic activity (EEA, 2010).

Thus, CLC data is aggregated from a 100m^2 to a 1km^2 grid-level for its use in constructing typologies that characterize land patterns in Europe. This harmonization is based on the principle that when aggregating CLC it is not possible to represent the entire mosaic of land cover classes or land cover changes for each 1km^2 cell. As such, the process represents a simplification of the data that is necessary for analysing important trends taking place on regional, national and European scales.

Aggregation to a 1km^2 grid is calculated using the CLC class (from 1-44) of the 100 grid-cells comprising each 1km^2. However, using one method of calculating an aggregated CLC class for a 1km^2 cell leaves open the possibility of significant mischaracterization. For example, Figure 1 provides a hypothetical example showing how CLC classes at a 100m^2 grid can be aggregated based on the maximum, minimum, median, mean and majority land class. Choosing between these different values reflects the ability of each to enhance and/or maintain different land cover characteristics in each of the 1km^2 areas. A minimum aggregation value of two corresponds to Discontinuous urban fabric while a maximum aggregation value of 41 corresponds to Water bodies. Median and majority classification result in different characterizations of Agricultural areas.

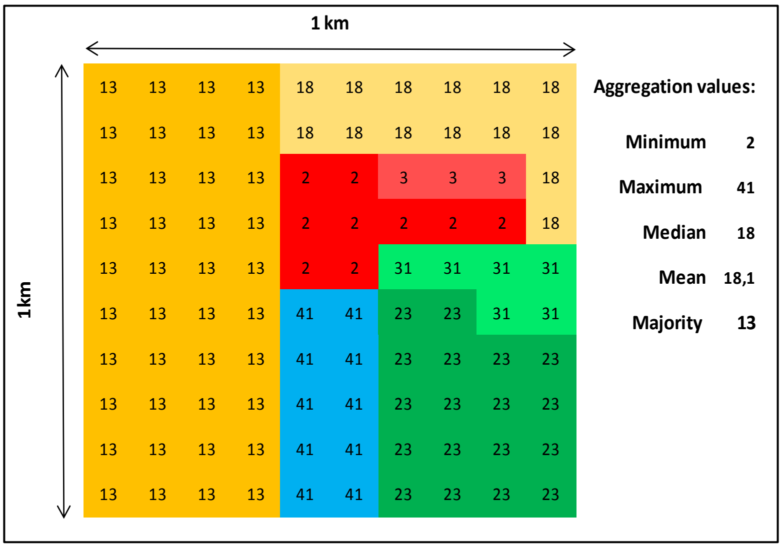

Figure 1 Hypothetical example of aggregating a $100m^2$ grid to $1km^2$ using five aggregation methods

Thus, each of the aggregation methods has their own advantages and disadvantages. For example, the maximum and minimum represent the span of CLC classes represented in a $1km^2$ - information which to some extent is indicative of the landscapes represented. Furthermore, the minimum aggregation determines if the area possesses any form of urban or agglomeration characteristics – a benefit that identifies discrete but crucial land classes that may otherwise disappear due to dominance of other classes. In contrast, the maximum aggregation provides a very good impression of where extensification thresholds could be impactful.

The median aggregation shows the dominant (majority) CLC class if one land type accounts for more than 50% of the cells in a given area. If this is not the case then it reports the CLC class that most likely dominates the area. As such, it limits the pull tendency of deviating outlier land classes in a given area and provides statistical results that come closest to reflecting the reality of the dominant CLC class. Yet perhaps most importantly, and in contrast to a majority aggregation that shows the most frequent CLC class in a given area, it also reflects on the associations of land cover classes in each cell, an issue that may become important when generalizing larger territorial structures based on a number of individual grid cells.

Most importantly, however, the aggregation possibilities highlighted above show that no single aggregation procedure effectively captures that land dynamics operating within a given area. This is a crucial component to the use of the aggregated CLC data in the typologies as the Maximum, Minimum, Median and Majority aggregations will be used together to formulate the dominant land cover type at a $1km^2$ scale.

1.5 Analysing land use patterns using typologies

Typologies are defined as the classification of entities into types based on shared or common characteristics. In the context of the EU LUPA, their general role is to serve as an analytical tool to support the development of land use policy recommendations for Europe. More specifically, through the use of CLC data, they are used to characterize land use and land use change in Europe.

In looking to develop typologies the answers to three central questions are sought:

1. What are the general characteristics of land use in Europe?
2. What characterizes land use changes?
3. How are land use patterns connected to socio-economic development?

Ultimately, it is the objective of this report to show that by responding to the first two questions the EU LUPA typologies provide an optimal characterization of land use patterns that reflect socio-economic dynamics. This in turn reveals additional insight into the nature of land use patterns and their relationships with socio-economic development.

It is also understood that concern during the typology formulation is that they should be simple, operational and easy to communicate, have a high explanatory power and be built on robust and complete data. The most immediate impact of these demands is that an individual typology cannot sufficiently characterize each of the dimensions required. Instead, one typology is necessary to interpret the prevailing characteristics of land use in Europe and another is needed to account for land use changes.

In generating typologies that seek to have a high explanatory power, it is advantageous to make them available for mapping at both the grid and regional formats. This relates to the need to integrate different dimensions of territorial structures; on one hand represented by land cover data that is “independent” independent of administrative bonds; and on the other hand by socio-economic data that is constructed by explicit administrative bonds – in this case, the NUTS2/3 level. At the same time, it is also important to point out that a gridded output is needed to acknowledge land functions that take place in overlapping or close proximity and for pursuing intra-regional analyses in the case studies.

Given the complexity of patterns and processes driving land use and land use change, as well as the nature of the data that is needed to account for both land cover and socio-economic dimensions, it is not possible to aggregate all of the relevant and interesting information into a single typology. Accordingly, a complete understanding requires consistent framework for integration of scales and themes. **The result is that this task uses CLC data in multiple ways to map spatial patterns of land use patterns in Europe:**

1. In relation to the prevailing characteristics of land use: answering the question, based on the distribution to CLC data 1990-2000-2006 what characterizes the land use in Europe? The results are two typologies
    a. The prevailing characteristics of land use at a $1km^2$ grid level
    b. The prevailing characteristics of land use at a NUTS2/3 level.
2. In relation to the amount of land use change, as a percentage of the total areas of NUTS2/3 regions. To simple answer the question, how much land is changing, and where?
3. In relation to the intensity of land use change in NUTS2/3 regions, to answer the question, what is the degree of human intervention on the land in order to meet the needs of our socio-economic activities?

4. In relation to the two previous outputs, a basic typology showing Hotspots of land use change. It generalizes regions based on a matrix of absolute change (by area) and intensity of change. This provides a generalized picture of which regions stick out in terms of high levels of physical land change, in terms of the degree of human intervention on the land, or both.
5. In relation to a Land use change typology: this is the cornerstone of the EU LUPA land use characterization and it answers the question, based on the regional clustering of classes of land cover flows (LCFs), and changes in land use intensity, what characterizes land use changes for NUTS2/3 regions in Europe?

2 Prevailing characteristics of land use: Specific methodologies, results and analysis

In this section of the report, the specific methods, results and analysis of our analysis of prevailing land characteristics using CLC are presented consecutively. Section 2.1 discusses the prevailing characteristics of land use at the grid level while Section 2.2 discusses the prevailing characteristics of land use at the NUTS 2/3 level.

2.1 Prevailing characteristics of land use – grid level

Method

The term "prevailing" is important in this connection because it implies that the unchanged elements of European land cover as well as any changes that take place are included in the typologies. The alternative approach would be to use data from a base year (e.g. 1990) to imply a point of departure for all observed land changes. The advantage of the former approach is that it provides a comprehensive interpretation of land cover that does not infer that land change is a fixed process with a clear beginning and end, but rather a dynamic and on-going *process* through time and space.

Section 1.4 described the multiple processes of aggregating CLC data from $100m^2$ to $1km^2$ and the benefit of the different approaches. Using these aggregations the process of developing the prevailing characteristics typologies are completed at two levels: the grid-level and the regionalized typology. These provide an overall characterization, which in turn acts as a point of departure for analysing land changes in Europe.

As shown in Figure 2, the method of creating the prevailing characteristics of land use typology begins with the previously discussed aggregation procedure, and algorithm step and a clustering procedure. This is broken down in the following steps:

1. The first step is to select the aggregation data to be used in the clustering. As described above, the maximum and minimum aggregations represent the span of land cover types in each $1km^2$ area, while the median and majority aggregation most effectively characterize the dominant land characteristics, as well as the association of vegetation characterizing the grid cell without being affected by outlier land covers. Therefore, these four datasets are used as inputs in the first clustering procedure.

It is also important to acknowledge the issue of gaps in the CLC data. One of the objectives of the prevailing characteristics typology is to provide a full European coverage while using CLC data going back to 1990. In order to achieve this data from the 2000 release of CLC is used in countries missing either 1990 or 2006 data.

2. The four datasets for each of the CLC time periods are then analysed using an algorithm that identifies similarities and differences between each of the Maximum, Minimum, Median and Majority aggregation procedures. The reason for this exercise is to emphasize the role of urban areas. Considering that artificial surfaces cover only 4% of Europe, it has a very low extent compared to its socio-economic impact. In order to ensure its proper representation in the cluster results any $1km^2$ grids showing an Artificial surfaces CLC class in at least two of the four aggregation processes is characterized as an urban cell. Similarly, an urban cell is identified if the average of the four clustering processes is between the values 1-11, i.e. one of the Artificial surfaces CLC classes. Any cell not identified as urban is considered a rural cell.

3. Next, two cluster procedures are completed; one for the 815 590 urban cells and one for the remaining rural cells. In both procedures Ward's cluster method is used to combine the four aggregation datasets for all three years[2]. The result is the generation of six clusters with an urban component and seven rural clusters. The clusters results are then smoothed using a GIS tool called Majority Filter. This tool runs a $3km^2x3km^2$ filter over the raster data and assigns the dominant cluster value to each of the nine $1km^2$ cells in the matrix. As with the intention of the aggregation procedure, this limits the singular occurrence of cells which can be considered "territorial outliers", and thereby eventually blur the general picture and make interpretation difficult.

4. The cluster results are named and therefore transformed from 13 clusters into 11 land use types - a reduction of two because two types includes the grid cells from two clusters together. These cover the spectrum of landscape in Europe – from dense urban cores with intensive human intervention to sparse and remote natural landscapes. The naming process is in many ways a subjective process that makes use of the statistics characterizing the clusters, first of all the mean and standard deviation values of the dominant value for the cluster, as well as tables showing the distribution of the 44 CLC classes[3] for each cluster. These tables are shown in Appendix 5.2, and summarized in Figure 3 to show the composition of land attributes in each cluster.

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[2] Datasets for 4 aggregation datasets times 3 time periods equals 12 CLC classification values for each cell the in the cluster procedure.

[3] The distribution of the grids among the 44 CLC classes is shown using the Majority aggregation method.

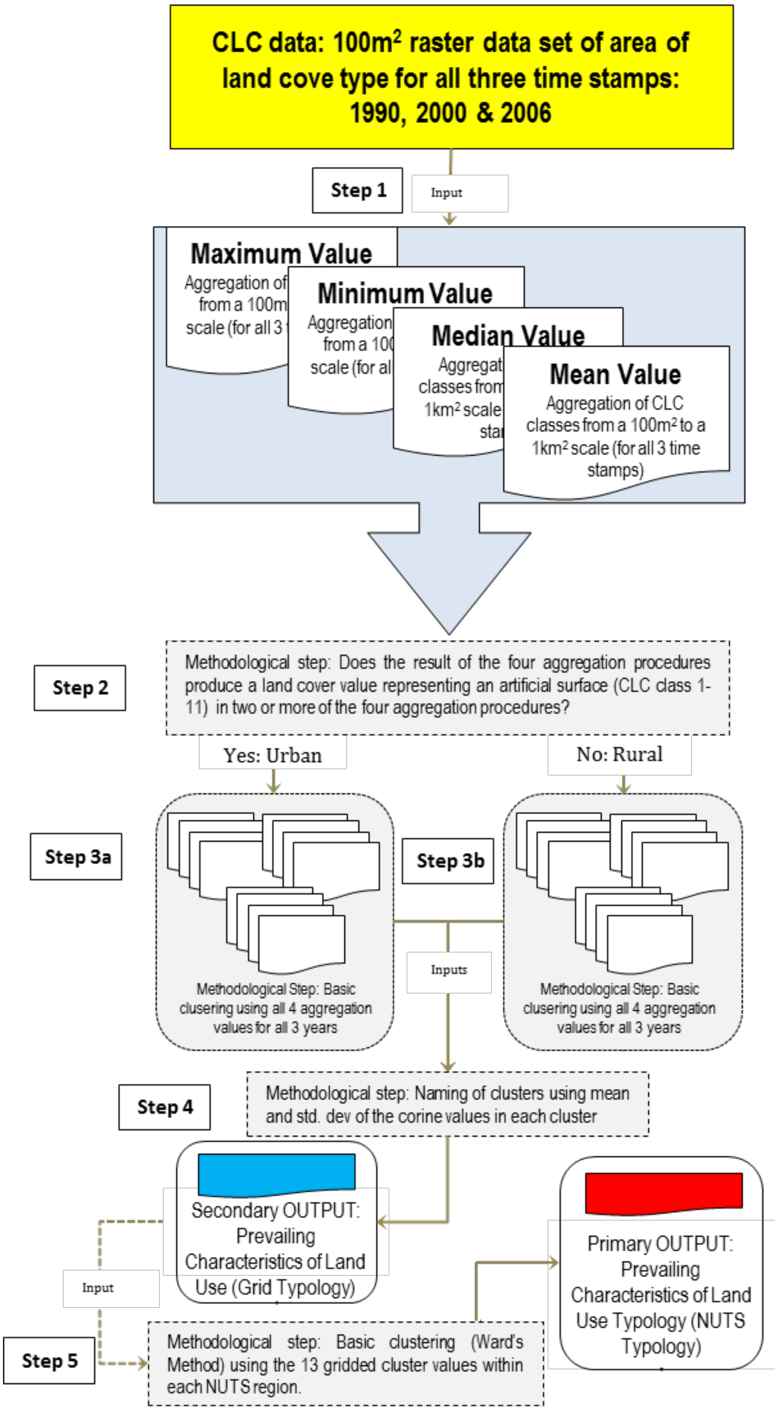


Figure 2 Methodological flow used to analyse prevailing land use characteristics

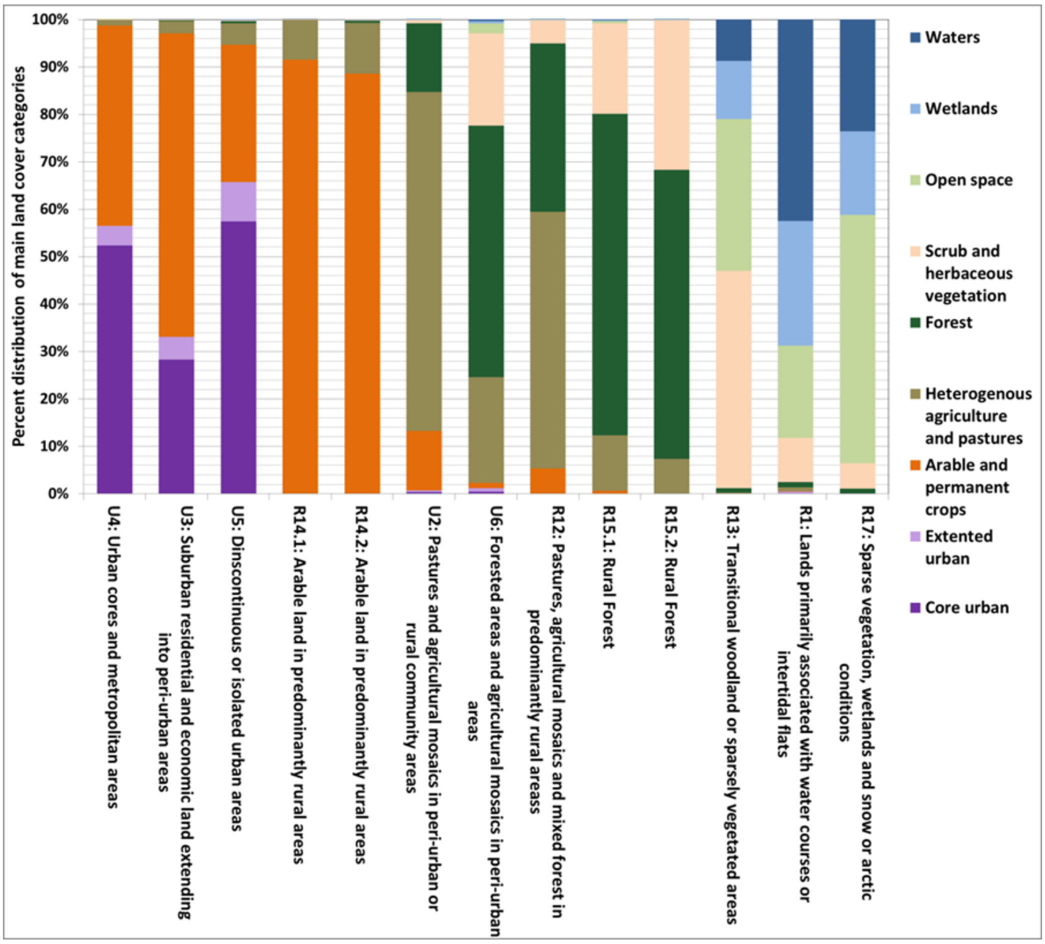
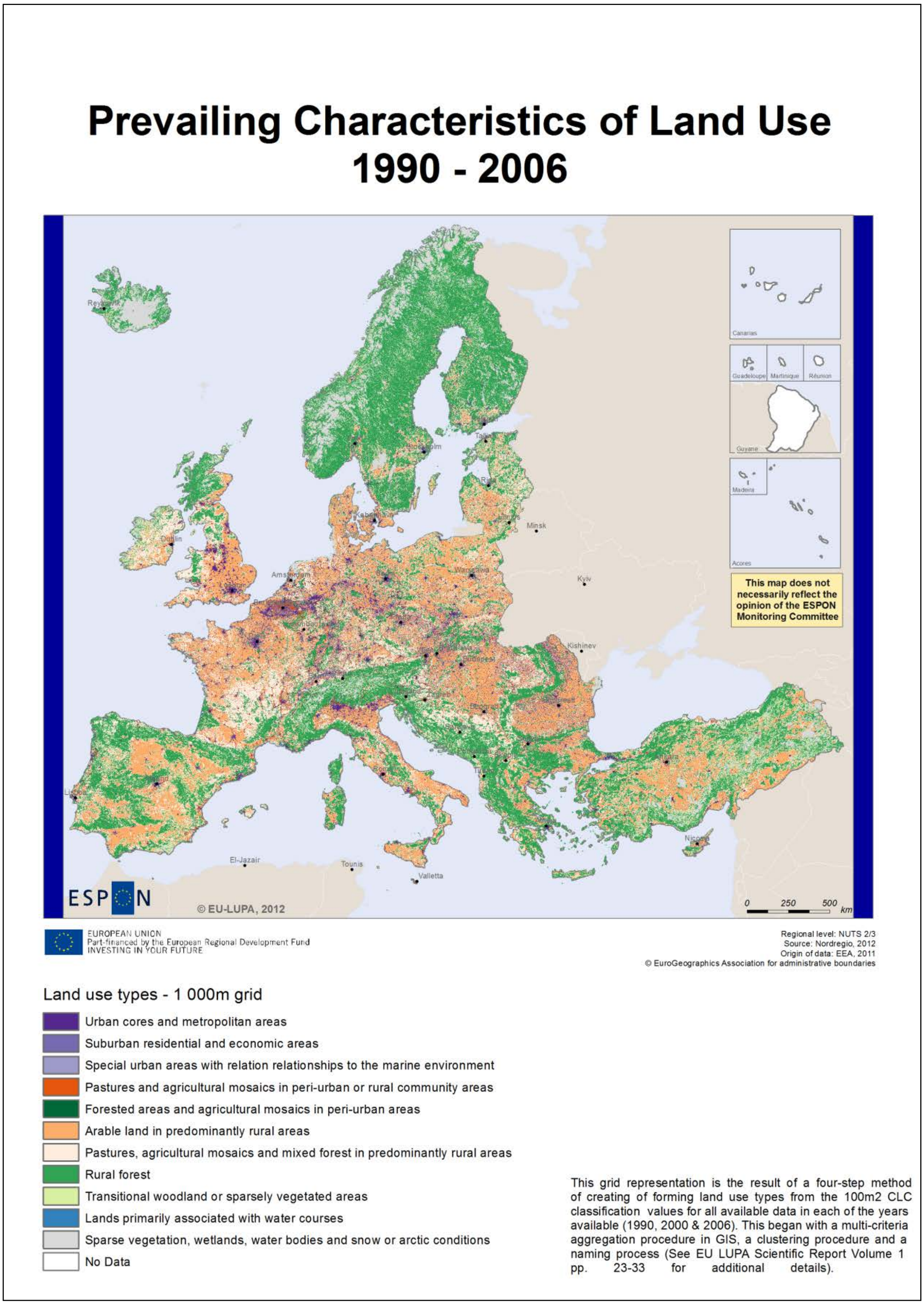


Figure 3 Distribution of main land cover classes (based on CLC classes) in each cluster used to generate the gridded Prevailing characteristics of land use typology

Results



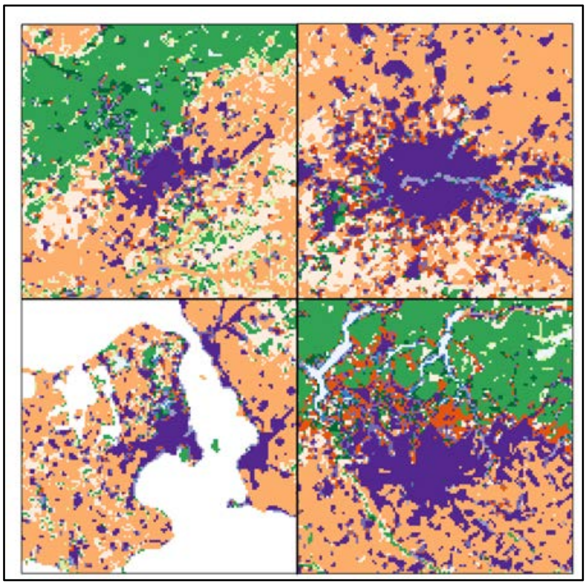
Map 1 Grid typology for the Prevailing characteristics of land use

Using the methodology described above, the results of the prevailing characteristics of land use typology at the grid level is presented in Map 1. The results can be summarized as follows:

1. U4: ***Urban cores and metropolitan areas*** – This land type is dominant for an average of 3.2%[4] of the land in Europe. Over two thirds of all "CLC - continuous urban fabric" is accounted for in this land type and over 55% of the area is characterized as "CLC – artificial surfaces". As shown in the maps of Madrid, London, Copenhagen and Milano this land type quite clearly conspires to what is generally viewed as the urban configurations of these city regions. The dark purple fills the city centres and expands outwards according to higher urban densities and transport infrastructure.

   Each of the images in Map 2 show that the urban cores and metropolitan areas land type "picks up" some land area that penetrates into suburban and peri-urban areas. This is reaffirmed by the graph in Figure 3 showing that over 40% of this land type is actually typified as arable land and permanent crops. Again, this is viewed as an advantage of this typology in that it is achieving its aim of identifying the *prevailing land use type* across the European landscape.

2. U3: ***Suburban residential and economic areas*** – Slightly higher than urban cores and metropolitan areas, this type is dominant for an average of 3.31% in Europe. Yet looking at the map of the urban cores above, it is quite easy to see its distinction from the previous land type. Whereas the urban cores and metropolitan areas basically accounts for exactly what its name implies, the lighter purple accounts for suburban and peri-urban conditions that are extending into the countryside. This is especially noticeable in the urban maps above where Madrid, Milano and to a lesser extent Copenhagen show that a "sprawled" urban configuration into the rural hinterland appears to be evident. In contrast, this seems to be less prevalent in London where satellite towns with a denser urban fabric seem to be the norm.



Map 2 Urban cores as shown through the results of the gridded typology on the Prevailing characteristics of land use. Clockwise from top-left: Madrid London Copenhagen Milano

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[4] The "average" is calculated based on the statistical dominance each land type shows across the range of available CLC data from 1990, 2000 and 2006.

3. U5: ***Special urban areas with relationships to the marine environment*** - Accounting for an average of only 0.7% of Europe's land, this is a very interesting urban land type. Even though the statistical results in Figure 3 above show a very low inclusion of waters or wetlands (less than 2%), analysis of the spatial distribution of this land type shows that the cluster analysis has identified land dominated by urban processes in that are in direct proximity to marine environments. As shown by the maps above, the urban area in direct proximity to the River Thames in London is included in this type, just as are the port and coastal areas surrounding Copenhagen. This pattern extends to all port, river, lakeside and coastal areas in Europe.

   The statistical results presented in Figure 3 and Appendix 5.2 validates this land use type by showing the comparatively low inclusion of non-Artificial surface land types (less than 30%). It also accounts for roughly 70% of land classified as port areas by CLC 2006 data.

4. R14.1 & R14.2: ***Arable land in predominantly rural areas*** – This land type accounts for an average of 22.36% of land in Europe. As shown in Figure 3 above, it is the result of merging two individual clusters that showed to have quite similar characteristics. Over 85% of the land in both clusters relates to land classified as "arable land" or "permanent crops" by the aggregated CLC data. The remaining area is almost exclusively related to pastures and rural mosaics. Map 1 shows that high concentrations of arable land are notable throughout continental Europe but excluding the Nordic countries, the Alpes region, Northwest Spain and the western Balkans where forest land cover is more dominant.
5. U2: ***Pastures and agricultural mosaics in peri-urban areas*** - Unlike arable land in rural areas, this land type accounts for only 3.28% of Europe. Based on its distribution in the urban core maps above it is clearly noticeable that it also has a much different cadastral structure compared to the more homogeneous distribution of arable land in rural areas. In this case land is separated much more heterogeneously into pastures and arable areas that are close proximity to urban conurbations. Both of these factors indicate that the relatively small land plots could be related to higher property values associated with their urban proximity.
6. U6: ***Forested areas and agricultural mosaics in peri-urban areas*** – At only 1.7% it is similar to the previous land type in that it covers a comparatively small area of Europe compared to rural forest. As is noticeable in the case of Milano and Copenhagen above, this relates to the fact that it accounts for land dominated by forested areas, but which is located in quite close proximity to larger urban areas.
7. R12: ***Pastures, agricultural mosaics and mixed forest in predominantly rural areas*** – Covering an average of 21.61% of Europe, this is the third most extensive land type in Europe. Similar to the previous land type (Forested areas and agricultural mosaics in peri-urban areas) it is a very diverse land type in which statistically significant proportions of land are covered by non-irrigated land, pastures, agricultural mosaics and forest land cover. It appears that this land type is accurately accounting for rural areas

that have quite diverse, transitional or heterogeneous land functions across a variety of sectors (e.g. diverse types of farming, forestry, tourism, etc.)

8. R15.1 & R15.2 ***Rural Forest*** – With an average coverage of 32.4% of Europe this is the most extensive land type. Similar to arable land in predominantly rural areas, this is the second land type that involves the amalgamation of two clusters into one land type. Figure 3 visualizes the justification for this by showing that both clusters have broad leaved, coniferous or mixed forest covering over 60% of the landscape. The matrix tables in Appendix 5.2 show that the only difference between the two clusters is a tradeoff between the amount of land covered by scrub and/or herbaceous vegetation associations and that which is covered by pastures heterogeneous agricultural areas.
9. R13: ***Transitional woodland or sparsely vegetated areas*** - Accounting for an average of 5.7% of Europe the statistics indicate that this land type is mainly transitional woodland and scrub, which is often associated with forestry activities, as well as open spaces with little or no vegetation. Spatially, this land type is concentrated in Sweden (likely associated with transitional woodland related to logging activity) and Ireland, southern Spain, and Turkey (likely related to areas of little very sparse vegetation and large areas of open land.
10. R11: ***Lands primarily associated with water courses*** – As shown by the statistics in Appendix 5.2, a majority of this land type is explained by the dominance of inland waters and this land type accounts for areas that that are in direct proximity to inland watercourses. Statistically it is rather insignificant as it only accounts for less than 0.3% of the space mapped by CLC data.
11. R 17: ***Sparse vegetation, wetlands, water bodies and snow or arctic conditions*** – This land type accounts for roughly 7% of Europe and it is quite clear on Map 1 above that this is concentrated in areas with seasonal or perpetual snow cover, such as Iceland, the Alpes and Norway. Large inland lakes such as those in Sweden are included in this land type, as well as the expansive intertidal flats in The Netherlands and Denmark.

Overall, spatial characteristics of land cover appear very clear on the map. For example, differences between urban versus non-urban as well as different types of rural landscapes are striking. This is especially true in relation to geography and topography, but also in terms of identifying different types of rural landscape. The plethora of forest in the Nordic countries, in Scotland, and northern Spain also provides a preamble for the importance of the forest sector in these regions.

The differences between arable land with a higher production potential (shown in orange) compared to less productive pasture, mosaics and mixed vegetation (shown in beige) are also notable. Another very interesting observation is noted by the distribution of the land cover types among the first three "urban" land types where, artificial surface land covers are almost exclusively paired with areas characterized as having some sort of agricultural function. In contrast, the statistical results in Appendix 5.2 show that an extremely small amount of forested areas are grouped in "urban" land types. This further validates the typology by reaffirming that a vast majority of land surrounding urban settlements is dominated by land use types reflecting some sort of socio-economic consumption.

Besides enabling a detailed overview of the distribution of dominant land types across the European landscapes, the main utility of the prevailing is to serve as an input into the generation of prevailing land types at the regional level. At the same time, the gridded results have also been valuable for characterizing landscapes at the regional and local level in the case studies. As such, further analysis of the results is available through each of the four case studies.

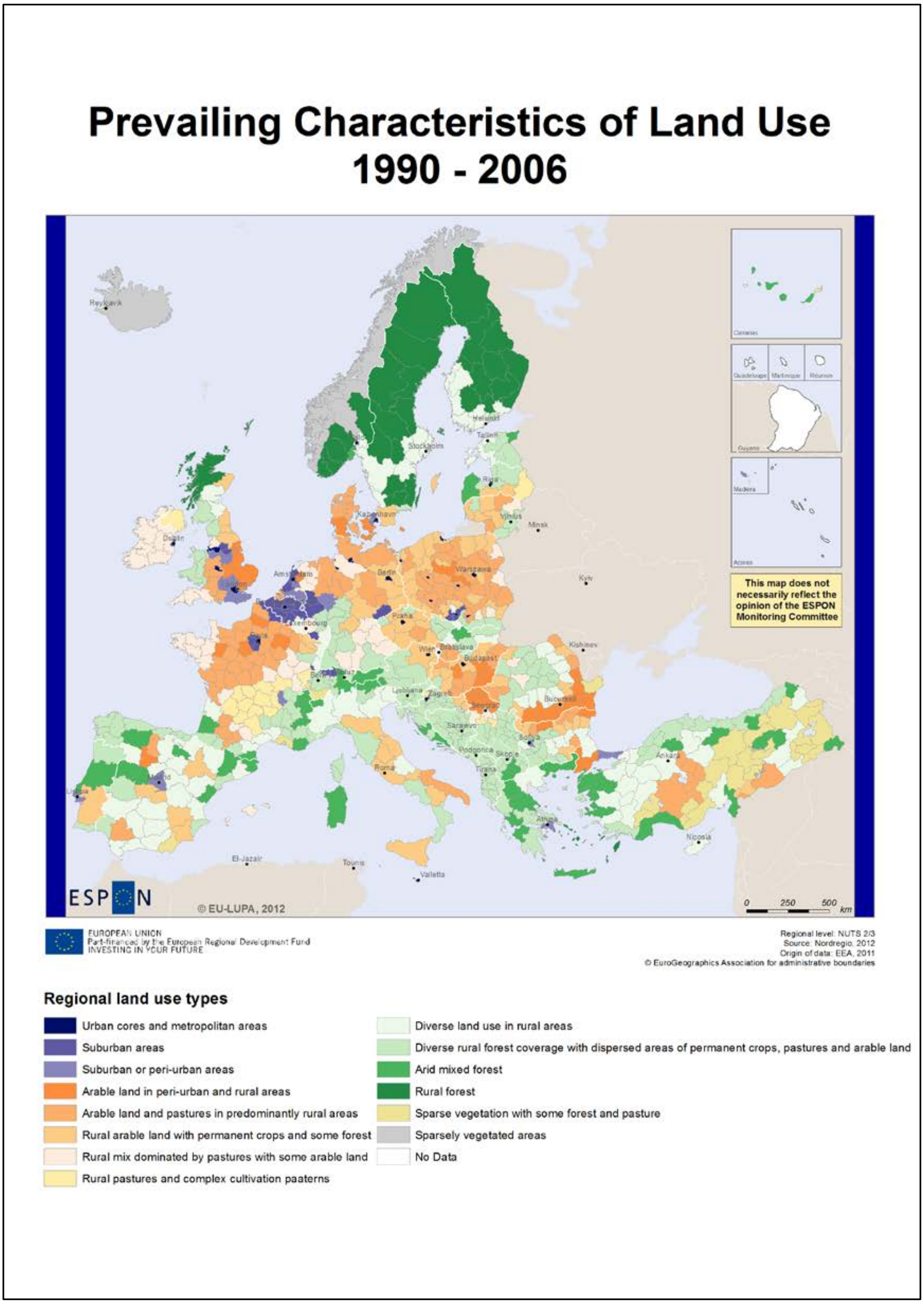
2.2 Prevailing characteristics of land use – NUTS2/3 level

Method

As shown in Figure 2, the 4-step methodological flow presented above includes a 5th step in order to regionalize the gridded typology to the NUTS2/3 level. While the first four steps worked with gridded data and resulting in a total of 6 urban and 7 rural land use categories, the first part of step 5 was a summarizing for each NUTS2/3 region of these 13 land cover categories followed by a calculation of their percent distribution for each region. Based on these regionalized distributions a second part of step 5 were the identification of similarities between the NUTS2/3 regions. This was handled through an additional clustering procedure where a first regionalized classification of the land use characteristics was provided by means of a basic clustering procedure (Ward's method, Cubic Clustering Criterion). This clustered the regions according to similarities in the percentage distribution of the 13 categories of land cover. The result was an initial identification of 16 clusters which eventually was reduced to 13 clusters which not only showed distinct characteristics but at the same time provided as sensible group sizes for each of the clusters. In addition, however, an algorithm was added emphasizing the urban component by providing an additional category of urban sprawl into predominantly rural areas. This category emphasize regions with urban and infrastructure land (Corine classes 1-11) above a threshold of ½ standard deviation above the European mean.

Result

The result is 14 clusters, which have been subjectively named and transformed in to regional land use types. The naming is based on the composition of CLC classes in each cluster, which is shown for the CLC 2006 data in Table 1 below (and for 1990 and 2000 data in Appendix 5.3).



Map 3 Regional typology of the prevailing characteristics of land use

Table 1 The distribution of CLC 2006 classes within each regional cluster (noted in the top row), leading to the formation (naming) of regional land use types (noted in the bottom row). The purple - orange colour scale shows the share of each CLC class group for each cluster and regional land use type.

			Cluster Numbers													
		CLC classes	CL15	CL16	cl20	CL02	CL07	CL03	CL-05	CL09	CL04	CL6	CL12	CL11	CL01	CL10
1 2 3	Artificial surfaces Artificial surfaces Artificial surfaces	Continuous Urban Fabric Discontinuous urban fabric Industrial or commercial units	52,41	18,15	13,38	4,78	4,23	3,99	4,05	2,51	3,15	3,07	1,94	1,17	0,63	0,32
4 5 6 7 8 9 10 11	Artificial surfaces Artificial surfaces Artificial surfaces Artificial surfaces Artificial surfaces Artificial surfaces Artificial surfaces Artificial surfaces	Roads and rail networks and associated land Port areas Airports Mineral extraction sites Dump sites Construction sites Green urban areas Port and leisure facilities	11,05	2,65	3,36	0,82	0,58	0,60	0,57	0,34	0,50	0,41	0,40	0,20	0,16	0,13
12 13 14 15	Agricultural areas Agricultural areas Agricultural areas Agricultural areas	Non-irrigated arable land Permanently irrigated land Rice fields Vineyards	11,75	32,98	27,53	71,61	52,66	40,29	24,94	6,99	28,23	12,32	15,40	16,97	2,36	0,71
16 17 18 19 20 21 22	Agricultural areas Agricultural areas Agricultural areas Agricultural areas Agricultural areas Agricultural areas Agricultural areas	Fruit trees and berry plantations Olive groves Pastures Annual crops ass. With permanent crops Complex cultivation Agriculture with sign. Areas of natural vegetation Agro-forestry areas	9,97	23,81	27,99	10,22	20,17	19,54	41,85	55,77	17,22	26,95	18,59	16,78	2,65	3,29
23 24 25 26 27 28 29	Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas	Broad leaved forests Coniferous forests Mixed forests Natural grasslands Moors and heathland Sclerophyllous vegetation Transitional woodland shrub	9,57	18,74	25,36	9,26	18,69	33,14	22,19	32,36	44,46	53,53	54,31	31,67	75,34	42,78
30 31 32 33 34	Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas Forest and semi natural areas	Beaches, dunes, sands Bare rocks Sparsely vegetated areas Burnt areas Glaciers and perpetual snow	0,10	0,10	0,25	0,09	1,32	0,50	0,23	0,03	3,47	2,24	7,94	28,73	3,42	42,66
35 36 37 38 39 40 41 42 43	Wetlands Wetlands Wetlands Wetlands Wetlands Water bodies Water bodies Water bodies Water bodies	Inland marshes Peat bogs Salt marshes Salines Intertidal flats Water courses Water bodies Coastal lagoons Estuaries	4,94	3,54	2,00	3,02	2,28	1,87	6,05	1,99	2,88	1,40	1,35	4,48	15,35	9,78
44	Water bodies	Sea and ocean	0,21	0,03	0,12	0,19	0,06	0,05	0,12	0,01	0,09	0,07	0,08	0,01	0,09	0,33
		Number of regions	29	32	21	41	97	81	52	18	97	171	56	56	30	27
		Percent of Europe	0,22	1,38	1,20	3,57	11,89	10,82	5,48	2,05	15,24	17,75	7,09	4,60	12,89	5,81
			Urban cores and metropolitan areas	Suburban areas	Suburban or peri-urban areas	Arable land in peri-urban and rural areas	Arable land and pastures in predominantly rural areas	Rural arable land with permanent crops and some forest	Rural mix dominated by pastures with some arable land	Rural pastures and complex cultivation paaterns	Diverse land use in rural areas	Diverse rural forest coverage with dispersed areas of permanent crops, pastures and arable land	Arid mixed forest	Sparse vegetation with some forest and pasture	Rural forest	Sparsely vegetated areas

1. ***Urban cores and metropolitan areas*** – 29 regions – show a situation where almost 60% of regions have land characterized as urban cores and metropolitan areas in the grid-level typology. As such, their spatial distributions are quite similar. At the same time, when grid data are summarized at the administrative level, it becomes very evident that urban cores in larger regions are becoming overshadowed by more dominant (rural) land types. As a consequence regions in this type are generally smaller regions which can be characterized as regional city-states, where peri-urban areas and rural hinterland is accounted for in neighbouring regions. Thus, the urban land features in this type are influential not only for the social, economic and environmental performance of regions within this type but also those regions within near proximity.

2. ***Suburban areas*** – 32 regions – Urban land types have the dominating influence in these regions and there is a clear connection to the gridded type "Suburban residential and economic land extending into peri-urban areas". Urban and infrastructural related land typically consumes 15-20% of the region and as a result, activities related to urban and infrastructural settings are highly influential in characterizing overall land use in the region. The distribution of regions in this type – for instance, most of Belgium – reiterates a noteworthy characteristic when regionalizing grid level results.

   The results of the cluster analysis emphasize the vast difference in the size of NUTS regions throughout Europe. Even though the NUTS2/3 hybrid helps overcome some of the problems with disproportionate regional sizes it is quite clear that heterogeneity is an unavoidable factor influencing the cluster results. For example, relatively small regions (in terms of area), such as those around Brussels and especially city-states have proportionally shares of urban land covers compared to relatively large regions that may be endowed by larger cities as well; such as Regions in Spain, France, Italy and the Nordic countries. As a result even though a city such as Madrid has an extensive urban area and a huge regional (and even national) influence, it can only be characterized as a "suburban or peri-urban" region because rural land covers still dominate in a physical perspective.

3. ***Suburban or peri-urban areas*** – 21 regions – Regions in this cluster are either situated in near proximity to large urban centres – such as London or Paris – or are similar to the previous land type in the sense that they have a higher urban land component because of the relatively small area of the region. The urban and infrastructural component typically covers around 15% (and up to 20%) of the land. Relatively high levels of artificial surfaces are also evident in certain regions where large urban areas are situated in relatively large regions (by physical size). For example, regions in Spain or those adjacent to city-states such as London fall into this group. Other examples include larger industrial areas, for instance in southern Poland, or further north in the UK where the region between Liverpool and Manchester serves as a densely populated hinterland for the city activities.

4. ***Arable land in peri-urban and rural areas*** is dominated by the very high content of arable land defined through CLC classes 12 to 15. These categories cover more than 70% of the land in the 41 regions characterized by this type. The historic role of the agricultural production potential of this land use type for Northern Europe, Central Europe and the Balkans is clearly indicated through its distribution as the immediate hinterland around the major urban centers in the Central-North, and the matrix which constitutes the core population areas along the rivers in the Balkan area.

   In addition to what is indicated through the three previous land use types, it is also notable that this land use type is becoming swallowed up by the sprawl of urban and residential related activities; especially in Central Europe. Being among some of the more fertile areas in Europe, the high intensities of crop growth has demanded a process where intensification is supported through increasing land prices. This, in conjunction with better loaning opportunities has limited the options for more traditional land use approaches. As such, these regions are an object of continued speculation in relation to future development and policy related to non-agrarian production and reproduction land uses.

5. ***Arable land and pastures in predominantly rural areas*** includes 97 regions that share many similarities to the “Arable land in peri-urban and rural areas” type discussed above. Both types are structured by combinations of the two grid typologies of “Arable land in predominantly rural areas” and “Pastures and agricultural mosaics in peri-urban or rural community areas”. They show a clear dominance of arable land in combination with permanent crops and some forest land. Both types also have CLC classes 1-3 covering over 4% of the regional area. The main difference however, is that while arable land covered more than 70% in the previous land use type it is down to 50% while pastures, permanent crops and forested areas make up for the remaining differential.

   In a von Thünean perspective of concentric farming types around urban areas it is likely that, compared to the previous land use type, we are moving to the next intensity level of concentric circles around the major cities. It seems common that regions in this type could still be highly influenced by the major cities and their constant expansion, though.

   Also, compared to the previous prevailing regional land use type, we are clearly moving into a situation where the land use mix is slightly more diverse and has a slightly lower production potential than strictly arable land. While this is a predominant characteristic of more peripheral areas in Northern Europe, it at the same time has occasional appearance in Southern Europe, for instance with coverage in Spain, Italy, Turkey and Greece, but especially in the Balkan region where it constitutes a natural continuum from the more fertile lowland towards the more mountainous parts of the countries. Nevertheless, it is clear that agricultural activity is still quite prevalent in these regions, but the relatively arid climate for many of the regions means that agriculture is often dominated by less intensive permanent crops.

6. ***Rural arable land with permanent crops and some forest*** is characterized by a mix of arable land, pastures, mosaics and some forest in the 81 regions covered by this regional type. Even with the risk of stretching the von Thünen analogy too long, these regions seem to add a further step in the von Thünen intensity ladder as it is very much a continuation of the trend noted in the previous types, where the dominance of agriculture is waning toward increased presence of agricultural mosaics, often associated with permanent crops, pastures and dispersed forest areas. Compared to the previous regional type, this one shows an increased reduction in arable land - even though it is still dominant with a percentage of around 40, followed by forest areas above 30% while permanent crops are around 20%.

   This prevailing regional type has a very diverse extent in Europe; stretching from southern Sweden and Finland through eastern, central and western Europe, while also playing an important role in the south. Its coverage is notable throughout Spain, in central as well as in northern Italy, Romania, Greece and Turkey.

   This type of diverse spatial coverage adds credence to the notion of it being a very diverse land structure, both in terms of rural land covers, but especially in relation to the mixed role of urban and rural landscapes.

7. ***Rural mix dominated by pastures with some arable land*** show a diverse land cover throughout its 52 regions. Again, this is a continuation of the trend in the previous three types where arable land, pastures, agricultural mosaics and sporadic forest are being replaced by first and foremost the permanent crops and forest land covers. However, given that no land type accounts for more than 43% of the areas in these regions it is safe to assume a quite diverse land mix in these regions.

   Spatially, regions in this type are situated together with the following regional type in the border zone between northern and southern land production types. This seems to indicate a production zone where on-going changes in climate could result in important changes both positively and negatively.

   What is even more interesting is the connection to the land situated in coastal areas stretching from Ireland through south-western England, Normandy, northwest coastal areas in The Netherlands and Germany, as well as down to the Spanish isles in the Mediterranean. It also appears to have relations to inland water and watercourses in central Europe. In both cases the interaction between land and water are important as they generate challenges as well as new opportunities. For example, opportunities exist in relation to tourism and possibilities for different types of renewable energy production.

8. ***Rural pastures and complex cultivation patterns*** is a relatively small but distinct type which to some extent covering 18 regions. It resembles the previous regional type by having a very high component of permanent crops in combination with some arable land as well as pastures, some agricultural mosaics and mixed forest. Its absolute dominance in south-central France and more occasional appearance in

Latvia, Northern Ireland, Romania, as well as in a few regions in central Balkan show that land is dominated by pastures, agricultural mosaics and mixed forest, while the presence of arable land is significantly diminished compared to the previous regional land types. This seems to point toward a few conditions that could be influencing the rural consumption of land. It is quite clear that pasturing is likely the dominant form of rural land use and the presence of forest may not be as high as compared to Estonia, Latvia or Romania where mix between forest and pasture activities is evident.

9. ***Diverse land use in rural areas*** is among the three major types encompassing a total of 97 regions, but actually represented through two distinctly different types – a northern and a southern type. These show similar overall coverage characteristics, but representing very different landscapes. Being one of the major categories represented in southern Europe and Turkey, it depicts what best can be characterized as typical Mediterranean landscapes. There is a diverse mix of land cover types with statistically significant levels of arable land (25-30%), permanent crops (15-20%) and forests (40-50%).

   Similar characteristics account for the distribution of this type in the Balkans, primarily in Romania and Bulgaria. The northern landscape encompassing this type is characterized by the same mix of land cover, but with arable and grazing land being the dominant characteristic compared to forest and scrub coverage in the southern regions. Furthermore, from southern Scotland, across Norway, Sweden, and Finland, as well as into the Baltic States this type is connected to the expansion of more urban activities into former rural areas previously dominated by forestry.

10. ***Diverse rural forest coverage with dispersed areas of permanent crops, pastures and arable land*** is by far the largest type represented by a total of 171 regions in Europe, and mainly related to mountainous regions dominated by forest. More than 50% of the land is forested, but substantial input of permanent crops (25-30%) and arable land (10-15%) provide a basis for other economic input. However, such a large number of regions in a single clustering with such large variation in terms of landscapes and accessibility make it difficult for further generalization.

11. ***Arid mixed forest*** - represented through 56 regions, this type is in many ways a continuation of the southern type of the diverse land use in rural areas, but with a higher percentage of forest (50-60%) and it is situated in areas with more mountainous characteristics. It stretches across the whole Mediterranean area from Portugal in west to the most eastern regions in Turkey.

12. ***Sparse vegetation with some forests and pastures*** has been identified throughout mountainous parts of Europe, and with a major part of the 56 regions situated in Turkey, while the others are dispersed over most of Europe. The regions are characterized by a mixture of forests (30-35%) in combination with sparse vegetation (25-30%) and with scattered areas of arable land (15-20%) and

permanent crops (15-20%). It seems safe to assume the land-based production potential could be quite low in terms of traditional rural activities.

13. ***Rural forest*** is typifies 30 regions with a clear northern orientation and where forest covers more than 75% of the areas, while water and sparsely vegetated areas constitutes the rest. In a Nordic setting these areas are responsible for a major part of forestry in the north stretching from Scotland through Norway, Sweden and Finland.
14. ***Sparsely vegetated areas*** constitute a total of 27 regions, mainly situated in Norway and Iceland, being characterized by a split between sparse vegetation and forest.

3 Land Changes: Specific methodologies, results and analysis

In this section of the report, the specific methods, results and analysis of our analysis land changes are presented consecutively. As is immediately noticeable in Figure 4, the production of spatial data of land changes is more complex than spatial data of the prevailing land use characteristics. There are four regionalized outputs regarding land changes that, when put together, provide an understanding of how different patterns of land change are distributed throughout Europe. These are:

1. Amount of land change
2. Intensity of land changes, including a validation of the intensity concept
3. Land change hotspots
4. Land use change typology

3.1 Amount of Land Change

It is not the intention here to provide a general analysis related to patterns of land use change in Europe. Instead, a preliminary set of results of the analysis in this project provides a starting point for discussions later on in the report.

Method

As shown by Figure 4, this is quite self-explanatory. All CLC changes are summed at the NUTS2/3 level. These totals are then divided by the area of the region to determine percentage of each region undergoing land change.

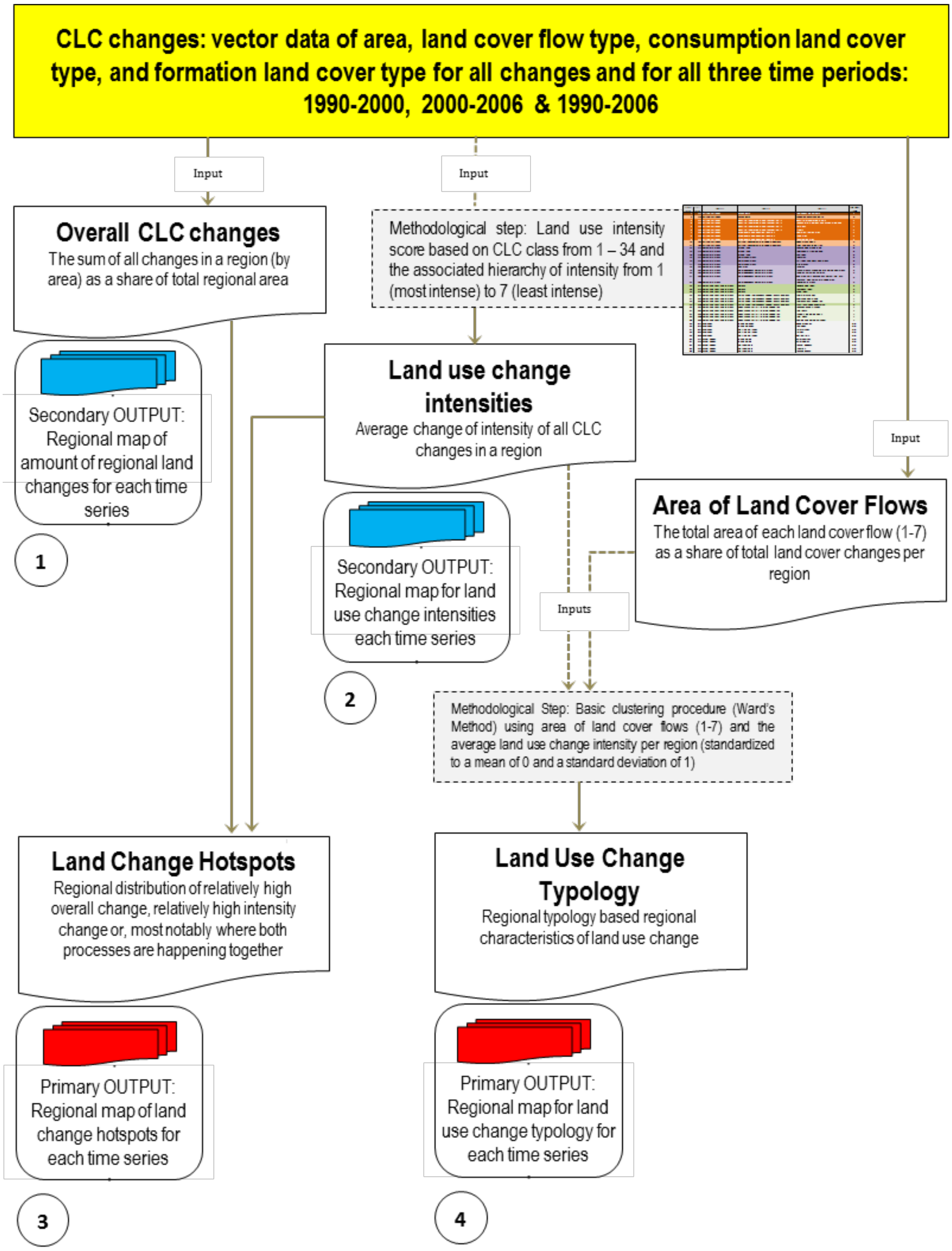


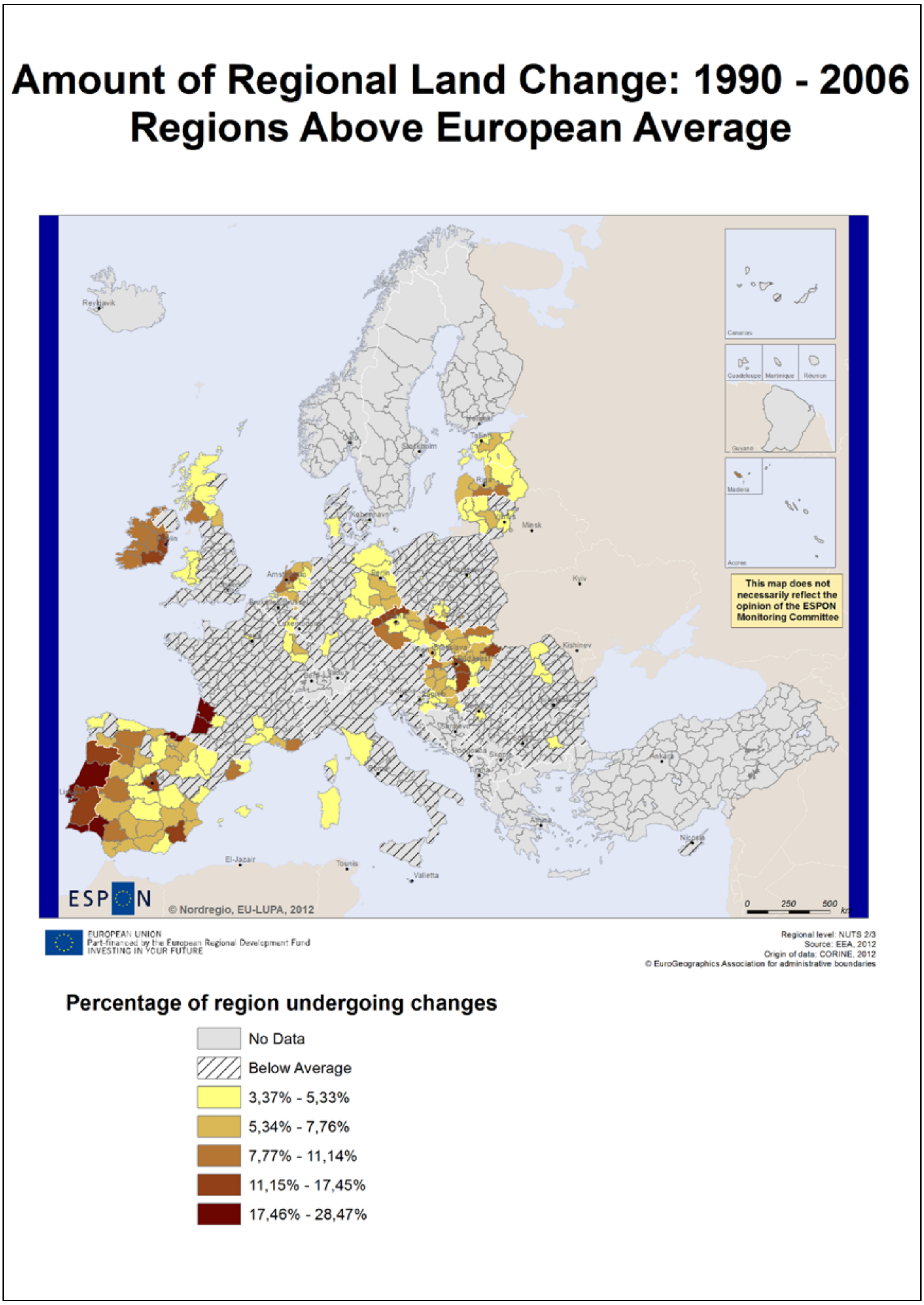
Figure 4 Methodological flow to analyse land changes in the EU LUPA project

Results

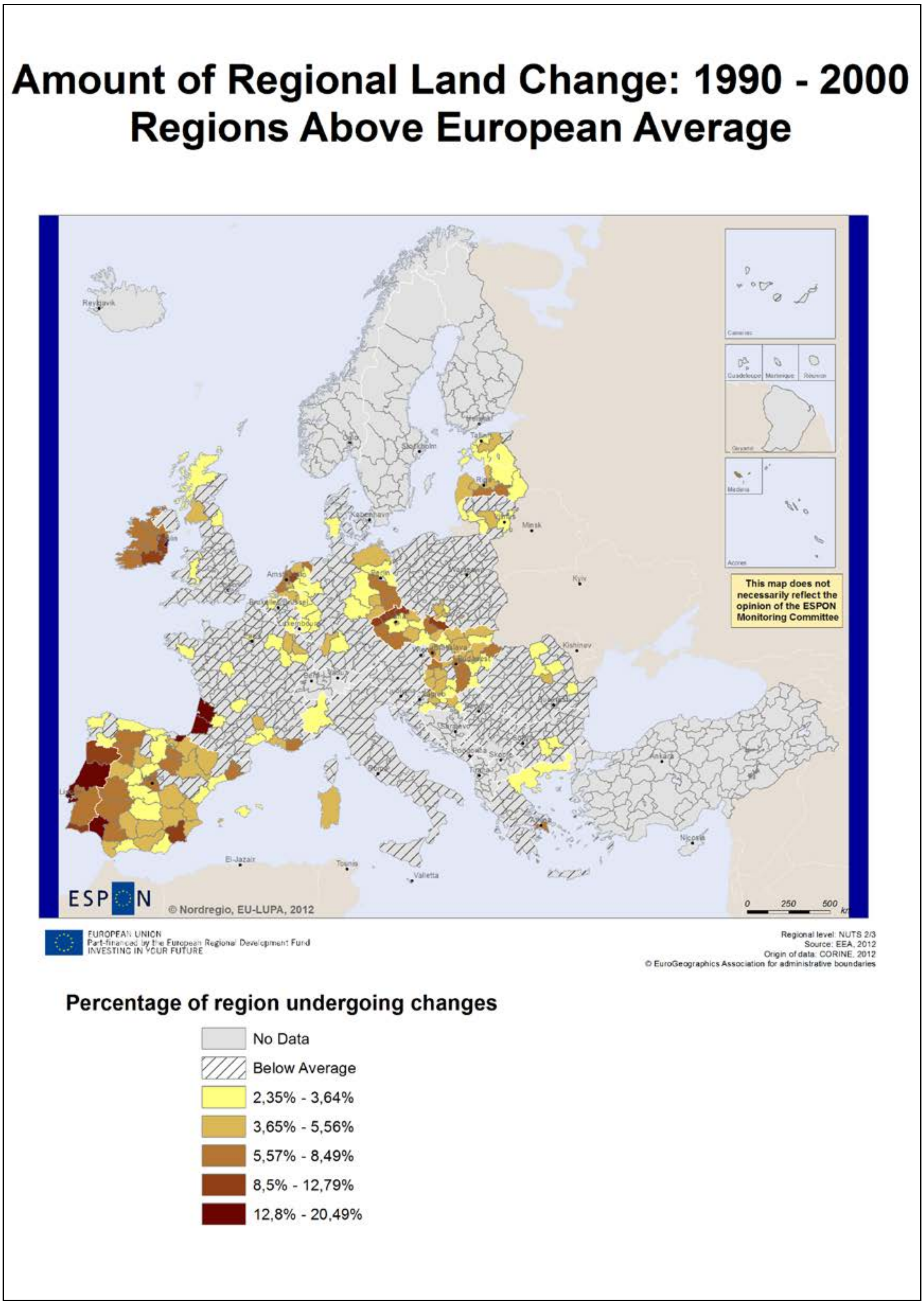
Map 4 Map 5 and Map 6 emphasize regions where the percentage of change is above the European average for each time period. When scrutinizing the maps it is important to keep in mind that not all countries and regions are represented throughout the 16-year time span from 1990 to 2006. This limits the opportunities for general interpretations regarding changing patterns between the 1990-2000 and 2000-2006 time series'.

Nevertheless, within the entire 16-year time period it is notable that some very significant levels of land change have taken place - in some regions almost 30% of the total area has reported change. The spatial distribution of these changes is also quite territorialized, where vast changes are especially evident in areas such as Spain, Portugal, the Czech Republic, The Netherlands and Ireland. What will be very interesting is to determine the socio-economic and environmental contexts of changes in these different national and regional contexts. This will be drawn out by investigating the intensity and types of changes that define these volumes.

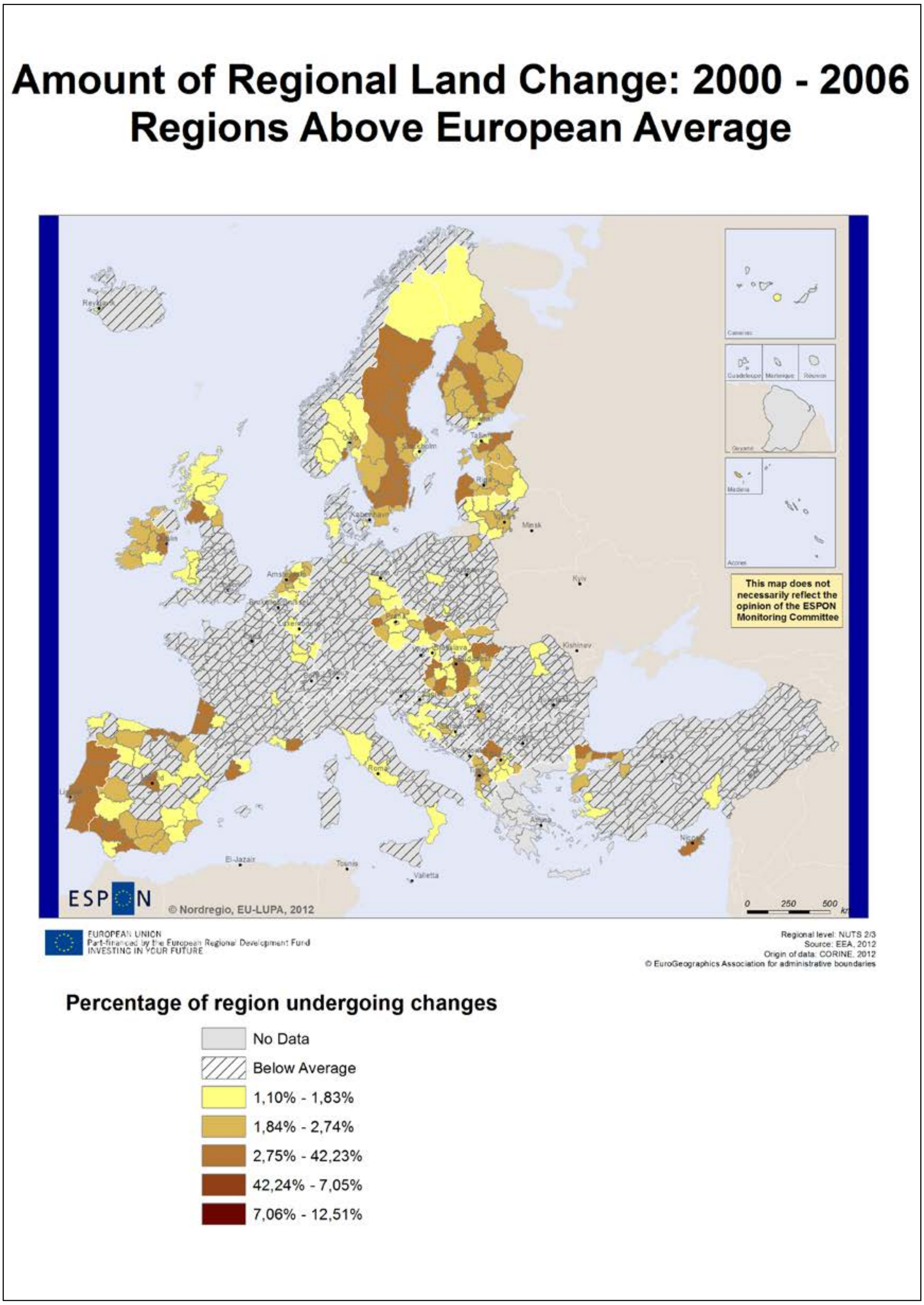
Some of the most significant changes between 1990 and 2000 took place on the Iberian Peninsula. Starting with the agrarian reforms taking off during the 1970's and culminating in the late 1980's, the changes are, in part, likely due to the ascension of Spain and Portugal to the EU in 1986. This resulted in a process where the former agricultural structure was broken up and in many places turned into more intensive forms of production. Also the land ownership reforms in Eastern Central Europe during the 1990s resulted in marked changes, a process which was further fuelled by the expectations regarding future membership of EU in the period up to and after the membership in 2004. These are important observations because they highlight the types of changes that can be expected by current or future candidate countries.



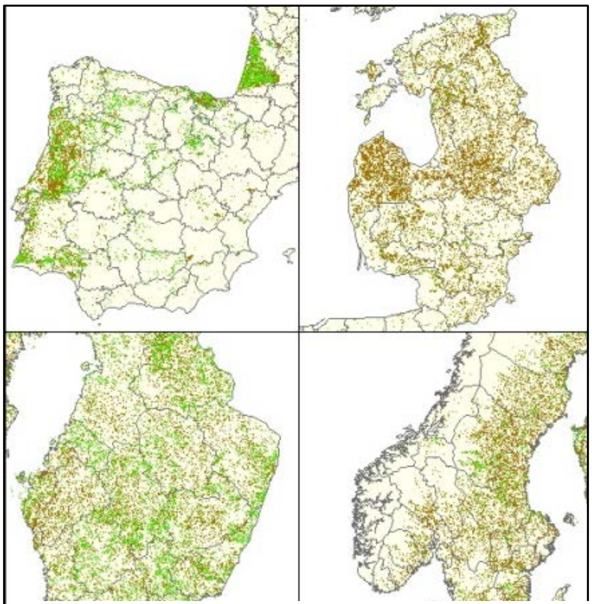
Map 4 Regions with cumulative land cover change that is above the European Average – 1990-2006



Map 5 Regions with cumulative land cover change that is above the European Average – 1990-2000



Map 6 Regions with cumulative land cover change that is above the European Average – 2000-2006



Map 7 Selected areas showing land forest land cover changes. Areas in green reflect afforestation while areas in brown reflect recent felling. Clockwise from top-left: Iberian Penninsula and Latvia/Estonia (CLC 1990-2006), as well as Sweden/ Norway and southern Finland (CLC 2000-2006)

Similar changes are not yet observed regarding the Balkan countries as discussions and uncertainties regarding membership in 2007 did not provide the same expectations. Therefore more limited changes during the 2000-2006 period are noted.

Returning the Iberian Penninsula, the conversion of agricultural and forest land are the primary drivers of land change. Forest conversions are particularly notable throughout Portugal and in northern Spain where a steady balance of land into and out-of forested land covers is notable (EEA, 2011). This is in fact an essential element to consider when investigating overall land cover changes in Europe.

As reflected in Map 7, the overwhelmingly dominant driver of land cover changes by area is related to the transition of forests. This is mainly due to on-going logging activities, but also includes land being set aside for a return to natural land cover. In terms of the former, forest areas are classed as CLC 23-25 (Forests), however after they are logged they become CLC 29 (Transitional Woodland and Shrub) before eventually return to forested areas. Without such and understanding of this formidable driver of land change, regions in countries where forest activities are present would appear to have a dynamic, less-stable land cover situation. As a consequence, an otherwise continuous land use process will appear as regions showing significant change during individual snapshots of time.

As shown in Map 7, the production cycle of many decades or even centuries related to forestry is responsible for a substantial part of the major changes registered in for instance Sweden and Finland, but also in Latvia, Estonia, Portugal, Spain and southwest France (See 2000-2006 time period below). It is also very interesting to see the different stages of the felling-afforestation-re-felling transformation cycle the four regions appear to be situated. While a relative dominance of afforestation appears to be taking place on the Iberian Peninsula and in southern Finland, recent felling appears as dominant in southern Sweden and especially in Latvia. It is clear that situations with continued felling without a balance of afforestation are an unsustainable land cover trend.

Yet all things considered, the most dramatic land change process taking place in Europe is predominantly driven by Europe's path of socio-economic development, which is taking place due to globalization and its effect on the global division of labour. The result has been the continued decline of land-based economic production – i.e. agriculture, forestry, mining and quarrying, etc. – in favour of knowledge-intensive, innovation-driven and service-based economies on the other hand. And this is where the notion of intensity adds to the understanding of processes and mechanisms behind land changes.

3.2 Land Use Change Intensity

Method

Land use intensity is the degree of human intervention caused by activities taking place on a given parcel of land. This quantitative assessment is created based on the inference that the ordering of the CLC classes – from CLC 34 – Glaciers and Perpetual Snow to CLC 1 – Continuous urban fabric – are representative of an increasing level of land use intensity. As shown in the column “intensity code” in Table 2, 34 of the 44 CLC classes are assigned an intensity score, with the score of 1 being the most intensive. This ordering is based on a conservative set of guidelines assumptions that that are used to reinforce the plausibility of scoring land use intensity through the CLC classification hierarchy in lieu of additional validation. According to the ranking in Table 2:

- CLC classes between 35 and 44 (Wetlands or Water bodies) have not been considered in the analysis due to uncertainty over the associated socio-economic activities taking place on these land cover types. When scrutinized in detail the classes reveal intensities and change in intensities covering a wide span of activities. As such, these categories are not left out due to insignificance, but because changes obviously relate to other rationales than the general land cover changes.
- In total, seven intensity scales have been generated – three levels in the Artificial surfaces class and two classes in both the Agricultural areas and Forest and Semi Natural Areas classes.
- In terms of the Artificial surfaces class, Continuous urban fabric is the most intensive land cover type because it represents urban cores and centres of sub-urban areas where over 80% of the land is impervious (Bossard et al. 2000). Likewise, these are areas that are known to support a majority of economic activity in Europe, as well as being the home to a high share of the European population.

Table 2 Ranking of CLC classes based on Land Use Intensity

GRID CODE	CLC CODE	LABEL1	LABEL2	LABEL3	Intensity Code
1	111	Artificial surfaces	Urban fabric	Continuous urban fabric	1
2	112	Artificial surfaces	Urban fabric	Discontinuous urban fabric	3
3	121	Artificial surfaces	Industrial, commercial and transport units	Industrial or commercial units	2
4	122	Artificial surfaces	Industrial, commercial and transport units	Road and rail networks and associated land	2
5	123	Artificial surfaces	Industrial, commercial and transport units	Port areas	2
6	124	Artificial surfaces	Industrial, commercial and transport units	Airports	2
7	125	Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites	2
8	126	Artificial surfaces	Mine, dump and construction sites	Dump sites	2
9	127	Artificial surfaces	Mine, dump and construction sites	Construction sites	2
10	141	Artificial surfaces	Artificial, non-agricultural vegetated areas	Green urban areas	3
11	142	Artificial surfaces	Artificial, non-agricultural vegetated areas	Sport and leisure facilities	3
12	211	Agricultural areas	Arable land	Non-irrigated arable land	4
13	212	Agricultural areas	Arable land	Permanently irrigated land	4
14	213	Agricultural areas	Arable land	Rice fields	4
15	221	Agricultural areas	Permanent crops	Vineyards	4
16	222	Agricultural areas	Permanent crops	Fruit trees and berry plantations	4
17	223	Agricultural areas	Permanent crops	Olive groves	4
18	231	Agricultural areas	Pastures	Pastures	5
19	241	Agricultural areas	Heterogeneous agricultural areas	Annual crops associated with permanent crops	5
20	242	Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns	5
21	243	Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation	5
22	244	Agricultural areas	Heterogeneous agricultural areas	Agro-forestry areas	5
23	311	Forest and semi natural areas	Forests	Broad-leaved forest	6
24	312	Forest and semi natural areas	Forests	Coniferous forest	6
25	313	Forest and semi natural areas	Forests	Mixed forest	6
26	321	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands	7
27	322	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Moors and heathland	7
28	323	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophyllous vegetation	7
29	324	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Transitional woodland-shrub	6
30	331	Forest and semi natural areas	Open spaces with little or no vegetation	Beaches, dunes, sands	7
31	332	Forest and semi natural areas	Open spaces with little or no vegetation	Bare rocks	7
32	333	Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas	7
33	334	Forest and semi natural areas	Open spaces with little or no vegetation	Burnt areas	7
34	335	Forest and semi natural areas	Open spaces with little or no vegetation	Glaciers and perpetual snow	7
35	411	Wetlands	Inland wetlands	Inland marshes	N/A
36	412	Wetlands	Inland wetlands	Peat bogs	N/A
37	421	Wetlands	Maritime wetlands	Salt marshes	N/A
38	422	Wetlands	Maritime wetlands	Salines	N/A
39	423	Wetlands	Maritime wetlands	Intertidal flats	N/A
40	511	Water bodies	Inland waters	Water courses	N/A
41	512	Water bodies	Inland waters	Water bodies	N/A
42	521	Water bodies	Marine waters	Coastal lagoons	N/A
43	522	Water bodies	Marine waters	Estuaries	N/A
44	523	Water bodies	Marine waters	Sea and ocean	N/A

- CLC classes 3-9 (Industrial, Commercial and Transport Units or Mine, Dump and Construction Sites) are ranked in second place because they classify land that is highly manipulated and related directly to meeting the needs of socio-economic production.
- CLC classes 2 and 10-11 represent the third most intensive urban type. Class 2 – Discontinuous urban fabric – accounts for land where vegetated areas that cover between 20-70% of the land surface (Bossard et al. 2000). It therefore represents transitional, suburban areas between cities and the rural hinterland where the intensity of human intervention is reduced relative to Continuous urban fabric. Green urban areas and Sports and leisure facilities are also included in this group. These are areas of increased protection compared to more intensive urban classes, but are still more intensive than agricultural or forest land due to their proximity to urban areas, and thus heightened contribution to social functions.
- Agricultural classes are, for the most part, grouped together because it is is very difficult to differentiate agricultural intensities due to regional topographical, territorial, cadastral and economic (land value) conditions, which are strong drivers determining agricultural land structure (see Gabrielsen, 2005). The only distinction that has been made within the 11 agricultural classes is where the land classes in the groups Arable

land and Permanent crops are allocated an intensity score of 4 and Pastures and Heterogeneous Agricultural areas are given a score of 5.

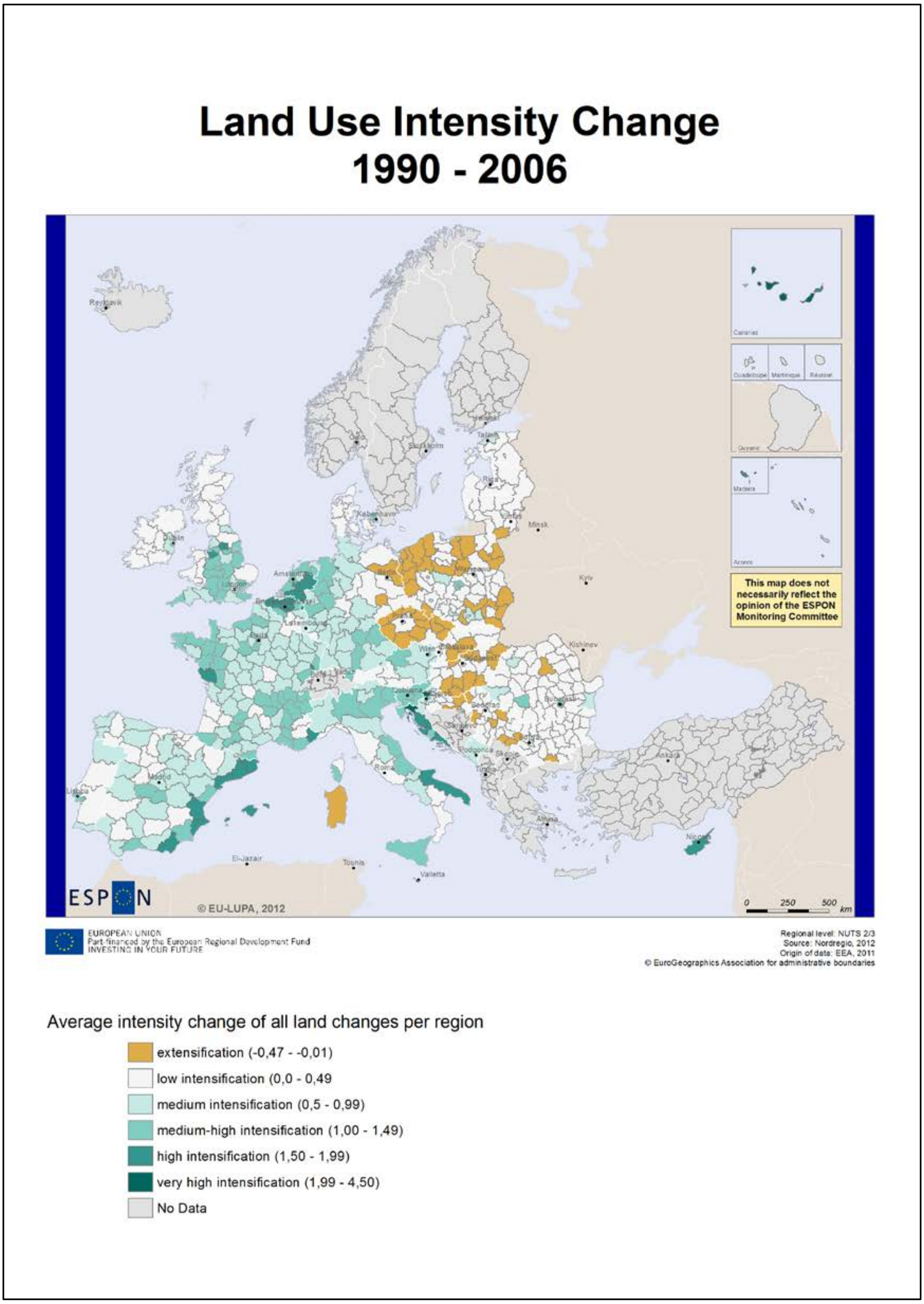
The rationale behind this distinction is that the former group is indicative of agricultural areas that are strictly dedicated to food production through cropping. In agricultural terms this is characterized as an intensive activity demanding high inputs, especially fertilizer, water, labour and management (Gabrielsen, 2005). In contrast, the latter group is representative of a mosaic of agricultural activity with a generally lower level of intensity. For instance, by area, Pastures is a dominant CLC class in this group, and is an activity characterized as being relatively low-input (Gabrielsen, 2005). Agricultural areas with significant areas of natural vegetation and Agro-forestry Areas are included in the latter group, which further indicative of a pattern of reduced land use intensity.

- The 11 Forest and Semi-natural Areas classes are broken down into two groups, with CLC classes 23-25 and 29 having a score of 6 and the remainder having a score of seven. The reason for prioritizing the first group of classes is that they represent an economic production dynamic in the forest sector; where harvested forest areas are next classified as Transitional Woodland-shrub. By area, this is by far the most prevalent land cover transition that takes place in Europe. The remaining classes encompass landscapes either covered by vegetation without a specific production potential or by little or no vegetation as all. In turn, they are essentially natural landscapes with minimal prospects for substantial human intervention.

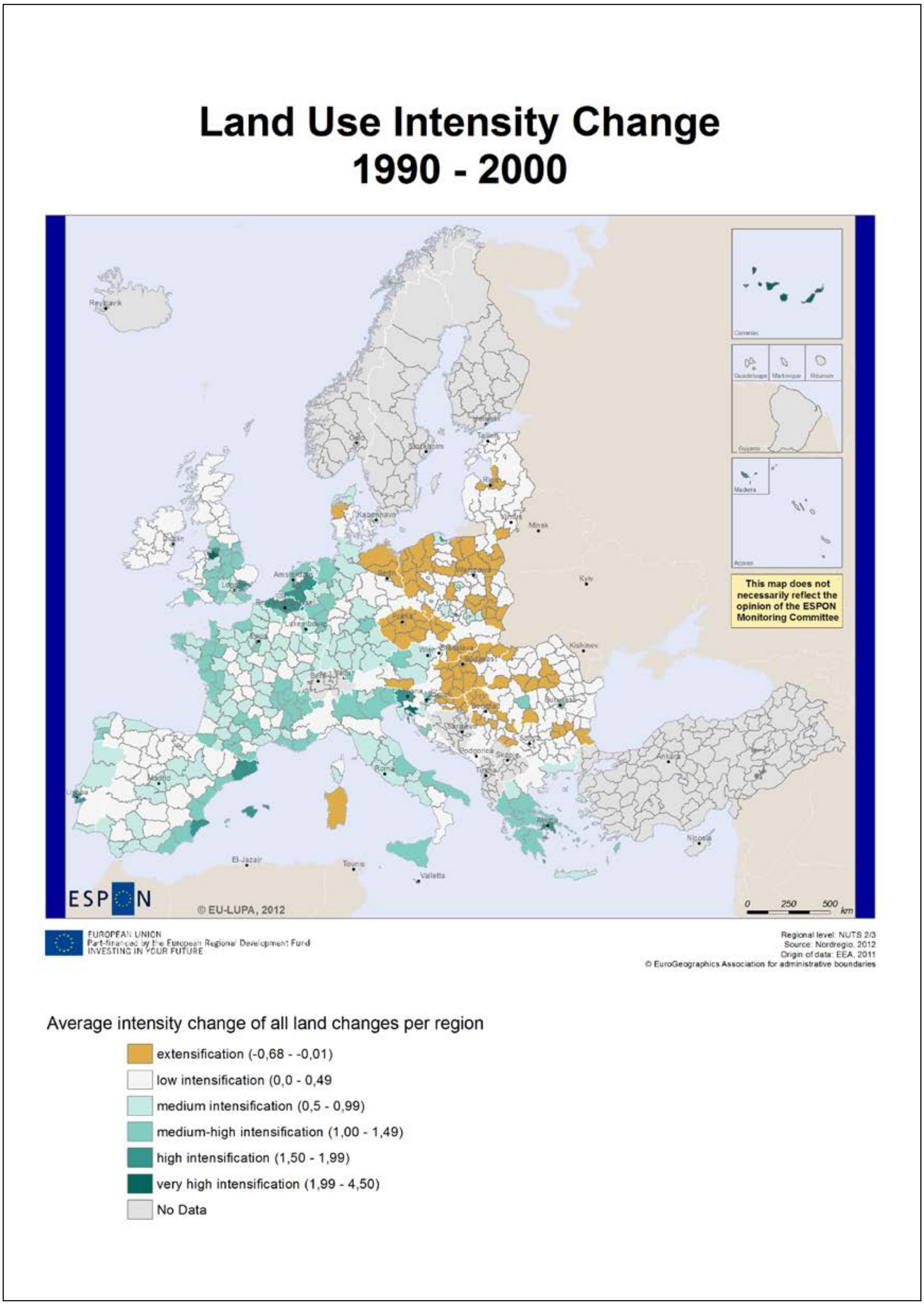
The utility of ranking CLC classes according to intensity allows for the possibility to assess land changes in terms of intensification or extensification of land use. To achieve this, all land changes are accounted based on the consumption intensity score (what the land changes from) and the formation intensity score (what the land changes to). By subtracting the intensity score in the latter year from the intensity score from the former year the intensity score of each land change is determined. For example, a change from Natural Grassland (CLC class: 26, intensity score: 7) to an Airport (CLC class 6, intensity score 2) is an intensification of five. Likewise, a change from Pastures (CLC class 18, intensity score: 5) to Natural Grassland (CLC class 26, intensity score 7) is and extensification of negative 2.

The average intensity score for all changes in each NUTS2/3 regions then provides the regionalized land use change intensity. This does <u>not</u> consider the size (area) of the change, only the change of intensity.

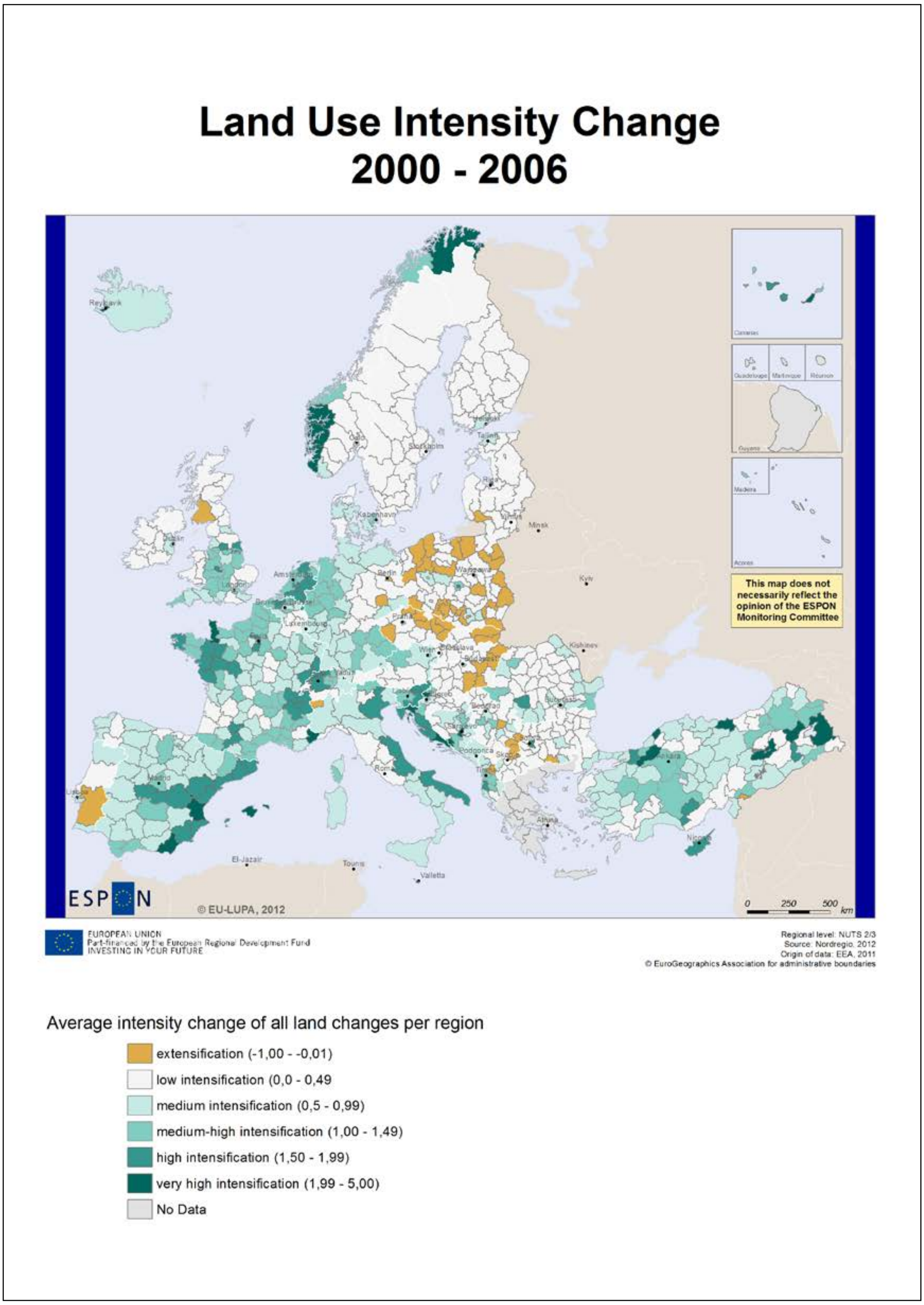
Access to CLC data provides an unparalleled amount of information on the characteristics of land use in Europe, including the patterns and processes and quantities of land change. While the quantity of land change was introduced in the previous section, the advent of the land use intensity concept allows for a characterization how land change processes affect the magnitude of human intervention on the landscape; or in other words, how intensively the land is being used.



Map 8 Land use intensity change – 1990-2006



Map 9 Land use intensity change – 1990-2000



Map 10 Land use intensity change – 2000-2006

Each of the three maps below (Map 8 Map 9 Map 10) show the regional change of land use intensity, where the changes in regions in white are characterized as relatively stable. In these regions, a relatively high number of changes taking place are between CLC classes grouped with the same, or nearly the same, intensity score. As such, it is likely that drivers of land change processes– urbanization or industrial change for instance – have either already taken place, are not yet taking place or are not likely to take place at any point in the near future.

Regions in deepening shades of green are undergoing land changes that cause increases in the socio-economic intensity of land use - toward increased property values and growth of urban areas (artificial surfaces)[5]. Conversely, shades of brown indicate regions where reductions of the intensity of land use are incurred by land changes. In reality, this situation could be due to economically driven processes where activities are no longer profitable, or where policies have had an effect on land use.

In terms of intensifications, in 1990, 4.1 % of the EU territory was classified as artificial surface – a share that increased to 4.4 % (an 8.8 % increase) by 2006. Even more telling is that the European population grew by only 5 % in the same time period (Prokop et al. 2011). This 3.8% differential represents an increased per capita land take as a result of the demand for newer and bigger housing, more roads, and growth of business locations; each of which represents the effect of development on the European landscape.

However, national or regional performance for limiting the extent of artificial surfaces cannot simply be judged based on total area or percentage of growth, especially over such a short window of time as 1990-2006. One issue is that the development of sealed surfaces is path dependent on socio-economic positioning and comparing rapidly developing regions against already established ones would be short-sighted and unfair to those regions that are "catching-up". Established regions have already undergone this process, it's just that they have done so in the decades or centuries prior to 1990.

Another issue is that the percentage of artificial surfaces in a given region is highly related to population density. As such it is not surprising that Member States with the highest rates of intensification include ones with regions that are relatively small in area but include relatively large urban areas.

But in terms of per capita urban land take – which is a much more relevant indicator in terms of measuring efficiency or performance of land - the main influences are the existence of second homes, large touristic infrastructures and a dispersed settlement structure. Relatively large shares of second homes are notable to varying degrees in the Mediterranean regions, as well as in Finland, Estonia, Denmark and Sweden, often tied to coastal or mountainous areas where former small scale primary sector activities (fisheries, farming, forestry) have been or are in decline. Meanwhile, extensive touristic infrastructure coupled with a very high average population density is the driver of such a high degree of urban land take in Malta and coastal zones especially around the Mediterranean Sea.

Some of the highlights noticeable in Map 8 Map 9 Map 10 include:

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[5] Artificial surfaces and soils surfaces are taken to be synonymous with urban or settlement areas. The only difference is that the former is determined by remote sensing while the latter is defined by spatial planners (Prokop et al. (2011).

- There is a clear east-west dimension in each of the maps. Large volumes of land use extensification are almost exclusively found in Eastern European member states; particularly in Poland, The Czech Republic and Hungary. This pattern is very dominant in the 1990-2000 period but continues in 2000-2006 as well.
- High volumes of land use intensification are especially notable in countries such as The Netherlands, Brussels, Spain, Portugal and Croatia. In Spain, this is especially evident for regions along the south and east coast as well as the island regions. On regional/territorial level it is evident that intensification is associated with the growth (sprawl) of urban areas and their associated artificial surfaces. But furthermore – and in a very high degree in, for instance in Portugal, Spain and other Mediterranean areas, the issue of ownership reforms and characteristics of land tenure are a driver of intenisfication. This issue will be dealt with in more detail in relation to the identification of land change hotspots. Intensification also appears to take place in a greater degree for coastal regions (cf. in Spain, France, Croatia). It is possible that this pattern is related to the growth of the coastal tourism in these regions, but additional validation is necessary.
- In the Czech situation it is interesting to point out the seemingly high degree of rural extensification being countered by urban-related intensification in the capital region of Prague. Further, when comparing the 1990-2000 and the 2000-2006 results (Map 8 and Map 9), even while taking into account the much larger time span in the former time period) it appears that extensification processes have slowed for the country as a whole. EEA country analyses show that the main driver of extensification has been the conversion of different crop areas into land for pasture. This is a process which has been driven by national policy that uses subsidies to encourage the grassing of arable and extensive grassland management.

  The shift from 1990-2000 to 2000-2006 also relates to changes in mobility, where halted subsidies for dwellings and an increase of suburbanization have been influential on the slowing down and decline in extensification (Vobecká 2010), an issue which is dealt with further in connection with the Land Change Hotspots. In the 2000-2006 (Map 9) time series from very significant intensification is especially notable in particular regions of Norway. These are regions that, based on Maps 1-3, we know have undergone relatively little amounts of land change (by area); however the changes that have taken place were very intensive. This is due to the development on intensive mining, hydrocarbon extraction and other heavy industrial activities in rural and remote locations. Interestingly, these intensifications are not taking place in parallel with extensification of other land covers in these areas, which indicate that these are "new" economic activities that are taking place on previously stable and unchanged land.
- Quite high rates intensification is notable for many regions in Spain in all three time series. The highest levels of intensification have taken place for coastal regions along the Mediterranean and for the island regions. This is clearly related to the growth of artificial surfaces in urban areas. CLC flow data and EEA land cover analysis (EEA, 2011) indicates that much of this intensification is due to the sprawl of economic sites and

infrastructures (which both construction areas and transport infrastructure are grouped).

- For agricultural withdrawal, abandonment processes have been most pronounced in the central-south and north-east regions of Hungary (between 2000 and 2006), on the Italian island of Sardinia (between 1990-2000), and in Ireland southern Portugal to differing degrees throughout the 1990-2006 period.

3.3 Validation of the intensity concept

Due to the fact that the land use intensity concept is a novel approach for the EU LUPA project, it is crucial to validate it by comparing the scale of intensity score for the CLC classes directly to indicators of socio-economic performance. Here, two major socio-economic characteristics – population density and GDP – are useful indicators in relation to the two major dimensions of human activities.

The presence of greater concentrations of people (population density) is quite clearly indicative of higher land use intensity. This impacts land especially through the development of artificial surfaces in order for people to establish their everyday lives and routines in space. As mentioned, the desire for increased living and recreation space reiterates that increased population in a given area creates more intensive land use – which through the creation of impervious surfaces reflects the complete manipulation of land. However, an underlying problem in relation to population density being an optimal indicator of social intensity is that individuals are only registered in one location, usually characterized as place of residence. But for most people their activities are not only related to the land in and around this place; for instance, suburb residents within commuting distance to larger towns or cities who therefore have their daily activities tied to different places. And in connection with vacations, second homes or visits to parks where several locations are involved.

GDP is also a good indication of land use intensity because of the safe assumption that increasing economic output is equal to situations of greater land intervention. This is not only placed in terms of land-based production but also incorporates the role of urban areas as areas of relatively high economic output. However, one of the problems in relation to GDP being a perfect indicator of intensity is that economic outcome of the land use activities may not always be registered where the economic activity takes place. For instance, the registration of the economic outcome of production from a factory may depend on the accounting system, i.e. whether it is registered where the production takes place, where the workforce is living, or where the central office of the factory is situated. Similarly the energy outcome of a windmill may be registered where it is situated or where the owner of the mill is residing.

In many cases population density and GDP indicators can be considered as measures basically showing the same issue – intensity of human activities. There is, however, an important potential territorial distinction between them: While population density shows a continuous presence of humans involved in the use of the land either for production or reproduction related activities, the GDP indicates human exploitation of land which does not necessarily require such a continuous presence, or showing that even a low level of population density may result in an intensive use of the land. This is for instance shown in rural areas where high levels of GDP are maintained in situations with declining population because a continuous intensification in land use is taking place through the replacement of manpower by technology. Accordingly, it is valuable to utilize both indicators in this validation exercise.

Overall intensity relations

By intersecting the gridded distribution of CLC classes with regional boundaries a regional average of land use intensity has been calculated at the NUTS2/3 level. This allows for the simple correlation between intensity and the GDP and Population Density. This is shown by the correlation coefficients in 2000 and 2006 respectively results in Table 3 below. It is important to emphasize that even though the numbers may be seen as low, they are significant ($p<.0001$).

As shown in the column (Number of regions) not all Member States have provided sufficient GDP and Population density data to Eurostat. As such, only those regions providing aggregated data on intensity, GDP and Population density have been included in the analysis. In all cases the correlations are clearly statistical significant ($p<.001$), and the differences between the two years, 2000 and 2006, are very small, showing that it is not so much the absolute levels – GDP in 2006 considerably larger compared to 2000 – but the regional differentiation that is important. The correlation coefficients are negative due to the fact that high values for intensities actually indicate the least intensive land covers (Open spaces with little or no vegetation=7) while low levels indicate high intensities (Continuous urban fabric=1).

Table 3 Correlation between intensities and GDP and Population Density in 2000 and 2006

Pearson Correlation Coefficients Prob>|r| under H0: Rho=0			
	Correlation Coefficient between intensities and:	**Probability of rejection**	**Number of regions**
GDP 2000	-0,2113	<0,0001	674
GDP 2006	-0,23137	<0,0001	604
Population Density 2000	-0,38166	<0,0001	618
Population density 2006	-0,38012	<0,0001	648

Population Density: The level of correlation is generally much higher in relation to population density compared to GDP, for instance being at a level of -0,38012 for Population density in 2006 while it is -0,23137 for GDP in 2006. This relates to the fact that even changes in demographic parameters may differ across regions, they are much more stable over time (compared to shorter term changes in economic performance), and in this context, are primarily influenced by the territorial characteristics connected to urban versus rural structures. Even though mobility influences the population densities the changes are rarely short term and abrupt to an extent that will be able to result in marked changes within the time frames we are talking about here. Consequently regional variations are less tied to national settings and more to regional characteristics, which obviously show through a higher regional correlation.

Gross Domestic Product: In contrast, regional economic performance is fluctuating much more because it is influenced by long term as well as short term changes where only a portion of capital is fixed, and therefore is less bound to specific territories. As a consequence the national setting – and thereby the more recent history – results in differences between nations which tend to fluctuate to a greater degree that population density. This results in differences in national levels which in the end show as lower level of correlation at the regional level.

Elimination of national differences

As a consequence of the influence of national differences in GDP between EU countries the elimination of these differences is necessary in order to enable a more precise comparison between regions. A simple way to do so is by calculating national indexes for the parameters where such national differences exist. National averages of GDP in 2006 have been calculated, and by dividing each of the regional GDP values in 2006 by the national average an index value is generated. These index values are then used instead of the original GDP values in order to show more comparable regional variations in GDP.

A transformation procedure has been applied in relation to Population density as well. Due to the very large differences in population density between urban dominated and rural dominated regions, the densities have been re-calculated by a logarithmic function (log10) whereby a data structure resembling a linear structure is achieved.

Table 4 Overview of intensities and original and re-calculated values for GDP and Population Density in 2000 and 2006. The average intensity of each prevailing land use type is shown in column 1, the original averages in GDP in 2000 and 2006 are shown in columns 2 and 4, just as the original averages of population densities in 2000 and 2006 are shown in columns 6 and 9, the calculated index values for all four values are shown in columns 3, 5, 8 and 11. Finally, the logarithmic re-calculation of the population densities is shown in columns 7 and 10. The use of colors (red-yellow-green are used to rank the values in each column.

Intensity and regional socio-economic parameters - GDP and Population density - in 2000 and 2006												
	1	2	3	4	5	6	7	8	9	10	11	12
Land types	Intensity	Intensity index	GDP in 2000	Regional Index GDP in 2000	GDP in 2006	Regional Index GDP in 2006	Population density 2000	Log10. Pop density 2000	Regional Index Pop. Density 2000	Population density 2006	Log10. pop density 2006	Regional Index Pop. Density 2006
01, Urban cores and metropolitan areas	3,80	0,79	23 874	1,75	31 621	1,74	5 207	3,72	11,26	5 077	3,71	10,37
02, Suburban areas	4,51	0,95	19 707	1,05	24 600	1,07	638	2,80	1,56	657	2,82	1,55
03, Suburban or peri-urban areas	4,80	0,99	22 228	1,24	29 037	1,20	856	2,93	4,47	832	2,92	4,02
04, Arable land in peri-urban and rural areas	4,43	0,91	10 019	0,96	15 150	0,87	122	2,08	0,36	120	2,08	0,34
05, Arable land and pastures in predom, rural	4,69	0,96	11 035	0,91	15 752	0,92	115	2,06	0,40	115	2,06	0,37
06, Rural arable with perm, crops and forest	5,01	1,01	9 115	0,91	12 079	0,91	107	2,03	0,55	108	2,03	0,55
07, Rural mix dom, by pastures with arable	5,03	1,03	19 184	0,95	24 120	0,93	121	2,08	0,31	129	2,11	0,34
08, Rural pastures and complex cult, patterns	5,36	1,08	16 919	0,86	20 650	0,87	62	1,80	0,16	63	1,80	0,15
09, Diverse land use in rural areas	5,29	1,03	12 067	1,04	18 795	1,01	103	2,01	0,87	105	2,02	0,84
10, Diverse rural forest intersected by other	5,55	1,07	10 427	0,98	14 801	0,96	109	2,04	0,59	110	2,04	0,57
11, Arid mixed forest	5,46	1,04	11 355	0,97	18 818	0,99	73	1,86	0,50	105	2,02	0,56
12, Sparse vegetation with forest and pasture	4,48	0,87	5 081	0,80	20 120	1,05	72	1,86	0,51	79	1,90	0,49
13, Rural (Northern) forest	5,22	1,03	25 044	1,01	30 904	1,02	17	1,23	0,40	17	1,23	0,38
14, Sparsely vegetated areas	3,47	0,81	na	na	na	na	13	1,10	0,14	13	1,12	0,14

Table 5 Overview of intensities and original and re-calculated values for GDP and Population Density in 2000 and 2006

	Intensity	GDP in 2000	Regional Index GDP in 2000	GDP in 2006	Regional Index GDP in 2006	Population density 2000	Log. Pop density 2000	Regional Index Pop. Density 2000	Population density 2006	Log pop density 2006	Regional Index Pop. Density 2006
Intensity	1,000										
GDP in 2000	-0,185	1,000									
Regional Index GDP in 2000	-0,576	0,617	1,000								
GDP in 2006	-0,346	0,888	0,639	1,000							
Regional Index GDP in 2006	-0,652	0,521	0,945	0,674	1,000						
Population density 2000	-0,473	0,481	0,944	0,552	0,956	1,000					
Log. Pop density 2000	-0,226	0,389	0,838	0,413	0,810	0,791	1,000				
Regional Index Pop. Density 2000	-0,435	0,525	0,971	0,609	0,974	0,975	0,836	1,000			
Population density 2006	-0,472	0,481	0,944	0,552	0,956	1,000	0,793	0,975	1,000		
Log pop density 2006	-0,212	0,374	0,834	0,409	0,812	0,787	0,998	0,831	0,789	1,000	
Regional Index Pop. Density 2006	-0,434	0,524	0,971	0,607	0,976	0,977	0,838	1,000	0,977	0,834	1,000

Correlations of intensities of Types of Prevailing Characteristics and the socio-economic parameters

In order to take advantage of the adjusted data and the distribution of values on the land use types, a more detailed correlation analysis is required. This correlation matrix is shown in Table 5 and some very substantial improvements in correlations have been the result of the new calculations. First and foremost: The correlation between Intensity and the indexed GDP in 2000 and 2006 has increased to -0,576 and -0,652 respectively, which is very substantial. The indexing procedure has eliminated the fact that national levels of GDP in both years have differed substantially due to many reasons, for instance level of industrialization, technological development, level and time of involvement in EU etc. And the higher value in 2006 compared to 2000 is probably due to the fact that regional policies during the 6 year period – first and foremost in an EU setting and primarily in relation to recent members - has eliminated some of the regional differences which have no relation to land use intensity.

In relation to Population density an indexing of the national values does not really change anything. For population density in 2000 the correlation was -0,473 while a correlation based on indexed values actually drops to -0,435. And in 2006 the correlation changes from a correlation value based on the absolute data of -0,472 to an indexed correlation of -0,434. Again a small drop in correlation, and in both cases an illustration of what has been emphasized before, namely that settlement and population structures are changing much more slowly, so when they are aggregated at the regional level they are pretty persistent in relation to the factors which have been shaping the overall population structures during many centuries, and mostly based on production potentials of land. Even previous centuries where trade, industrialization and related infrastructural arrangements have added to the complexity of the processes determining the settlement structure, only the last century has contributed to a process where land use potentials have become less decisive in relation to the localization of human activities.

As mentioned above the re-calculation of population densities by means of a logarithmic scale seems to indicate a substantial drop in correlation with intensities, but this is due to the fact that correlations in this context are based on linear relations between the parameters. And this is of course not the case when we are dealing with logarithmic functions where a simple linear correlation relation is not to be expected, which will be shown below:

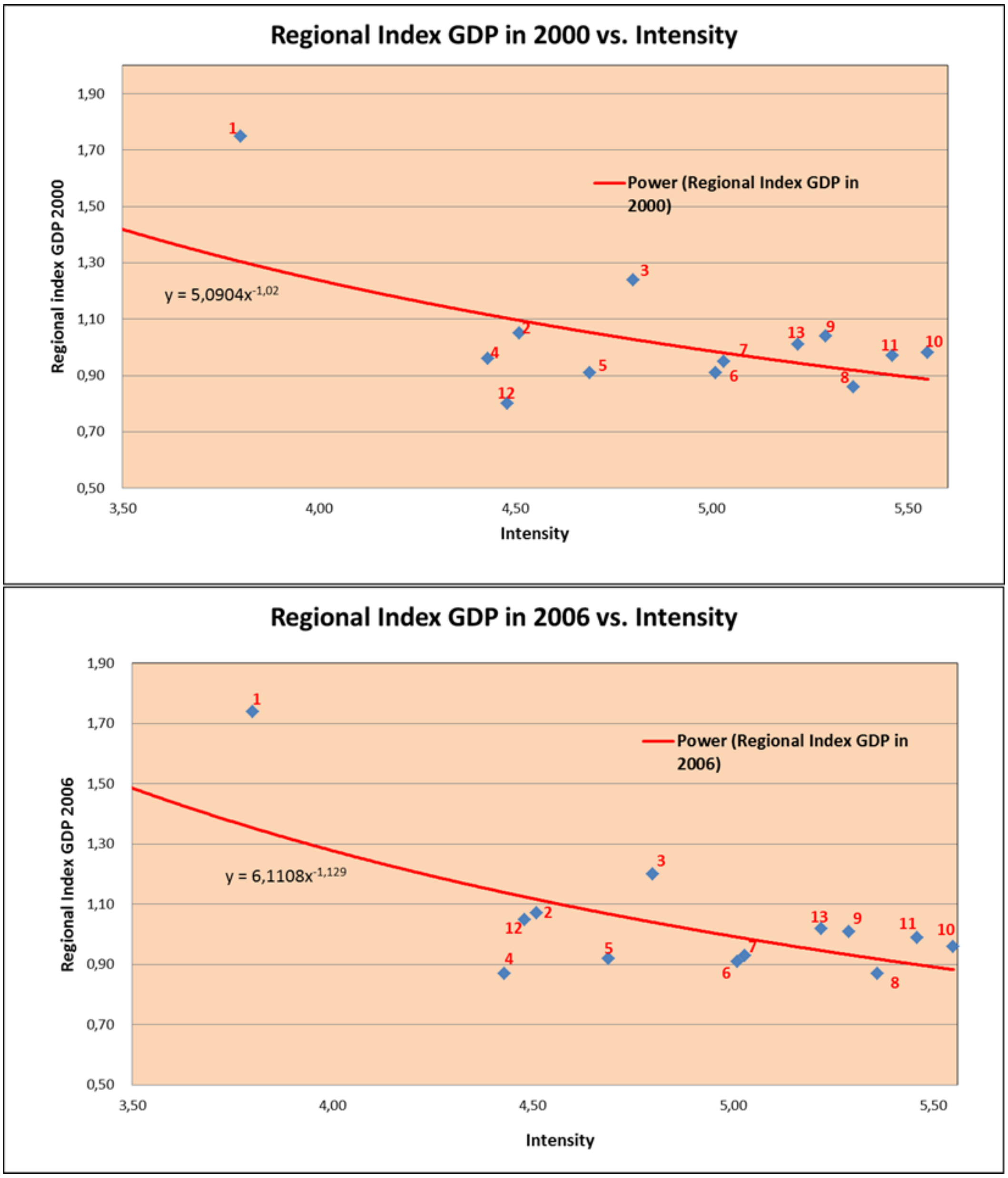


Figure 5 Graph showing relationship between Regional Index of GDP in 2000 and 2006 and calculated intensities for the types of prevailing characteristics. Each of the points have been numbered according to the land type they represent.

As indicated by the graph there is a very clear relationship between the two components: regional indexes and intensities. And, furthermore, that the line best describing the regional trend is a power function of intensity. In both years only one major outlier appears, marked on the graph by the number 1. It is he urban cores and metropolitan areas where the level of GDP deviating so much from the other land use categories that it is difficult to make it fit into the general trend. The other categories relating to urban sprawl are situated very well in the graph, still, however, representing some minor variations. For instance Arable land in peri-urban and rural areas (Land type 4) dropping from an index value from 0,96 in 2000 to 0,87 in 2006. And in the opposite direction from a low of 0,80 in 2000 for Sparse vegetation with forest and pasture (Land type 12) to a high of 1,05 in 2006.

At the same time, however, the change in trend from 2000 to 2006 show that the gap to the Urban cores and metropolitan areas is minimizing, This relates to a situation where greening of city cores and urban sprawl into adjacent areas are contributing to a more even distribution of the population in relation to land cover characteristics. While former urban sprawl has been characterized by replacement of one mono-function – typically agriculture – by another mono-function – residential areas – the present trend in relation to urban sprawl is increasingly characterized by co-existence of different land uses, which in practice means multi-functionality.

In relation to population density the graphs on Figure 6 clearly shows how the logarithmic relationship between intensity and population density generates the best fit, and the trend line therefore is exponential. There are only minor differences between 2000 and 2006, and the outliers are showing the same structure. The points are numbered according to the land type they represent, and basically only two of these are significantly deviating from the general structure. It is the regional land use types with maximum (outlier number 1) and minimum (outlier number 14) population density respectively represented by regional land use type 1 (Urban cores and metropolitan areas) and type 14 (Sparsely populated areas). The reason behind outlier 1 is similar to what was described by the GDP graphs, while outlier 2 has to do with the fact that even these regions are sparsely vegetated substantial economic activities actually takes place. Many regions in both Iceland and Norway are situated in this category, and the reason for as well high economic performance and high population density relates to the fact that a substantial part of the population are situated in the coastal regions and depending on non-land based activities. Outlier 13 is in many ways defined by the same characteristics described above, i.e. non land based activities being the major reason for both a high level of economic activities and a population density considerably lower than what would be expected due to the GDP performance.

As mentioned above it can be discussed whether the dots marked as outlier 2 and 3 actually are outliers. Both relates do urban characteristics, outlier 2 identifying regional land use type 2 (Suburban areas) and outlier 3 identifying land use type 3 (Suburban or peri-urban areas). Presently they deviate from the trend generated by the other regional land use types, but as discussed above the present trend of urban sprawl characterized by co-existence of parallel uses of land may result in a situation where the two outliers becomes parts of a general trend.

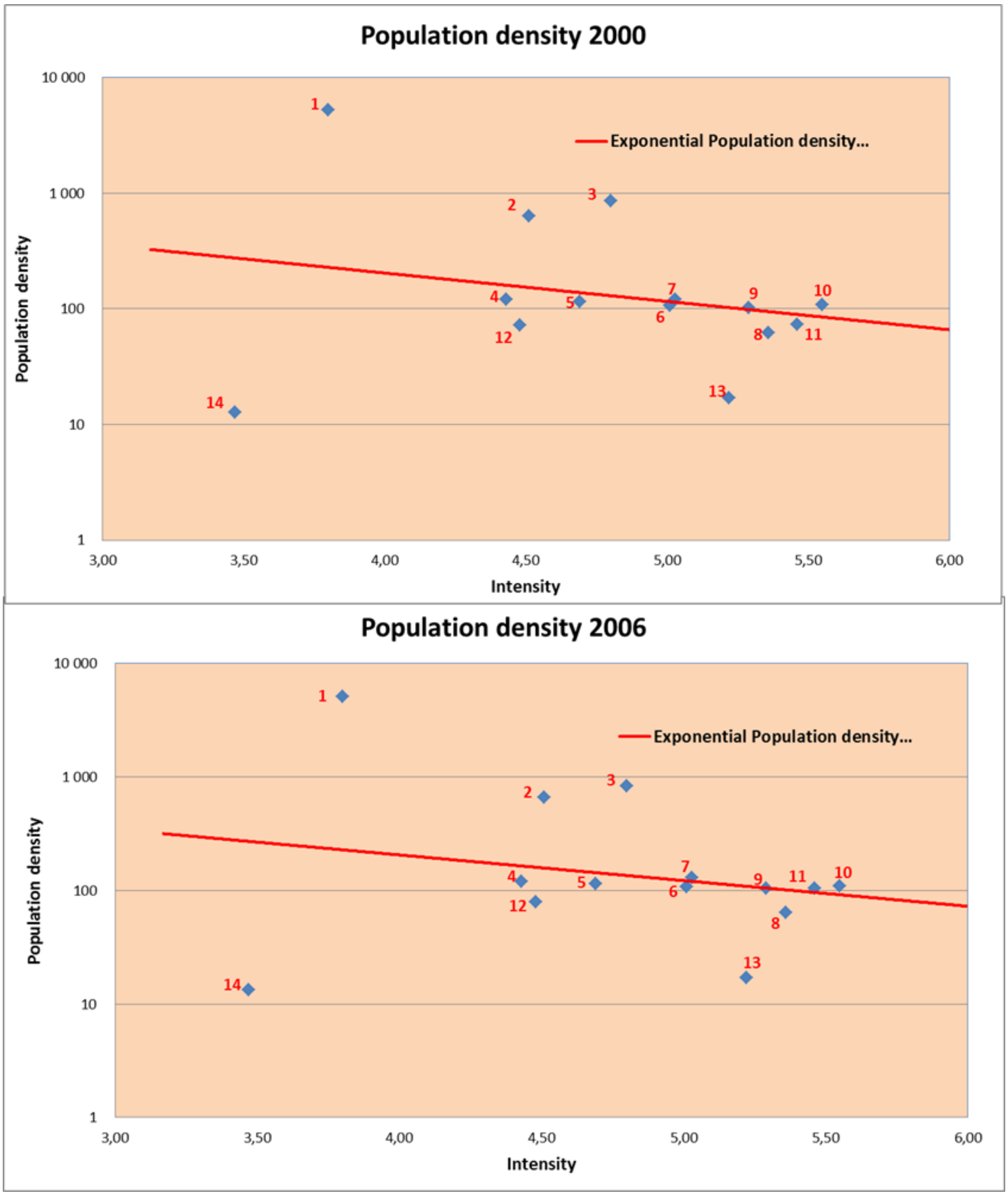


Figure 6 Graph showing relationship between Population Density in 2000 and 2006 and calculated intensities for the types of prevailing characteristics. Please note that the y-axis is logarithmic. Each of the points have been numbered according to the land type they represent

The two dimensions of intensity

As has been discussed above, GDP and Population density reflects two characteristic of intensities in relation to the use of land. It has been documented above that the intensities of land use reflected through the Land use types are clearly correlated to both population density and to GDP. It appears also that it may be relevant in situations to differentiate between them, and use the differences as an important indicator. In Table 6 the intensity has been subdivided in three categories (Low – 33%, Medium – 33%, High – 33%) where it is important to remember that high intensity means high levels of population density and economic activities and identified by low score in the Corine classification where

1=continuous urban fabric, while low intensity means low level of population density and economic activities and identified by high score in the Corine classification where 7=open spaces with little or no vegetation. The two components Population Density and GDP have been subdivided in two categories (Low – 50%, High – 50%), and are organized in the following table:

Table 6 Relations between intensity, population density, and GDP and the 14 Regional land use types.

Regional Land Use type	Intensity	Population density	GDP	Description of regional land use types
1	1. low	2. High	2. High	01, Urban cores and metropolitan areas
2	1. low	2. High	2. High	02, Suburban areas
4	1. low	2. High	1. Low	04, Arable land in peri-urban and rural areas
12	1. low	1. Low	2. High	12, Sparse vegetation with forest and pasture
14	1. low	1. Low	2. High	14, Sparsely vegetated areas
3	2. Medium	2. High	2. High	03, Suburban or peri-urban areas
5	2. Medium	2. High	1. Low	05, Arable land and pastures in predom, rural
7	2. Medium	2. High	1. Low	07, Rural mix dom, by pastures with arable
6	2. Medium	1. Low	2. High	06, Rural arable with perm, crops and forest
10	3. High	2. High	1. Low	10, Diverse rural forest intersected by other
11	3. High	1. Low	2. High	11, Arid mixed forest
13	3. High	1. Low	2. High	13, Rural (Northern) forest
8	3. High	1. Low	1. Low	08, Rural pastures and complex cult, patterns
9	3. High	1. Low	1. Low	09, Diverse land use in rural areas

By means of this table it is possible to see which of the two main socio- economic categories are dominant in explaining the intensities determined for the Regional land use types. This is an exercise that may be very useful not only in characterizing the Regional land use types, but also to locate where in Europe the major socio-economic functions have been influential on the regional land use changes.

As shown in the table, five types are characterized by either high or low intensities in both population density and GDP. The high/high categories are land use types 1, 2 and 3, with the two first being in the high intensity class while the third is in the medium intensity class. This is totally in line with what has previously been argued, with type 1 and 2 being urban categories while type 3 characterized by peri-urban functions which is a clearly mixed category with substantial land areas within areas related to agriculture, forestry, and leisure time activities being added to the suburban functions. The land use types 8 and 9 are characterizing the low/low end, with low levels of both population density and GDP, and obviously situated in the low intensity category.

In the high intensity category, three land use types are situated with either high population density and low level of GDP (type 4) or high level of GDP and low population density (type 12 and 14). As will be discussed further below, the two latter categories are situated in sparsely vegetated areas, but at the same time having large industrial complexes, mining activities, hydrocarbon extraction and similar capital intensive activities which results in the high GDP, while type 4 show a high population density, but with low level of GDP generation because these regions may serve as residential areas for nearby urban areas, but with the economy generated through activities related to arable land.

In the low intensity category the mixed types showing either high population density or high level of GDP are characterized by mixed land use types where high population density (land use type 10) are forested areas but with intersections of other rural activities, while the high level of GDP (type 11 and 13) are related to land use with high economic value but sparsely populated, for instance forestry or forest related types of crops such as olives, nuts etc.

And finally, in the medium intensity class are, besides land use type 3 mentioned above, found primarily relatively densely populated land use types (type 5 and 7) with low economic productivity, or a single type (type 6) showing relatively high economic performance from permanent crops requiring less permanent labor force, and therefore characterized by low population density.

3.4 Land Change Hotspots

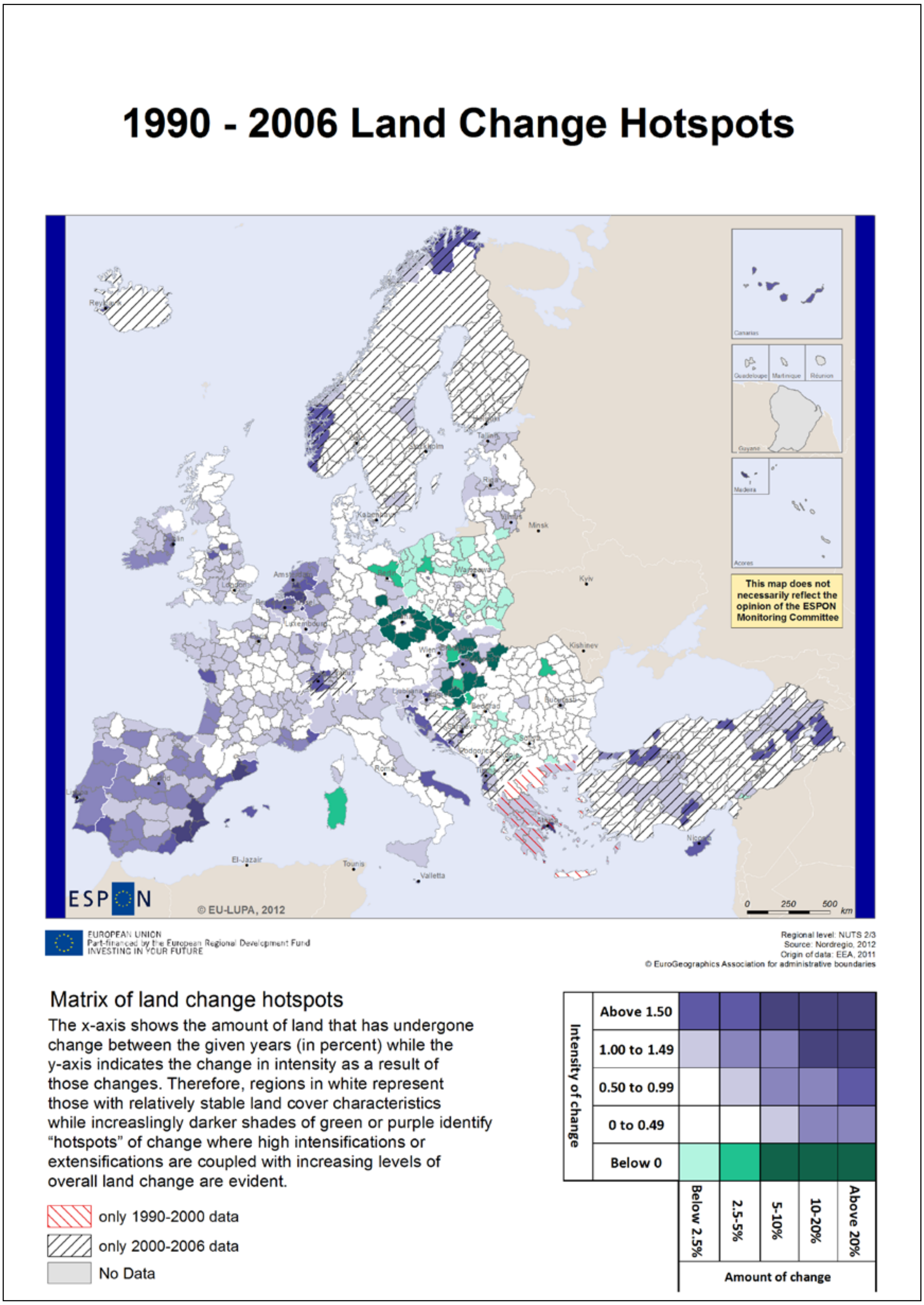
Hotspots are in this context regions characterized by change towards either intensification or extensification, and where different levels of changes in intensity are coupled with increasing levels of overall land change.

Method

The method used to determine the hotspots was to create a 5x5 matrix where land use intensity change is classed in five groups on the y-axis and the amount of regional change (in percent) is classed in 5 groups on the x-axis. Using this matrix, regions in white are considered to have relatively stable land use characteristics while increasingly darker shades of green or purple identify “hotspots” of change where high intensifications or extensifications are coupled with increasing levels of overall land change. The scales of intensification and physical change were selected based on the wish to have a simple and consistent classification.

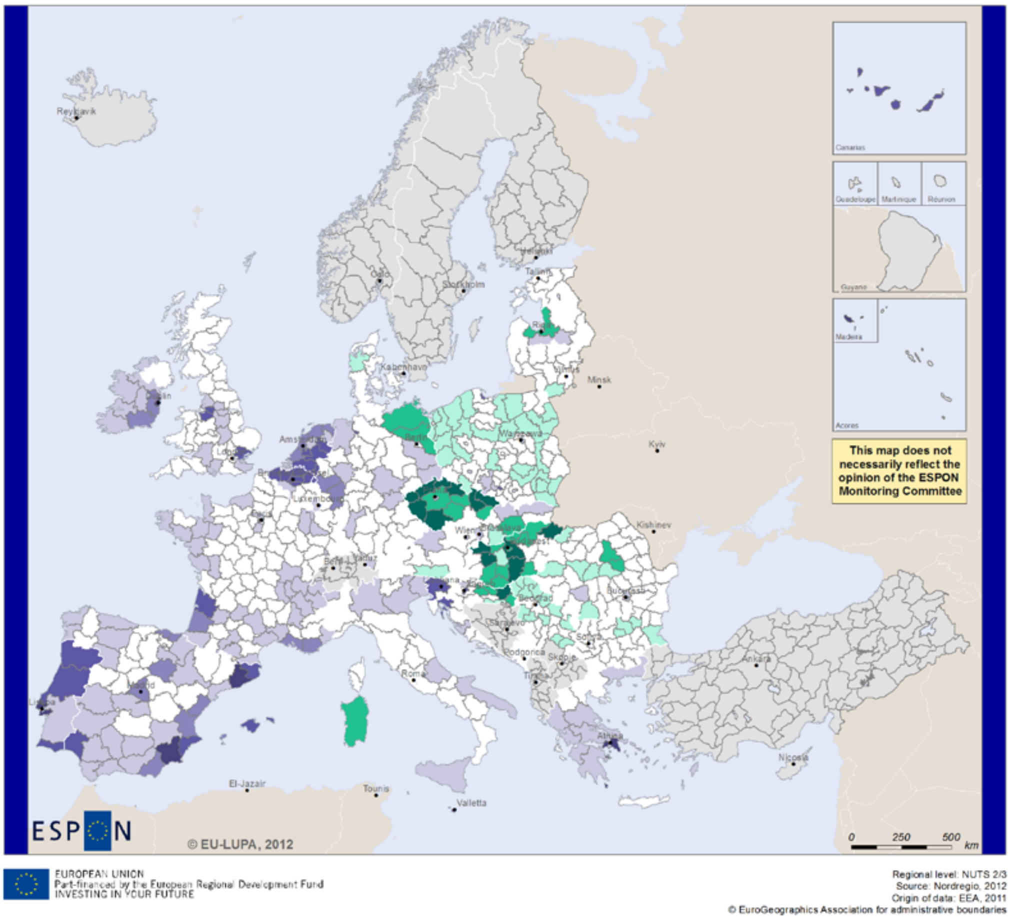
Results

One map for each CLC time series is presented below along with notes on the key spatial characteristics that are taken from the maps.



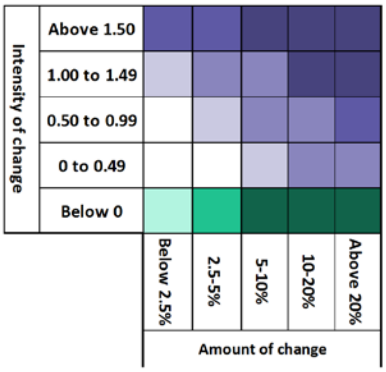
Map 11 Hotspots of land change – 1990-2006

1990 - 2000 Land Change Hotspots



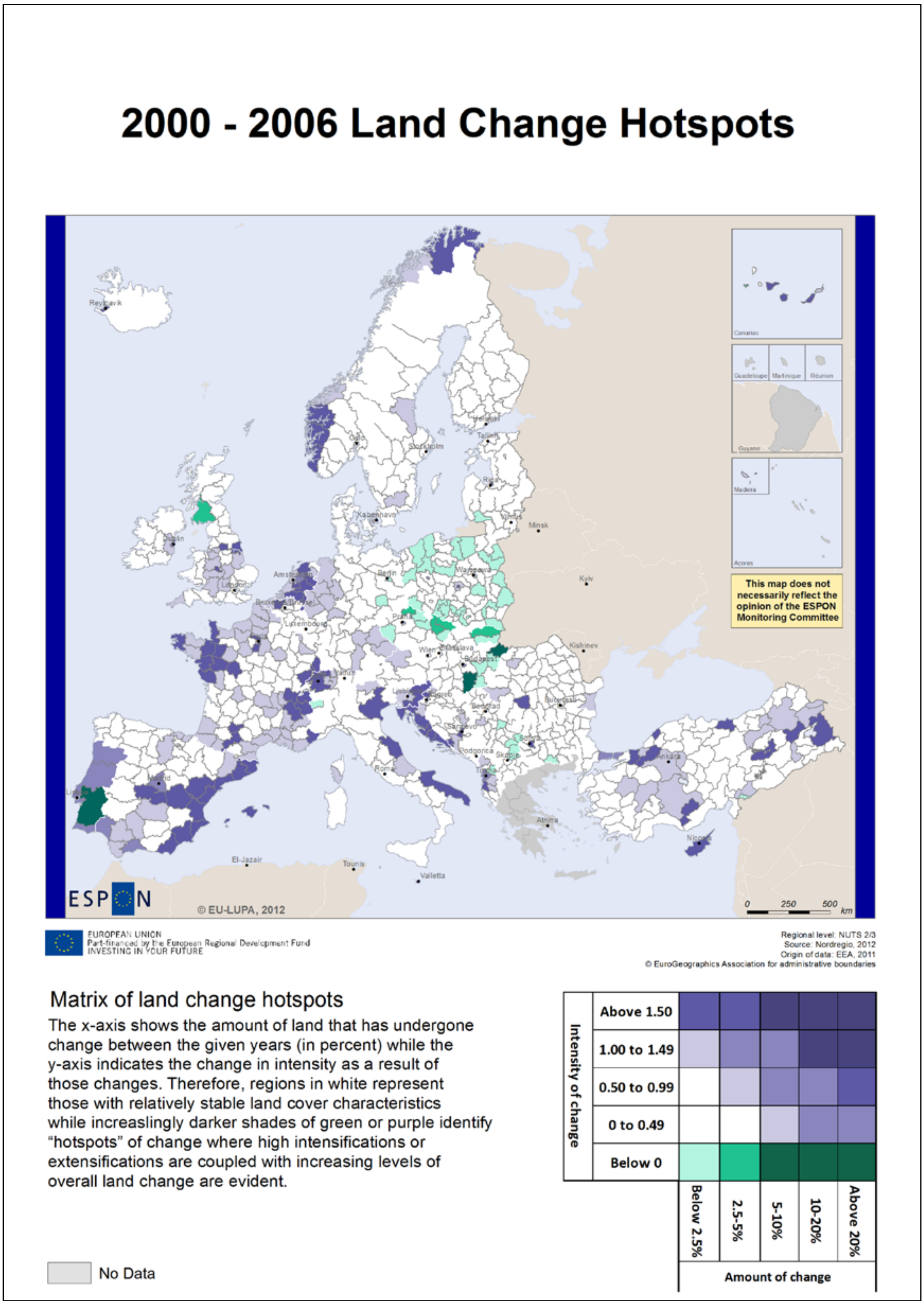
Matrix of land change hotspots

The x-axis shows the amount of land that has undergone change between the given years (in percent) while the y-axis indicates the change in intensity as a result of those changes. Therefore, regions in white represent those with relatively stable land cover characteristics while increaslingly darker shades of green or purple identify "hotspots" of change where high intensifications are coupled with increasing levels of overall land change are evident.



No Data

Map 12 Hotspots of land change – 1990-2000



Map 13 Hotspots of land change – 2000-2006

- The question of land ownership and land tenure has been extremely important in in relation to the registered changes in Southern Europe, and especially on the Iberian Peninsula. Both Spain and especially Portugal land ownership was until the late 1970s and 1980s characterized by Latifundias, i.e. extremely large private estates with the owner usually living in the larger cities. Even providing job opportunities to workers and to some extent leasing out land to tenants, this type of land use has mostly been characterized by very low land use intensity. In Portugal the Agrarian Reform in 1975 being an important part of the “Carnation Revolution” laid down the principles for the expropriation of land from the Latifundias and distributing ownership to former workers or tenants. Even some intensification took place the attempts to establishing cooperatives had limited effect, and a break-through in relation to market based economy followed by the reformed Agrarian law enacted by the parliament in late 1988. This enabled the new ownerships to move towards more intense production structures. At the time of EEC membership in 1986, low land and labor productivities were the most striking features of Portuguese agriculture, reaching before entry only 46% and 13% of EU-10 average, respectively (Mykolenko, Raymond, & Henry, 1987). Especially in areas close to urban centres were the first places to take advantage of the opportunities connected to the CAP (Diogo and Koomen, 2010).

As an important consequence all regions in Portugal are identified as hotspots – albeit to differing degrees – in all of the time series’. Consultation with the maps showing total land change by area (Appendix 5.1) shows that – as indicated above - this is mainly due to the fact that all regions show very high levels of overall change. This is by the high levels of ongoing changes related to forest management. Conversely, the intensity maps above show more stable patterns with the exception of two regions. Lisbon and Alentejo. In the former, intensification is predominantly related to residential sprawl between 1990 and 2000; a process that has slowed considerably since then (EEA, 2011). In Alentejo, relatively high land change is characterized as an extensification process. This is due to the fact that land abandonment due to the withdrawal of farming activities (EEA, 2011).

- Besides processes similar to the above described, where a clear divide between latifundios (dominating in the south) and minifundios (dominating in the north) both have been characterized by low productivity the membership of EU has had some of the same land use consequences as in Portugal. Intensification due to structural changes in land ownership has been an important factor, and this combined with the CAP accounts for much of the intensification taking place in rural areas. As emphasized by Molina (2002, p2), however, “Land tenure is, after decentralization, the second most important supporting/impeding factor for National/Regional Forest Programmes in the Mediterranean regions”. In the case of rural Spain the changes can be illustrated through the example of the Dehesas, a traditional, low-input, extensive agroforestry system (Meeus 1995, here from Plieninger and Schaar, 2008) combining forestry with extensive livestock grazing and farming. Low productivity and low intensity has been an easy target for intensification where the most influential force being the Common Agricultural Policy, which supported the production of cereals and cattle, sheep, and goat husbandry in the dehesas. Again an important process adding to explaining the changes in intensification.
- On the Iberian Peninsula, but definitely also in other parts of Southern Europe, a starting point characterized by very low land use intensities in rural areas and farming practices

more related to subsistence and local markets than to European and World Market conditions have been an obvious starting point for a process of land use intensification in rural areas that took off before 1990, peaked in the period 1990 to 2000, and now being more or less “normalized” except for regions in Portugal where intensification of rural areas are still ongoing. And instead of rural intensification related to rural activities many of former rural areas – especially in coastal areas – are exposed to a new category of intensification related to urban sprawl.

- In contrast to the situation on the Iberian Peninsula, the immediate effects of the inclusion of East-Central European countries - previously part of the “East Block” mostly characterized by state and cooperative ownerships - are reflected through a drastic decline in intensity over substantial areas in the period from 1990 to 2000. In contrary to the situation in Spain and Portugal the basic land reforms distributing former estate land to small and medium scale farming had taken place pre Second World War, and in many cases during the 19th century. The structural changes connected to the post WW2 reforms in ownership instead resulted in the establishing of state farms and cooperatives. It had some immediate consequences in relation to both intensity and productivity, and was paralleled by regional policies in relation to rural areas due to the state interests in maintain a high level of production to serve the requests from the Soviet Union through COMECON. And as a consequence transfer payments and subsidies enabled intensities and productivities that were unrelated to market conditions. So the development from 1990 and onwards abandoning the former state and cooperative ownerships forms has had some immediate consequences in relation to intensity. On one hand that many of the new private farms were small and did not have the necessary means to ensure a high intensity in land use. And on the other hand that the larger farms with intensification potentials in many cases involved foreign investments which did not necessarily lead to intensifications. The situation in Poland being different in this respect because of a dominance of private land use activities, and as a consequence effects as described above only relating to the relatively smaller areas owned by cooperatives and a few state holdings as well.
- The situation in Poland was, however also affected through the lack of funding for investments in many of the small farms functioning more as subsistence bases for a still older population – a situation that can be found in rural areas, not the least in regions remote to the capital regions or in mountainous areas in most of the former “East Block”. And several of the regions where this has been the dominating characteristic has continued being regions of decreasing intensity through the 2000-2006 period as well. One important element in this connection has in Poland been the small size of a substantial part of the already private farms. The advantage in other parts of East-central Europe has been that in the aftermath of the first round of extensification the new private farms were able to establish themselves not as subsistence activities but as professional and capital intensive farms on previous state or cooperative owned large scale farms. And similar situations have appeared in relation to other types of land use.

- Ireland being a “hotspot” for IT development during the 1990’s had some spin-off in relation to increased intensification of activities related to land use. Partly because the attraction of labour force away from direct land use to industrial activities required adjustment in land related activities requiring technology to replace the missing workforce. With a partly collapse of the IT-adventure after 2000 the process described above came to a halt, and the shift is apparent when comparing the 1990-2000 and the 2000-2006 situations.
- While missing data for Sweden, Finland and Norway for the period 1990-2000 does not allow a comparison between the two periods, an important issue of the effects of increasing activities related to resource extraction, especially in relation to oil and gas development, is very apparent for the 2000-2006 period shown for Norway. While fisheries used to be a mainstay for coastal communities in Norway the picture today is a high degree of dependency on the sea, but in relation to energy resource extraction. This leads to the inclusion of large areas for on-shore production facilities, but requires at the same time related economic activities – processing, investigation, planning, education etc., which shows through inclusion of still larger areas for housing.
- European tourism is an activity requiring still larger areas, and the development of the Spanish coastline illustrates that it is not only a question of short term changes, but seems to have been a consistent development process throughout the whole period from 1990 to 2006.

While the hotspots enables us to identify places in Europe where marked changes have been taking place during the last 16 years, the development of a typology which is able to capture these changes and provide a connection between types and processes of change, an important planning instrument will be at hand. So the next step is to turn the focus on such a typology.

3.5 Regional Typology of Land Use Change

Method

The account of land changes are based on the EEA’s release of GIS vector data for all CLC changes for the 1990-2000-2006 time periods. These changes were then allocated with values based on the EEA’s production of land cover flow (LCF) data. Compared to the 1892 possible combinations of land cover changes the identification of nice generalized land cover flows provides a good point of departure for analysing land changes. The nine LCF types are as follows:

LCF1 Urban land management

LCF2 Urban residential sprawl

LCF3 Sprawl of economic sites and infrastructures

LCF4 Agriculture internal conversions

LCF5 Conversion from forested & natural land to agriculture

LCF6 Withdrawal of farming

LCF7 Forests creation and management

LCF8 Water bodies creation and management

LCF9 Changes of Land Cover due to natural and multiple causes

For our typology we have not added LCF8 and LCF9 due to uncertainty over the drivers of such land changes.

Using GIS, vector data for all of the considered LCFs is intersected by the NUTS2/3 administrative areas in order to regionalize the data. Accordingly, the first input into a regional clustering procedure is regional data on the share of the first seven LCFs as a percentage of the total land cover change in each NUTS2/3 region. It has been considered to use the raw percentages of the LCFs as a share of all regional changes because it not only provides the relative distribution (percentages) of the LCFs, but also the amount of changes that have taken place area-wise.

The second input is the average change in land use intensity based on all changes in each region. In order to bring the intensity data to a numerical level comparative to the LCF classes mentioned above, it has been standardized to a new mean of 0 and a standard deviation of 1.

The Ward's Method of clustering was conducted with a query to form 10 clusters. The rationale to choose 10 (rather than 5 or 15) was to on one hand limit outliers with only single or a few NUTS2/3 regions, while at the same time preventing too large clusters that do not allow for major regional variations to be highlighted.

Unlike the typology for the Prevailing characteristics of land use, where an aggregated typology for the full 1990-2006 time period was optimal, this situation is not replicated for the Land Use Change Typologies because coverage of CLC data is neither unanimous nor consistent for the three time periods. As such, only including regions with CLC representation would not sufficiently cover the extent of the ESPON territory. Another reason for keeping the time periods separate is that providing a Land Use Change typology for 2000-2006 allows us to compare the results of the typology with the LUFs analysis. And certainly not least, the ability to keep the typologies separate for each CLC time series improves the analytical capability of the typologies by allowing for more detailed analysis of the interplay between the temporal, spatial and socio-economic dimensions that both drive and react to land use change.

The statistical results of each cluster procedure were organized into tables in order to interpret the results and ultimately organize the clusters into groups of Land use change types. This includes Table 7 for the 1990-2006 time series below and Appendix 5.4 for 1990-2000 and 2000-2006 time series'. In Table 7, from top to bottom, first we see the number of regions in each cluster, followed by the distribution of how much each LCF accounts for the land changes for the regions in each cluster. For example, we see that in Cluster 10, 0.07% of the total area of the regions in that cluster underwent land change classed as LCF1. The orange-blue colour ramp is used to reiterate which LCF's – and in which clusters – account for the highest relative share of land change. This not only shows which types of changes are most prevalent (area-wise) but also shows how certain regions undergo rather specific change processes, will others show a very dynamic interplay between all of the LCF's.

The next set of data shows how much each LCF in the cluster results accounts for the total changes in each cluster of regions. Using the same example, we see that of all the land changes accounted for in Cluster 10, 12.1% of them are classed as LCF1. Again, the orange-blue colour ramp is used to reiterate which LCF's – and in which clusters – account for the highest share of land change.

Next, in order to emphasize urban processes, the percentage of changes in each cluster recorded as LCF1, LCF2 or LCF3 – any land change resulting in an artificial surface – is recorded. This is followed by the average change in land intensity caused by the land changes in each cluster, as well as the percentage of the total area of regions undergoing change in each cluster. Again, a red-green colour ramp is used to show the pattern of these indicators through the ten clusters. And finally, the ultimate grouping of the clusters into Land use change types is previewed on the bottom row.

It is important to point out that the land use intensity perspective is crucial to our method as it allows us to incorporate the notion of land *use* into the typologies. As such, the colour-coding of the row labelled "Average change in land intensity for each land change" shows that the clusters are ordered from the highest level of intensification down to the highest level of extensification. This is transposed into the nomenclature of the Land use change types so that the each reflects a kind of hierarchy of change in terms of land use intensity (human intervention on the land for socio-economic purposes).

Nevertheless, the results of the cluster analysis produced 10 clusters in each of the three time series. However, this posed the initial challenge of how to group the 30 clusters into explanatory and policy relevant groups. But as the process unfolded iteratively, it became clear that the similar processes (but happening at different intensities and in comprising different regions) were typical in clusters across multiple time periods. As such, the focus was to identify patterns (groups of clusters) in the 1990-2006 data, and then determining how the other two time series' corresponded to the full time series.

Table 7 Statistical results of the cluster procedure used to identify and interpret the Land use change types – 1990-2006.

From top to bottom: first, we see the number of regions in each cluster, followed by the distribution of how much each LCF accounts for the land changes for the regions in each cluster. The next set of data shows how much each LCF in the cluster results accounts for the total changes in each cluster of regions. The orange-blue colour ramp is used to reiterate which LCF's – and in which clusters – explain the highest shares of land change.

Next, the grouping of the clusters into Land use change types is presented. Under this, the aggregated averages for the percentage of changes in each type recorded as LCF1, LCF2 or LCF3 – any land change resulting in an artificial surface – is recorded. This is followed by the average change in land intensity caused by the land changes in each cluster, as well as the percentage of the total area of regions undergoing change in each cluster. A red-green colour ramp is used to show the pattern of these indicators through the ten clusters.

1990-2006	Percentage of the total area of NUTS273 regions corresponding to each Land Cover Flow									
Land Cover Flow Type	**Cluster 10**	**Cluster 9**	**Cluster 8**	**Cluster 1**	**Cluster 4**	**Cluster 5**	**Cluster 7**	**Cluster 3**	**Cluster 2**	**Cluster 6**
Number of regions	2	9	31	36	71	42	87	86	178	19
LCF1 Urban Land Management	0,07	0,06	0,37	0,12	0,19	0,17	0,11	0,09	0,02	0,01
LCF2 Urban residential sprawl	0,25	0,26	0,61	0,52	0,36	0,29	0,17	0,12	0,03	0,02
LCF3 Sprawl of economic sites and infrastructures	0,28	0,44	1,06	0,54	0,58	0,55	0,37	0,27	0,10	0,09
LCF4 Agriculture internal conversions	0,00	0,13	0,34	0,26	0,50	0,40	0,82	0,92	0,80	2,88
LCF5 Conversion from other land cover to agriculture	0,01	0,15	0,18	0,12	0,10	0,14	0,25	0,13	0,06	0,05
LCF6 Withdrawal of farming	0,00	0,00	0,14	0,09	0,06	0,12	0,20	0,15	0,19	0,52
LCF7 Forests creation and management	0,00	0,08	0,46	0,56	0,56	0,93	1,51	1,97	2,23	2,05
	Percentage of each Land Cover Flow accounting for the total land change in regions									
LCF1 Urban Land Management	12,10	5,48	10,27	5,15	7,40	5,97	2,99	2,35	0,55	0,24
LCF2 Urban residential sprawl	41,00	22,70	17,23	22,71	14,12	10,33	4,79	3,11	0,94	0,37
LCF3 Sprawl of economic sites and infrastructures	45,63	38,89	29,81	23,29	22,52	19,27	10,22	6,87	2,86	1,61
LCF4 Agriculture internal conversions	0,00	11,23	9,51	11,51	19,42	14,14	22,62	23,59	22,84	50,73
LCF5 Conversion from other land cover to agriculture	1,01	13,48	5,18	5,01	3,84	5,01	6,95	3,36	1,73	0,82
LCF6 Withdrawal of farming	0,00	0,16	3,97	4,02	2,36	4,21	5,55	3,91	5,42	9,15
LCF7 Forests creation and management	0,00	6,64	12,95	24,26	21,72	32,81	41,91	50,67	63,42	36,01
Land Use Change Type	1	2	2	2	3	4	5	6	6	7
Average percent of change urban (LCF 1-3)	98,73	58,51			44,04	35,58	18,00	8,34		2,22
Average change in intensity for each land change	4,17	1,84			1,09	0,85	0,62	0,20		-0,29
Average amount of change (%) (LCF 1-7 only)	0,61	2,33			2,58	2,83	3,61	3,70		5,68

Using the table above, and as shown by the illustration in Figure 7, the 10 *clusters* for the 1990-2006 time series were first organized into seven *groups* based on a qualitative assessment of statistical similarity and difference between the clusters. This procedure represents a further generalization of the land change processes beyond what is delivered by the clustering procedure itself. It was first and foremost based on the share of total land changes that are related to urban processes, and consideration on the average change of land use intensity for regions in each cluster, which emphasizes urbanization and extensification (agricultural withdrawal) processes taking place in regions.

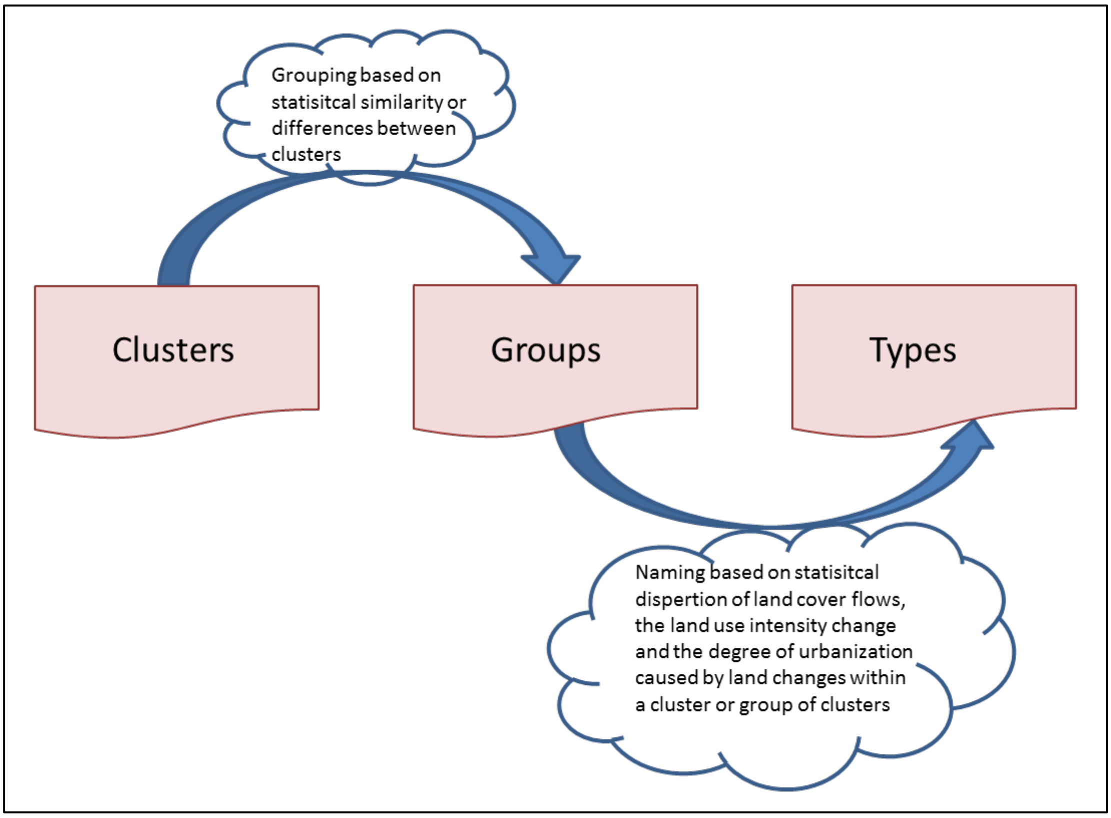


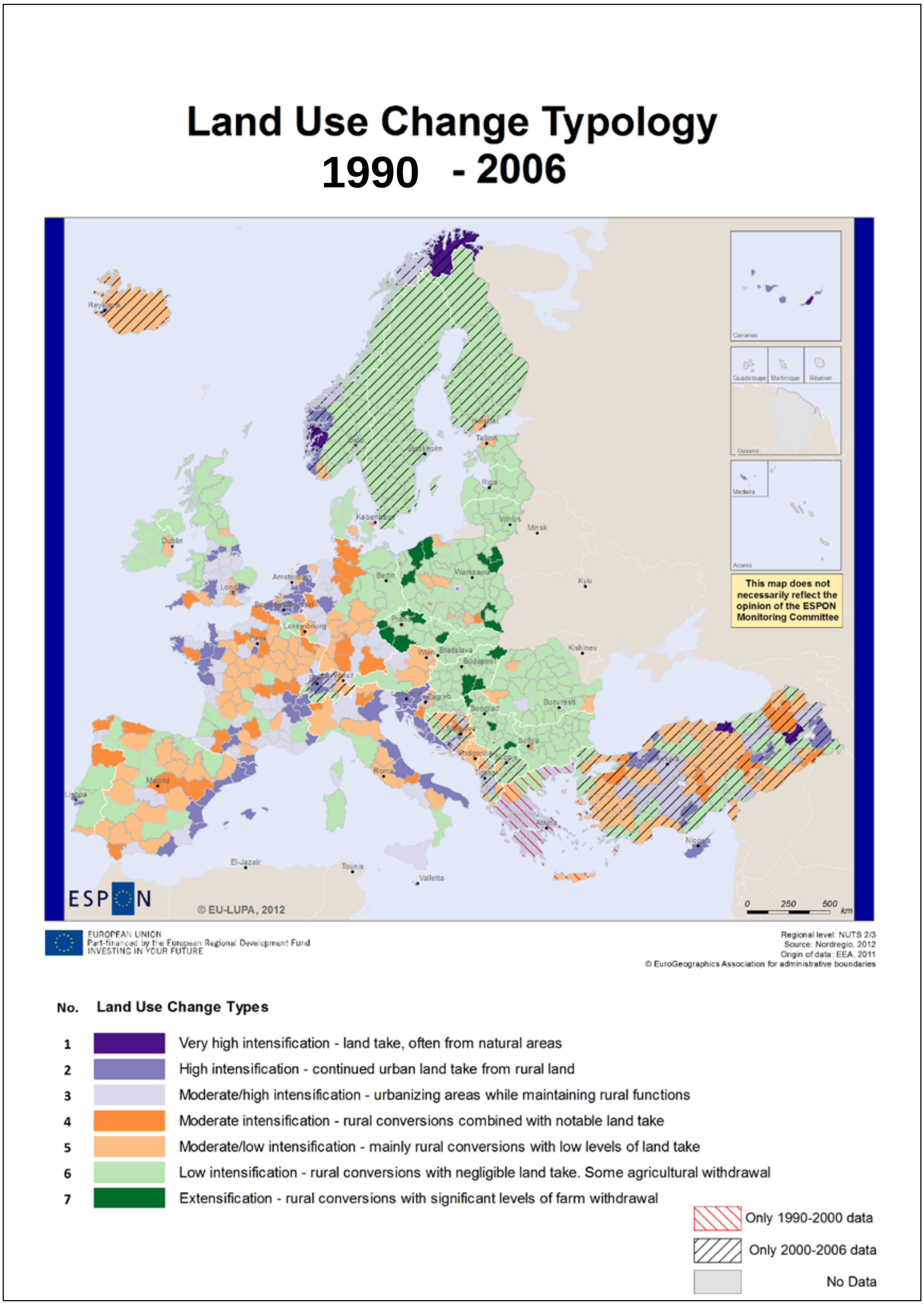
Figure 7 Overview of transforming the cluster results into Land use change type

Once this was completed, clusters from the 1990-2000 and 2000-2006 time series were grouped with the goal of maintaining the statistical characteristics identified by the 1990-2006 grouping. As shown in Figure 8 below (in the three columns under the heading "Cluster Number", all but one of the seven groups contains at least one cluster of regions from each time series (the only exception being for the 1990 – 2000 time series where "Moderate intensification - rural conversions combined with notable land take" isn't included). The rationale for this will be taken up after the description of each Land use change type below.

As again shown in Figure 7, the seven groups were then named based on their internal distribution of land cover flows, the degree of changes toward artificial surfaces (urbanization), and not least, their hierarchy of inferred land use intensity changes. Analysis of these elements therefore converted the groups of clusters into *types* with an explanatory value. The naming of the types has sought to be descriptive of the predominant changes in each type as well as the key differences between the types.

No.	Land Use Change Types	Cluster Number			Average Percent Urban Change			Average Intensity Change		
		1990 - 2000	2000 - 2006	1990 - 2006	1990 - 2000	2000 - 2006	1990 - 2006	1990 - 2000	2000 - 2006	1990 - 2006
1	Very high intensification - land take, often from natural areas	7 and 10	9 and 10	10	88-96	96	99	3,08 - 4,29	2,81 - 4,69	4,17
2	High intensification - continued urban land take from rural land	9	5 and 7	1, 8 and 9	73	56-61	51-67	1,98	1,75 - 2,11	1,40 - 2,45
3	Moderate/high intensification - urbanizing areas while maintaining rural functions	8 and 2	6	4	49-37	67	44	1,09 - 1,52	1,3	1,09
4	Moderate intensification - rural conversions combined with notable land take	N/A	4	5	N/A	36	36	N/A	0,95	0,85
5	Moderate/low intensification - mainly rural conversions with low levels of land take	3	3	7	22	22	18	0,72	0,64	0,62
6	Low intensification - rural conversions with negligible land take. Some agricultural withdrawal	1, 4 and 6	1 and 2	2 and 3	6 -11	4 - 12	4 - 12	0,20 - 0,44	0,06 - 0,32	0,05 - 0,35
7	Extensification - rural conversions with significant levels of farm withdrawal	5	8	6	3	9	2	-0,35	-0,35	-0,29

Figure 8 Legend of all Land use change types. The left column shows the name of each type, followed by three columns showing the grouping of cluster value(s) corresponding to each type. The next three columns show the percentage of land change (by area) that involves some process of conversion into an artificial surface (Either LCF 1 – urban land management; LCF 2 – urban residential sprawl; or LCF 3 – sprawl of economic sites and infrastructures. The three columns on the right show the average level of change in intensity for changes in each cluster of regions.



Map 14 Land Use Change Typology – 1990-2006

Map 14 shows the distribution of Land use change types among NUTS2/3 regions for the 1990-2006 time series. However, only 561 of the 772 NUTS2/3 regions have CLC data for all three time periods. Regions missing data for one of the periods are filled using data from either the 1990-2000 (Greece) or the 2000-2006 (all black cross-hatched regions) time series.

Using Table 7 and Figure 8 as a basis, each of the Land use change types are interpreted in relation to the 1990-2006 time series below. It should be noted that the presentation of the information box for each type covers the statistical breakdown of the 1990-2006 data only, while, as mentioned, the map above has filled the gaps using typology results from the other available time series'.

Following the description of each Land use change type the presentation of the individual time series' (1990-2000 and 2000-2006) will help to identify some of the changing patterns of land use change for Europe.

Table 8 Type 1: Very high intensification - land take, often from natural areas

Cluster number	10
Number of regions	2
Average Percent Urban Change	99%
Average change of intensity	4,17

Figure 8 shows that the three regions in this cluster are very unique. The land changes that have taken place are almost exclusively related to development of artificial surfaces, and especially the extension of these surfaces on previously natural land (only 12% of the changes are changes from one form of urban surface to another, while 87% relate to sprawl into previously unsealed surfaces. This pattern is reflected by the average intensity change of four. The very high level of intensification indicates the formation of these land uses results from the consumption of very low intensity land covers; most likely natural landscapes. Presence of this Land Use Change Type is limited to the Canary Islands and northern Norway.

Table 7 also shows that the area of the change is very small, thus indicating very concentrated developments. This is substantiated when looking at the regions in this type (Grand Canaria, and Malta for the 1990-2006 period, but also including coastal regions in Norway and two regions in Turkey). In the case of the Spanish regions and Malta it is clear that sprawl of touristic infrastructure into natural landscapes is taking place. In Norway, it is clear that the typology reflects the continued development of infrastructure needed to support the growing oil and gas development as well as the mining sectors. These activities are expected to expand further in sparsely populated areas of most of the Nordic countries in the next decades.

Table 9 Type 2: High intensification - continued urban land take from rural land

Cluster number	1, 8 and 9
Number of regions	71
Average Percent Urban Change	51 - 67%
Average change of intensity	1,40 - 2,45

This type includes regions from three clusters, each where more than 50% of the land changes resulted in a further urbanization. (15%, 57% and 67% for clusters 1,8 and 9 respectively). This is also reflected by the high intensity scores, which together show that the dominating process taking place is land take and thus urbanization. Interpreted through Map 14 we see that this type reflects at least two types of regions: first, those regions encompassing national capital or large urban centres (or in daily commuting distances). This reflects the reality of growth of urban regions in Europe and is especially evident in the U.K., The Netherlands, Belgium, Switzerland and France. In this context, the term "continued" is used in the naming of the type to reflect that many of these regions could already be defined as containing dominant "urban functions" prior to the 1990. The fact that very few "rural" land changes (forest conversions or agricultural changes) appear to be taking place also insinuates that these are already established urban areas.

In this context it is also interesting to point out that large, global cities (which are NUTS2/3 regions in and of themselves) are not characterized through these Land use change types reflecting intensive, urbanizing land changes. In contrast it is the surrounding, functional region where the most intensive land changes are occurring, which reflects the process of sprawl associated with growing urban regions.

In addition to these existing urban centres, and like the regions in the previous type, this type also includes regions where land change processes are clearly dominated by a growing tourist economy. For example, almost all of the regions accounting for the Spanish Mediterranean coast and the Balearic Island are included, while the same holds true for coastal Italy, throughout Croatia and in Cyprus. This is substantiated by a recent report on best practices for limiting soil sealing (Prokop et al. 2011) where the main driver of high soil sealing per capita is the experience economy (second homes, touristic infrastructures, etc.). Not underestimated as a driver of land use change in these regions is the development of large infrastructure projects, such as highways, which we know to be responsible for land take in Spain and Croatia among other countries.

Table 10 Type 3: Moderate/high intensification - urbanizing areas while maintaining rural functions

Cluster number	4
Number of regions	72
Average Percent Urban Change	44%
Average change of intensity	1,09

The distribution of LCF's 1-7 in this type are quite diverse, yet it is possible to make some general characterizations, especially when considering the spatial distribution of the 72 regions making up this type in the 1990-2006 data (again, additional regions are added when using 1990-2000 and 2000-2006 data to fill the gaps). Here, we clearly see that, apart from regions in the "blue banana" with land changes reflected in the previous two types, this type fills in much of the remaining gaps (e.g. the southern half of the U.K., through The Netherlands and Western Germany, and south into France and Switzerland and extending to the large NUTS3 region where Milan is situated).

In addition to the blue banana we also see this type extending through southern France, in two "peri-urban" regions surrounding Madrid, throughout Greece (in the 1990-2000 data) and, notably, in selected urban regions in city-state regions (or those directly surrounding them) in Poland (ie. Warsaw, Ludz and Poznan). In general we also see that this land use type is predominantly located in Western European regions.

The statistical information from Table 7 shows that a relatively high percentage of the changes, 7.4%, relates to LCF 1 – Urban land management. This insinuates that these regions have established urban activities, likely in contrast to very recent processes of urbanization, and that the sprawl of housing, economic sites and infrastructures (LCF 2 and LCF 3, totalling 37%) is taking place around established centres of socio-economic activity. Yet while this 44% of changes are attributed to urban processes, it is notable that rates of both agricultural formation (LCF5) and withdrawal of farming (LCF6) are very low (under 4% of total changes for each). Coupled with moderate levels of agricultural internal conversions (LCF4 – 19%) and forest creation and management (LCF7 – 22%) we can conclude that these rural land functions are still important contributors to socio-economic development, and that these processes appear to be quite stable.

Table 11 Type 4: Moderate intensification - rural conversions combined with notable land take

Cluster number	5
Number of regions	42
Average Percent Urban Change	36%
Average change of intensity	0,85

Unlike the previous clusters, a threshold has been crossed where the average level of land use intensity change is now less than 1. Similarly, the share of "urban" land changes is reduced to 36%, but is still a notable impact of land change. As such, regions in this type appear to have *mainly* rural land functions but urban changes are perhaps increasing in number and are important for meeting development goals. Further, it seems that this type, along with the next type as well, indicate regions with very diverse constellations of land changes taking place.

As mentioned previously, the statistical characteristics of this type were found in the 1990-2006 and the 2000-2006 data, but not in the 1990-2000 time series. As will be discussed below this could be indicative of a further "mainstreaming" of urbanization throughout a wider share of previously rural regions in Europe compared to the 1990-2000 period.

However, we also see that many of the regions in this group are relatively large area-wise. As such this could indicate an unavoidable constraint of the typology classification for relatively large regions: where rural land changes take place over broad areas trump urban land change processes that are very intensive but take place on a comparatively smaller scale. This reiterates a key challenge of the project: to attempt to merge spatial phenomenon which operates relatively independent from administrative/political spatial structures with administrative boundaries that are hugely disproportionate in size.

For example, we know that regions with large cities in their borders, such as Madrid, are regions where a vast majority of people live in the urban centre, and where urban sprawl is taking place. Yet due to the large surrounding areas within the administrative border the region appears with non-urban land changes as dominant.

Table 12 Type 5: Moderate/low intensification - mainly rural conversions with low levels of land take

Cluster number	7
Number of regions	87
Average Percent Urban Change	18%
Average change of intensity	0,62

The land use change characteristics in this type are similar to the previous type except the rural land change process processes increase in their role of defining regional changes ("urban" land changes in LCF's 1-3 decrease by 50% from the previous type and are mostly replaced by agricultural conversions and forest creation and management). This appears to emphasize a transition toward regions that are understood as mainly rural from a socio-economic perspective.

Similar to the each of the previous types there is quite a clear east west dimension to this type as well. However, it is interesting to note that while this type is dominant in Western Europe (it is the most common type in continental Western Europe) it characterizes the land use changes in selected regions in selected Eastern European Member States as well. For example, we know that Poland has continued to shift toward the socio-economic standards defining regions in Western Europe – and has done so to a greater degree than other New member States such as Romania, Latvia Estonia, Bulgaria, Slovakia, etc. Consequently, we see more orange regions - with at least a medium level of relative intensification toward urban land uses - in Poland (compared to the green regions in the other Member States, which show that rural land changes still dominate).

This adds credence to a type of processional shift in land use that could be an almost unavoidable impact of socio-economic development toward a modern economic economy. If this holds true we could expect that future regional land use changes types in Poland (which became a Member State in 2004) could reflect those shown for inland Spain (which joined the EU in 1986).

Table 13 Type 6: Low intensification - rural conversions with negligible land take. Some agricultural withdrawal

Cluster number	2 and 3
Number of regions	264
Average Percent Urban Change	4 - 12%
Average change of intensity	0,05 - 0,35

Table 13 shows that regions in this type are characterized by land changes that, put together, result in a very neutral level of intensification. However, based on the discussion above rural land changes trumping urbanization in relatively large regions, we know that this low intensification could be the result of two different trends. For example, the Skåne region in southern Sweden is in this type, but as reflected in the case study on the Øresund region (see Volume VI) we know that quite high urban development took place around the City of Malmö during and following the construction of the Øresund Bridge. However, the large amount of agricultural conversion in the rural parts of the region appears to mask this development in the typology results. Again, this reflects the difficulty of attempting to formulate a typology that can overcome both the scale factor (differing size of regions), the time factor (results of rapid changes take time to be registered!) as well as the underlying reality that a diverse set of land uses and changes (which are often completely isolated from one another in space) are occurring in the same region.

Nevertheless, the more common representation is of regions that are rural and with urbanization land changes accounting for only 4-12% are, for the most part, are staying that way. The changes that do take place predominantly relate to forest and agricultural conversions (mainly forest in the Baltic Sea Region and mainly agricultural in most of continental Europe. However, we do begin to see a slight rise in LCF6 – withdrawal of farming, which implies that certain regions in this type are being exposed to pressures of changing socio-economic realties, not least population loss due to the increasing supply of jobs in urban centres.

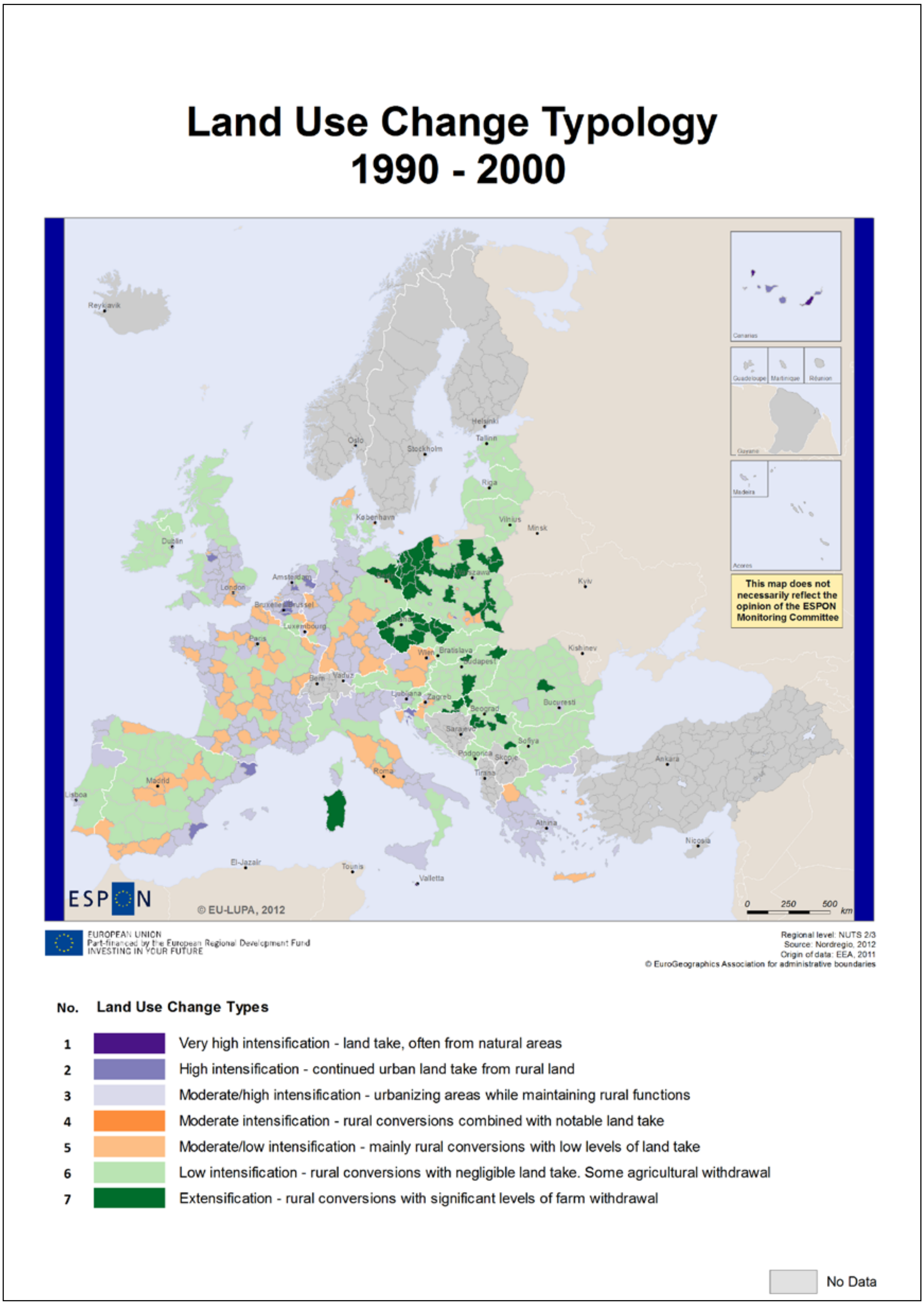
Table 14 Type 7: Extensification - rural conversions with significant levels of farm withdrawal

Cluster number	6
Number of regions	19
Average Percent Urban Change	2%
Average change of intensity	-0,29

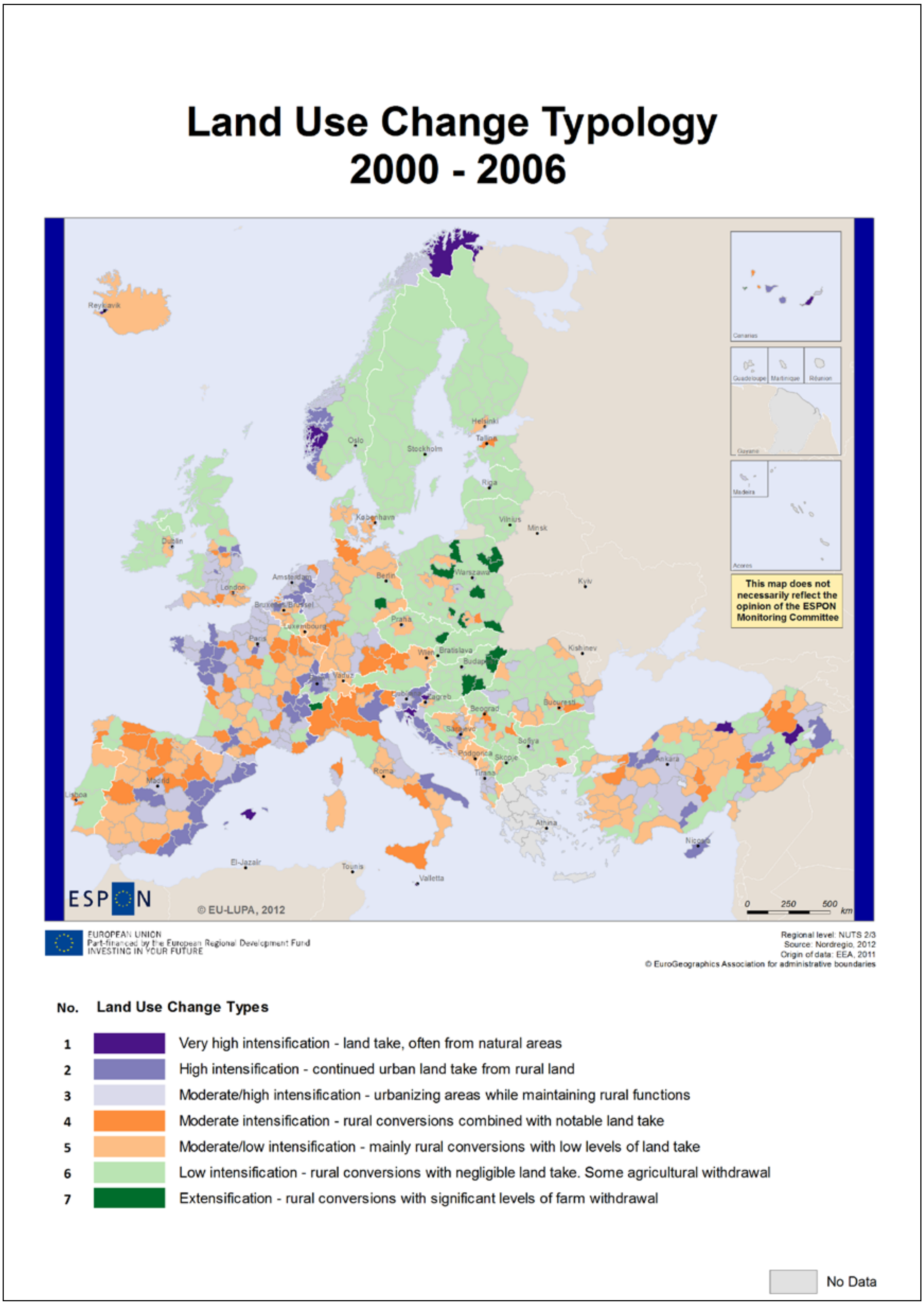
Regions in this “extensification” type are unique and important to acknowledge because they highlight regions where cumulative land changes in have resulted in an extensification of socio-economic activities taking place on the landscape. For a vast majority of the regions, if not all, the dominant driver is the reduction of agricultural activities. On average, 9% of the land change in these regions is related to agricultural withdrawal – a significant share indeed. Not surprisingly, this trend is driven by urbanization, particularly of younger people to urban centres in search of higher quality jobs but to some extend also through withdrawal of activities which have been kept “alive” through different supporting mechanisms. Consequently, traditional jobs in rural areas suffer from low replacement rates of an aging labour force. As such, land use changes seem to reveal a socio-economic trend of rural stagnation and decline as rural land-based activities are being replaced by growth that is concentrated in urban areas.

Regions in this type are exclusive to Eastern European and new member states, with notable distributions in Poland and the Czech Republic. What is important to consider however, is that the processes of urban development (the purples and oranges in the typology) and the processes of rural stagnation or decline (the greens in the typology) do only reflect independent drivers. From a theoretical perspective of Growth Poles, a clear example of this is in Poland where urbanization processes in selected regions appears stronger than in other New Member States. However, to meet this growth urban centres are plucking their labour force from rural regions, therefore leading to extensification of rural area.

As such, a common challenge of land use change reflects the polarization of economic activity: rural areas could continue to experience significant agricultural withdrawal while urban centres will continue to expand as population growth and economic activities continue to be concentrated in them. Another important challenge is related to future situations where policy measures in relation to for instance re-organization of the CAP, change in regional supporting mechanisms from block grants to targeted issues such as poverty, environmental protection, or change in perceptions of what are “liveable landscapes” etc. may have on the direction of land use change. In this context typologies where measures of intensities combined with basic socio-economic accounts such as population density and GDP seem to be very useful!



Map 15 Land Use Change Typology – 1990 -2000



Map 16 Land Use Change Typology – 2000-2006

In addition to showing the main Land Use Change Typology for the 1990-2006 time series it is advantageous to show the 1990-2000 and 2000-2006 time series' as well. On one hand, this data has been used to fill gaps in the main typology where CLC data is unavailable. But it also highlights important spatial trends of land use development.

For example, it was mentioned that the Land use change type "Moderate intensification - rural conversions combined with notable land take" is the only type not included in all three of the time series (it isn't included in the 1990 – 2000 time series, but is prominent in the 2000-2006 time series). Likewise, it is clear to see the much higher number of regions in the "High intensification – continued land take from rural land" type in the 2000-2006 time series compared to the 1990-2000 time series as well.

Both of these observations indicate that processes of urbanization are becoming a more mainstream, and dominant phenomenon defining the general direction of land use changes for more regions. This is reiterated by EEA's State and Outlook Report on land use, which described that land take for urban area and infrastructure accelerated from 0.57%/year during 1990-2000 to 0.61% for 2000-2006 (EEA, 2010). This is supported by the tables in Appendix 5.4, which show that three of the clusters in the 1990-2000 time series have urban changes (LCF's 1-3) accounting for over 50% of all land changes, compared to five clusters in the 2000-2006 time series.

A closer observation of the maps of the two time series' above shows that the acceleration of changes dominated by urban formation is uneven throughout Europe. It is especially true for regions in Spain, France, The Netherlands, Denmark, Poland and in Luxembourg. This does not necessarily mean that more land is actually being covered by artificial surfaces in these regions, but it does imply that a greater share of land changes is resulting in urbanization.

The increase of land use change types showing a much more diverse and heterogeneous pattern throughout especially Central and Southern Europe in 2000-2006 compared to the 1990-2000 also seems to indicate that the "older newcomers" to EU have reached development characteristics complying with most of EU. At the same time that many of the "newer newcomers" are still in the process of adjusting, but haven't reached the same level of regional diversity. Furthermore, the sparsely populated areas in Northern Europe are in a situation where land use intensities differs so much from the rest of Europe that special change typologies may be needed in order to capture details in land use changes in these regions.

A second observation is that the number of regions in the Land use type "Extensification – rural conversions with significant levels of farm withdrawals" appears to decrease quite significantly in the 2000-2006 period compared to the 1990-2000 period, especially in The Czech Republic and in Poland. In the case of the Czech Republic we know that that the extensification in the 1990's driven by policy to convert crop land into pastures in order to promote grassland formation. But as emphasized above it takes time for newcomers to EU to adjust to the new conditions. And as mentioned before, some were more prepared and ready than others and are in the process of moving towards similar patterns as in the rest of Europe, while others are proceeding at a slower pace.

4 Discussion

A great volume of spatial output and analysis has been provided above, which makes it important to reflect on how each component relates to each other. Likewise, to protect against potentially unfounded conclusions being drawn from the maps it is also important to comment on the limitations of the outputs. This provides a basis for more general comments on how this evidence base fits together to provide a set of information that benefits ESPON's collective knowledge of regional studies and territorial analysis.

First, the typology on the Prevailing characteristics of land use provides a state-of-the-art on the current picture of land use at the regional level. For instance, it says that, based on CLC data, a given region has a certain generalized characteristic and these other regions in Europe share this same characteristic. It also provides a platform for investigating land use changes in individual regions. Results provided at the gridded level contribute to sub-regional analysis of land use and land use changes in taken up in the case studies.

In terms of land use changes, it quickly became clear that no single regional output could capture all of the necessary dimensions of land use change, especially not how land use change coincides with socio-economic changes. As a result, the analysis of land use change was built up starting from a basic measure of how much land is changing in European regions, which showed quite clearly how amounts of physical land change are based on policy agendas and political changes. We see in the maps in Appendix 5.1 that there are very clear disparities between neighbouring countries, but also high differences between many neighbouring regions. For instance, for France vis-à-vis Spain we know that large amounts of building, infrastructure development and agricultural changes have taken place in Spain while, apart from selected regions in France land use has been very stable. Similarly we see marked differences in the volume of land change in between old East and West Germany since the fall of the Berlin Wall.

Thus, on one hand, visualization of these differences only reaffirms the importance of considering land use implications when assessing the feasibility or appropriateness of policy. At the same time, knowing the amount of land change says nothing about changes in land use intensity – in how much the land is being manipulated to meet the needs/goals of socio-economic development. This is where the notion of intensity needs to be added to the picture.

The mapping of intensity changes in land use really highlights the magnitude of human activity on land. For instance when we see regions where changes have resulted in high intensifications we know that whatever land that is undergoing changes is being impacted a great deal by changes in levels of socio-economic development. This has been validated in Section 3.3 where a correlation was shown between the CLC classes (which where regionalized in the land use types for the Prevailing characteristics of land use) and changes in population density and GDP. Very clear examples were reiterated in terms of intensive development of the oil, gas and mineral sectors in Norway as well as the land use impact of the tourist economy in coastal and island regions of Spain. At the same time, we were also able to see the profound levels of land use extensification, for instance in Poland due to the lack of investment in the transition of subsistence farming into a competitive agricultural industry. And in that connection also identify regions where former policy measures (and support mechanisms) have been replaced by other resulting in a time slot where moving from one set of constraints to another may have unforeseen and maybe also unwanted consequences in land use patterns.

In an effort to combine the measures of amount of change and intensity, and to flag regions where one, the other, or both phenomenon have taken place the Land change hotspots indicator was generated. It especially emphasized regions with combined high intensification and area of land change, regions which should, at a minimum, take note of how future land use changes interact with goals of biodiversity, landscape preservation, environmental protection, etc. This in turn would promote increased focus on activities such as brownfield development and infilling rather than continuing land take for urban development. However, such endeavours require coordinated policy approaches if they are to succeed in changing patterns of urban development.

The maps of “hotspots” represent a generalization of land changes which are based on absolute changes in land use. This is advantageous because there is no chance that it “misrepresents” certain land change phenomenon taking place in the regions. At the same time, it lacks in terms of characterizing the underlying processes that are actually the result of these intensifications, extensifications and/or high amounts of overall land change (i.e. the changing social and economic activities that take place as a result of such changes).

As an attempt to account for this void, the intention of the Land use change typology was to trade-out the measure of amount of land change in the hotspots map and replace it with a characterization of changing land uses. Regionalized land use change intensity is therefore combined with the distribution of the most telling groups of land cover changes (LCF’s) in a cluster analysis, and then grouping the results into descriptive Land use change types.

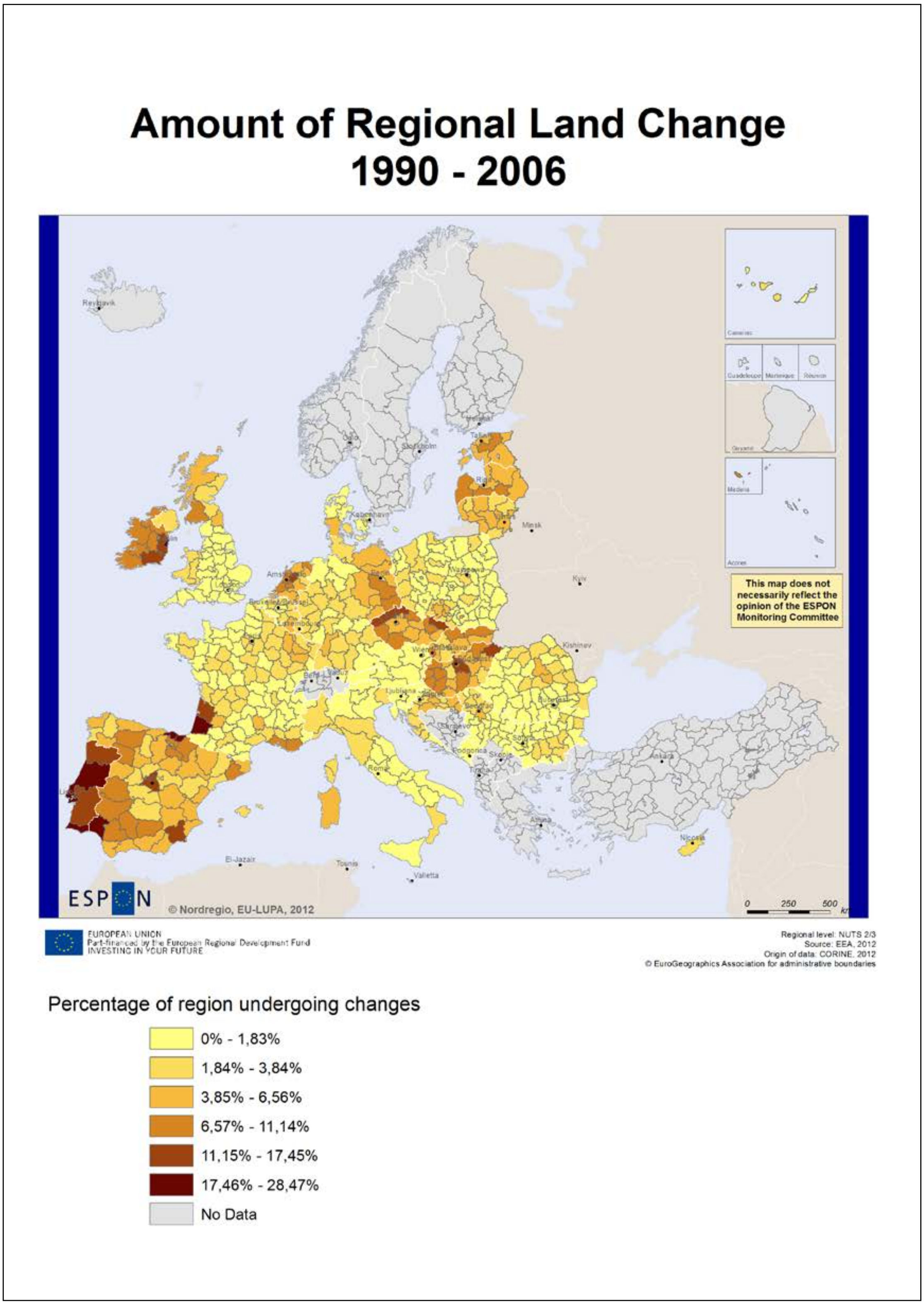
By comparing Map 11 - Hotspots of land change – 1990-2006 - and Map 14 - Land Use Change Typology – 1990-2006 – it is straightforward to see that many of the regions noted as a hotspot of land change are reflected as regions in shades of purple or bright orange – as being regions of at least moderate intensification. In this connection, the main benefit of the Land use change typology is that it is able to reflect a limited number of dominant characteristics of land use changes; especially, urbanization from natural areas, intensive urbanization, maintenance of rural functions, agricultural withdrawal, etc. In terms of urbanization for instance, it adds another dimension where population or employment data is often used to reflect the urban development of regions. Complementing this, we can now see a regional dimension to these processes as they take place, literally, on the ground. In this connection, a direction of further work could be to make a closer comparison to land changes resulting in new or maintained urban areas, and to compare this data with regional – or even municipal – population data. This could give an interesting insight into places that are either maintaining or growing their population (labour force) and what the implications re in terms of land take and urbanization.

While the descriptions of the Land use change types highlighted a number of very interesting trends – trends which were largely validated in the case studies - the reality is that they represent a further generalization of land change processes. And while it was shown to be beneficial to generalize land change trends it is also potentially misleading; not least due to the fact that any changes deviating from the “average changes” or dominant changes are not well reflected. Most notably, this relates to the “scale effect” where, as mentioned, rural land changes that are more extensive in area than concentrated urban changes are dominant in terms of average regional change. Consequently, the results of the Land use change types can have a tendency to over generalize land changes - and the processes behind those changes – for some region, especially relatively large ones.

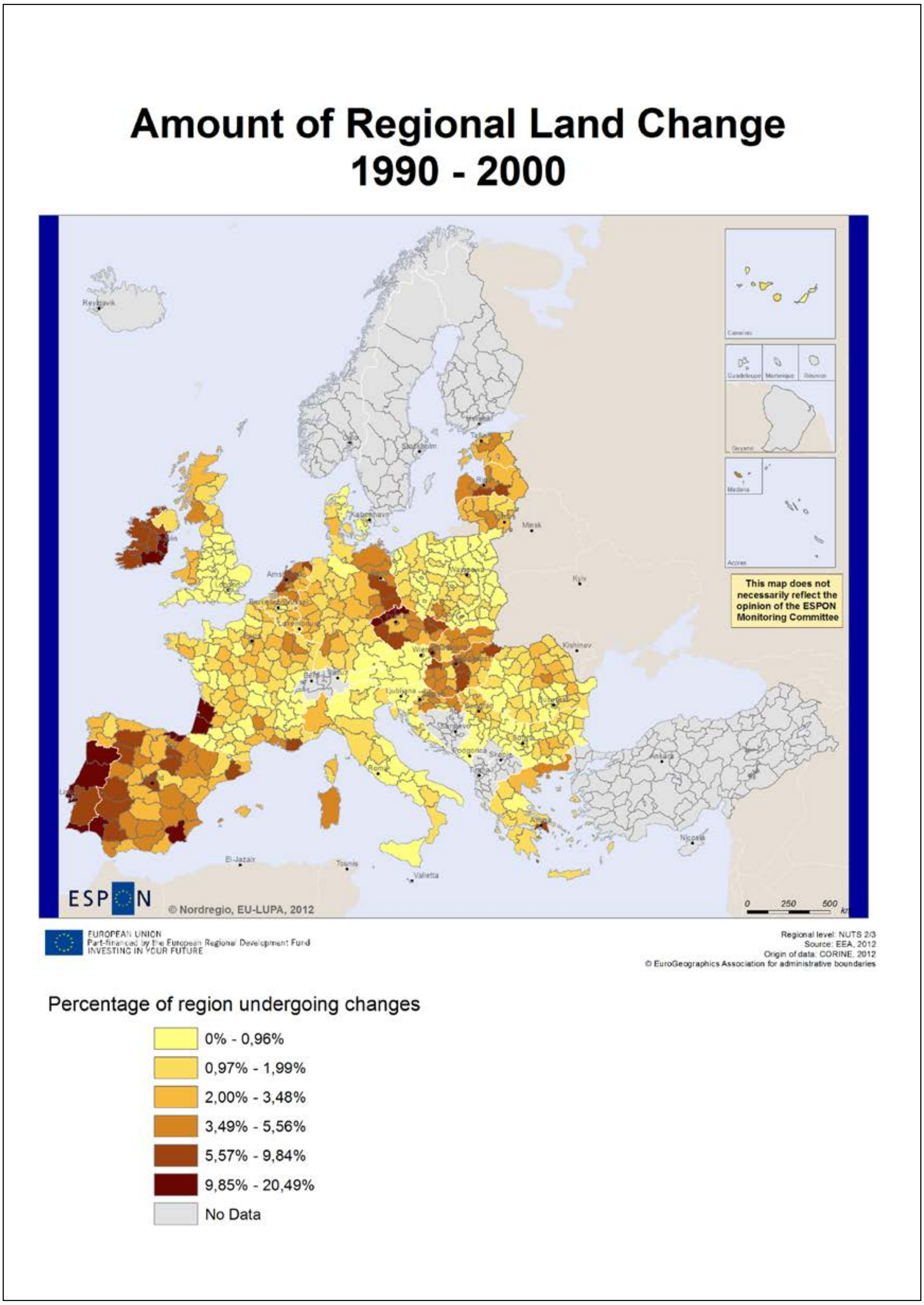
Two examples of this were mentioned; in the Skåne region of Southern Sweden (where urban sprawl resulting from the construction of the Oresund Bridge was reflected in the typology because of the dominant agricultural and forest conversions) and to a lesser extent in region containing Madrid. Thus, the Land use change typology's asset of providing a general picture of the characteristics of land changes is also its weakness. It shows that generalizing can be a risky objective; especially in terms of regional patterns of land use where a variety of interacting and independent changes reflect a very complex set of regional processes.

5 Appendix

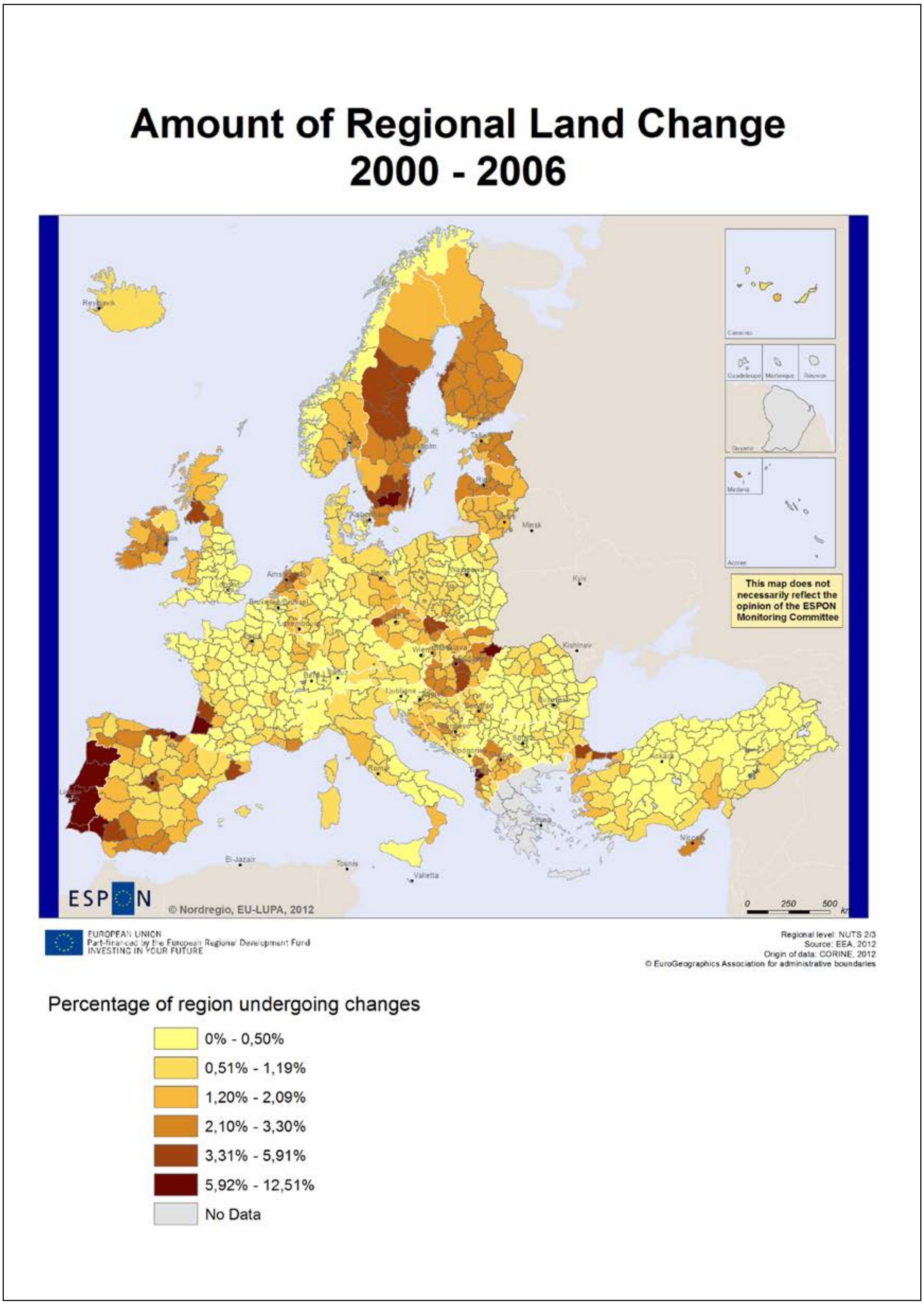
5.1 Amount of land change per region



Map 17 Amount of land change per region 1990-2006



Map 18 Amount of land change per region 1990-2000



Map 19 Amount of land change per region 2000-2006

5.2 CLC characteristics of the Prevailing characteristics of land use types – grid level

Table 15 The Distribution of the 44 CLC classes in 1990 among the land use types (gridded)

Corine land cover classes	#	Land Use Types												
		U4: Urban cores and metropolitan areas	U3: Suburban residential and economic land extending into peri-urban areas	U5: Dinscontinuous or isolated urban areas	R14: Arable land in predominantly rural areas		U2: Pastures and agricultural mosaics in peri-urban or rural community areas	U6: Forested areas and agricultural mosaics in peri-urban areas	R12: Pastures, agricultural mosaics and mixed forest in predominantly rural areass	R15: Rural Forest		R13: Transitional woodland or sparsely vegetated areas	R1: Lands primarily associated with water courses or intertidal flats	R17: Sparse vegetation, wetlands and snow or arctic conditions
Continuous urban fabric	1	4 600	849	1 239	0	0	0	14	0	0	0	0	0	0
Discontinuous urban fabric	2	80 325	45 930	18 684	0	0	31	277	0	0	0	0	0	0
Industrial or commercial units	3	11 025	4 965	3 369	0	0	17	60	0	0	0	0	1	0
Road and rail networks and associated land	4	601	513	198	0	0	3	10	0	0	0	0	0	0
Port areas	5	108	32	730	0	0	0	84	0	0	0	0	5	0
Airports	6	2 046	1 114	232	0	0	3	16	0	0	0	0	0	0
Mineral extraction sites	7	1 247	3 783	646	0	0	301	515	0	0	0	0	46	0
Dump sites	8	298	606	135	0	0	79	56	0	0	0	0	0	0
Construction sites	9	433	511	175	0	0	56	126	0	0	0	0	44	0
Green urban areas	10	1 678	598	512	0	0	5	19	0	0	0	0	1	0
Sport and leisure facilities	11	1 116	1 747	705	0	0	78	37	0	0	0	0	1	0
Arable land	12	76 040	120 615	10 589	794 885	239 783	5 520	586	30 067	1 033	29	17	23	0
Arable land	13	4 213	3 844	547	59 823	18 750	268	78	1 474	134	4	1	0	0
Arable land	14	476	276	45	5 645	1 428	22	6	168	39	0	1	0	0
Permanent crops	15	416	1 104	388	22 671	7 594	6 783	83	3 904	140	3	2	3	0
Permanent crops	16	259	483	438	11 200	5 742	6 747	175	4 656	154	66	0	2	0
Permanent crops	17	53	151	204	16 754	7 805	4 039	165	14 716	542	136	0	1	0
Pastures	18	1 129	2 642	1 065	55 664	24 847	55 959	4 731	239 197	12 881	2 836	82	35	16
Heterogeneous agricultural areas	19	33	170	27	340	240	1 565	301	7 197	136	276	0	0	0
Heterogeneous agricultural areas	20	1 211	2 543	644	16 244	5 875	53 655	8 547	208 285	8 816	16 564	37	35	1
Heterogeneous agricultural areas	21	142	643	340	9 312	3 068	27 503	8 739	153 516	20 333	71 889	282	48	13
Heterogeneous agricultural areas	22	2	21	0	15	42	194	163	10 464	676	20 649	28	1	0
Forests	23	30	175	71	377	824	20 703	13 255	184 967	48 052	296 813	328	44	501
Forests	24	15	199	65	18	243	4 574	25 013	153 518	149 482	444 851	898	94	2 363
Forests	25	10	103	44	4	141	2 649	15 479	62 277	48 064	198 893	1 033	37	1 749
Scrub and/or herbaceous vegetation associations	26	38	172	28	33	137	691	5 787	29 648	8 570	164 768	6 637	159	598
Scrub and/or herbaceous vegetation associations	27	6	33	35	0	10	116	1 156	2 406	33 880	121 272	7 692	236	8 445
Scrub and/or herbaceous vegetation associations	28	5	74	34	1	36	211	4 015	7 436	4 715	64 416	26 741	458	637
Scrub and/or herbaceous vegetation associations	29	3	108	27	10	106	363	8 679	13 846	21 325	133 213	113 279	588	14 651
Open spaces with little or no vegetation	30	0	2	4	0	1	9	329	351	657	277	1 977	249	3 520
Open spaces with little or no vegetation	31	0	0	0	0	0	6	194	116	262	380	20 206	179	71 335
Open spaces with little or no vegetation	32	1	2	6	0	5	25	1 069	1 177	721	359	84 681	1 932	142 255
Open spaces with little or no vegetation	33	0	2	0	0	0	1	98	41	13	282	889	12	256
Open spaces with little or no vegetation	34	0	0	5	0	0	18	504	0	0	0	4	715	16 705
Inland wetlands	35	0	1	5	0	33	1	61	198	221	24	5 931	353	6 439
Inland wetlands	36	0	0	2	0	2	2	27	14	159	8	31 580	358	60 777
Maritime wetlands	37	0	0	0	0	0	0	2	2	25	0	1 326	146	1 562
Maritime wetlands	38	0	0	0	0	0	0	19	0	0	0	204	925	456
Maritime wetlands	39	0	0	11	0	0	0	294	0	14	0	1 162	2 327	9 118
Inland waters	40	0	0	14	0	0	3	179	2	69	0	4 588	5 091	2 361
Inland waters	41	0	0	1	0	2	0	6	44	137	0	23 137	326	92 722
Marine waters	42	0	0	1	0	0	0	5	0	0	0	636	534	5 001
Marine waters	43	0	0	12	0	0	0	13	0	9	0	355	583	2 291
Marine waters	44	0	0	0	0	0	0	0	0	13	0	604	0	2 827
Total (km^2)		187 559	194 011	41 277	192 200	100 972	992 996	316 714	1 129 687	361 272	1 538 008	334 338	15 592	446 599
Percent		3,20	3,31	0,70	3,28	1,72	16,96	5,41	19,29	6,17	26,26	5,71	0,27	7,63

Table 16 The Distribution of the 44 CLC classes in 2000 among the land use types (gridded)

Corine land cover classes	#	Land Use Types: U4: Urban cores and metropolitan areas	U3: Suburban residential and economic land extending into peri-urban areas	U5: Dinscontinuous or isolated urban areas	R14: Arable land in predominantly rural areas		U2: Pastures and agricultural mosaics in peri-urban or rural community areas	U6: Forested areas and agricultural mosaics in peri-urban areas	R12: Pastures, agricultural mosaics and mixed forest in predominantly rural areass	R15: Rural Forest		R13: Transitional woodland or sparsely vegetated areas	R1: Lands primarily associated with water courses or intertidal flats	R17: Sparse vegetation, wetlands and snow or arctic conditions
Continuous urban fabric	1	4 711	951	1 259	0	0	3	15	0	0	0	0	0	0
Discontinuous urban fabric	2	81 923	48 264	18 994	0	0	66	307	0	0	0	0	2	0
Industrial or commercial units	3	12 098	6 118	3 542	0	0	33	80	0	0	0	0	2	0
Road and rail networks and associated land	4	661	665	219	0	0	11	20	0	0	0	0	0	0
Port areas	5	114	36	764	0	0	0	90	0	0	0	0	14	0
Airports	6	2 070	1 138	233	0	0	1	19	0	0	0	0	0	0
Mineral extraction sites	7	1 461	4 281	732	0	0	323	293	0	0	0	0	0	0
Dump sites	8	307	644	135	0	0	43	30	0	0	0	0	0	0
Construction sites	9	422	667	166	0	0	126	127	0	0	0	0	1	0
Green urban areas	10	1 674	607	514	0	0	15	19	0	0	0	0	1	0
Sport and leisure facilities	11	1 163	1 898	731	0	0	129	47	0	0	0	0	1	0
Arable land	12	74 019	119 724	10 356	789 419	237 038	3 786	442	42 401	1 433	281	267	3	4
Arable land	13	4 179	3 857	538	59 810	18 691	281	82	1 712	139	37	30	0	2
Arable land	14	469	277	47	5 803	1 478	23	6	191	35	0	7	0	0
Permanent crops	15	377	1 035	384	22 008	7 434	6 771	77	3 943	139	25	4	2	0
Permanent crops	16	140	327	418	11 501	5 815	6 784	162	5 124	157	144	10	0	0
Permanent crops	17	34	74	206	17 137	7 926	4 033	161	14 572	536	147	13	1	0
Pastures	18	682	1 676	977	55 554	24 205	56 916	4 728	235 042	12 114	3 989	447	19	34
Heterogeneous agricultural areas	19	7	36	16	447	264	1 523	296	6 896	127	301	0	0	0
Heterogeneous agricultural areas	20	938	1 340	533	15 966	5 854	54 182	8 572	198 928	8 605	16 861	104	25	5
Heterogeneous agricultural areas	21	77	261	290	10 013	3 228	27 637	8 690	148 338	20 004	72 775	573	35	36
Heterogeneous agricultural areas	22	0	1	0	328	172	189	170	10 656	660	21 128	4	0	0
Forests	23	22	48	54	651	1 024	20 755	13 410	183 200	48 047	293 852	512	35	522
Forests	24	2	23	50	270	457	4 505	24 782	151 697	145 652	433 027	1 350	87	2 399
Forests	25	2	13	40	86	396	2 624	15 510	64 301	49 302	202 040	1 432	36	1 790
Scrub and/or herbaceous vegetation associations	26	5	18	16	166	256	662	5 744	30 881	8 375	163 062	7 764	158	1 220
Scrub and/or herbaceous vegetation associations	27	0	4	19	13	17	117	1 148	2 630	33 026	115 073	5 091	234	7 264
Scrub and/or herbaceous vegetation associations	28	1	4	8	12	81	175	3 989	7 268	4 678	64 118	26 659	463	685
Scrub and/or herbaceous vegetation associations	29	1	22	15	177	460	404	8 952	18 170	23 911	145 950	113 648	598	14 991
Open spaces with little or no vegetation	30	0	0	4	2	14	9	326	348	740	282	1 899	248	3 531
Open spaces with little or no vegetation	31	0	0	0	0	0	5	193	93	249	582	18 955	179	70 886
Open spaces with little or no vegetation	32	0	1	0	2	22	43	1 195	1 176	811	2 173	83 875	1 934	142 455
Open spaces with little or no vegetation	33	0	0	0	1	1	0	42	44	24	550	461	11	62
Open spaces with little or no vegetation	34	0	0	1	0	0	22	508	0	0	0	4	710	16 280
Inland wetlands	35	0	0	0	9	62	1	53	166	323	36	5 559	352	6 357
Inland wetlands	36	0	0	1	1	7	1	24	62	992	1 356	33 549	358	61 672
Maritime wetlands	37	0	0	0	0	19	0	3	6	78	1	1 379	147	1 651
Maritime wetlands	38	0	0	0	0	0	0	19	0	0	0	140	921	439
Maritime wetlands	39	0	0	10	0	2	0	308	0	74	0	1 238	2 337	9 040
Inland waters	40	0	1	4	1	31	2	315	149	189	15	4 569	5 261	2 371
Inland waters	41	0	0	0	10	67	0	4	155	542	59	23 181	327	92 375
Marine waters	42	0	0	0	0	0	0	6	0	3	1	623	530	5 009
Marine waters	43	0	0	1	0	2	0	8	0	9	0	232	560	1 781
Marine waters	44	0	0	0	0	2	0	0	2	101	0	728	0	3 735
Total (km^2)		187 559	194 011	41 277	989 387	315 025	192 200	100 972	1 128 151	361 075	1 537 865	334 307	15 592	446 596
Percent		3,20	3,31	0,70	16,89	5,38	3,28	1,72	19,26	6,17	26,26	5,71	0,27	7,63

Table 17 The Distribution of the 44 CLC classes in 2006 among the land use types (gridded)

Corine land cover classes	#	Land Use Types: U4: Urban cores and metropolitan areas	U3: Suburban residential and economic land extending into peri-urban areas	U5: Disconntinuous or isolated urban areas	R14: Arable land in predominantly rural areas		U2: Pastures and agricultural mosaics in peri-urban or rural community areas	U6: Forested areas and agricultural mosaics in peri-urban areas	R12: Pastures, agricultural mosaics and mixed forest in predominantly rural areass	R15: Rural Forest		R13: Transitional woodland or sparsely vegetated areas	R1: Lands primarily associated with water courses or intertidal flats	R17: Sparse vegetation, wetlands and snow or arctic conditions
Continuous urban fabric	1	4 604	978	1 234	0	0	35	23	3	0	0	0	0	0
Discontinuous urban fabric	2	82 659	49 650	19 172	0	0	1 501	511	36	0	0	0	0	0
Industrial or commercial units	3	12 866	6 691	3 632	0	0	285	152	6	0	0	0	0	0
Road and rail networks and associated land	4	693	730	216	0	0	74	40	0	0	0	0	0	0
Port areas	5	118	36	777	0	0	5	99	16	0	0	0	0	0
Airports	6	2 102	1 115	240	0	0	29	35	0	0	0	0	0	0
Mineral extraction sites	7	1 474	4 057	668	0	0	366	287	6	0	0	0	0	0
Dump sites	8	285	601	138	0	0	42	37	7	0	0	0	0	0
Construction sites	9	310	392	152	0	0	183	104	4	0	0	0	0	0
Green urban areas	10	1 575	509	496	0	0	156	34	1	0	0	0	0	0
Sport and leisure facilities	11	1 303	2 054	800	0	0	368	106	2	0	0	0	0	0
Arable land	12	71 949	115 001	10 150	795 323	240 398	9 697	768	15	33 713	1 136	264	136	7
Arable land	13	4 113	3 809	507	57 561	18 027	262	84	0	1 358	122	1	7	1
Arable land	14	472	275	45	5 647	1 340	20	5	0	163	40	12	0	0
Permanent crops	15	386	922	376	22 691	7 583	6 470	86	1	3 929	137	8	4	0
Permanent crops	16	126	340	389	11 214	5 620	6 602	189	0	4 400	150	60	2	0
Permanent crops	17	28	58	202	16 345	7 710	3 949	170	2	14 553	543	130	13	0
Pastures	18	1 306	3 042	907	57 775	24 687	54 849	4 835	60	237 492	12 902	2 916	187	20
Heterogeneous agricultural areas	19	6	38	13	348	257	1 412	271	0	7 307	144	290	4	0
Heterogeneous agricultural areas	20	984	2 237	524	16 339	5 957	50 400	8 580	46	207 458	8 740	16 504	59	5
Heterogeneous agricultural areas	21	156	782	294	9 347	3 183	26 071	8 647	60	153 446	20 359	72 143	346	29
Heterogeneous agricultural areas	22	0	0	0	59	55	187	164	0	10 375	660	20 174	56	3
Forests	23	11	208	83	372	833	20 344	13 228	65	183 708	47 902	295 397	475	509
Forests	24	2	115	46	32	277	4 414	24 320	93	153 837	149 488	447 257	1 536	2 381
Forests	25	5	63	43	4	171	2 756	15 650	52	62 332	48 093	198 633	1 266	1 752
Scrub and/or herbaceous vegetation associations	26	6	51	17	127	364	626	5 386	171	29 801	8 557	165 405	6 805	650
Scrub and/or herbaceous vegetation associations	27	2	10	15	1	12	112	1 030	217	2 448	33 893	121 593	7 808	8 452
Scrub and/or herbaceous vegetation associations	28	1	19	8	25	151	149	3 959	454	7 520	4 743	65 111	26 981	670
Scrub and/or herbaceous vegetation associations	29	14	210	43	10	131	651	9 258	595	13 907	21 216	130 467	111 089	14 307
Open spaces with little or no vegetation	30	0	1	7	0	4	11	279	238	352	661	291	1 985	3 508
Open spaces with little or no vegetation	31	0	0	0	0	0	1	179	119	116	264	392	20 227	71 247
Open spaces with little or no vegetation	32	3	2	2	7	43	45	1 003	1 944	1 236	730	515	84 605	142 212
Open spaces with little or no vegetation	33	0	0	0	0	2	0	40	2	31	22	357	1 068	365
Open spaces with little or no vegetation	34	0	3	6	0	0	43	398	653	0	0	0	5	16 805
Inland wetlands	35	0	3	0	1	42	3	66	346	200	251	21	5 920	6 440
Inland wetlands	36	0	0	0	0	8	1	29	384	25	277	49	32 164	61 043
Maritime wetlands	37	0	0	0	0	0	0	3	95	4	30	0	1 322	1 558
Maritime wetlands	38	0	0	2	0	0	0	19	939	0	0	0	202	442
Maritime wetlands	39	0	4	27	0	0	19	385	2 312	0	13	0	1 178	9 026
Inland waters	40	0	5	37	0	13	62	481	5 221	6	72	0	4 581	2 362
Inland waters	41	0	0	0	0	5	0	5	330	24	107	2	22 706	92 557
Marine waters	42	0	0	2	0	0	0	6	374	0	1	0	637	5 003
Marine waters	43	0	0	7	0	0	0	21	723	0	8	0	354	2 291
Marine waters	44	0	0	0	0	0	0	0	0	1	22	16	612	2 954
Total (km^2)		187 559	194 011	41 277	993 228	316 873	192 200	100 972	15 592	1 129 742	361 283	1 538 008	334 340	446 599
Percent		3,20	3,31	0,70	16,96	5,41	3,28	1,72	0,27	19,29	6,17	26,26	5,71	7,63

5.3 CLC characteristics of the Prevailing characteristics of land use types – regional level

Table 18 The Distribution of the CLC classes in 1990 among the regional land use types

	CLC classes		Cluster Numbers													
			CL15	CL16	cl20	CL02	CL07	CL03	CL-05	CL09	CL04	CL6	CL12	CL11	CL01	CL10
1	Artificial surfaces	Continuous Urban Fabric	50,65	16,97	11,67	4,46	3,77	3,63	3,47	2,26	2,95	2,76	1,63	1,12	0,62	0,32
2	Artificial surfaces	Discontinuous urban fabric														
3	Artificial surfaces	Industrial or commercial units														
4	Artificial surfaces	Roads and rail networks and associated land	10,55	2,47	2,59	0,71	0,52	0,56	0,44	0,28	0,41	0,33	0,30	0,18	0,14	0,11
5	Artificial surfaces	Port areas														
6	Artificial surfaces	Airports														
7	Artificial surfaces	Mineral extraction sites														
8	Artificial surfaces	Dump sites														
9	Artificial surfaces	Construction sites														
10	Artificial surfaces	Green urban areas														
11	Artificial surfaces	Port and leisure facilities														
12	Agricultural areas	Non-irrigated arable land	11,67	33,43	28,85	72,31	52,76	41,07	22,78	8,12	28,67	12,13	15,45	16,94	2,22	0,71
13	Agricultural areas	Permanently irrigated land														
14	Agricultural areas	Rice fields														
15	Agricultural areas	Vineyards														
16	Agricultural areas	Fruit trees and berry plantations	12,13	24,92	28,43	10,08	20,88	19,38	44,78	54,50	17,05	27,46	19,09	16,76	2,87	3,29
17	Agricultural areas	Olive groves														
18	Agricultural areas	Pastures														
19	Agricultural areas	Annual crops ass. With permanent crops														
20	Agricultural areas	Complex cultivation														
21	Agricultural areas	Agriculture with sign. Areas of natural vegetation														
22	Agricultural areas	Agro-forestry areas														
23	Forest and semi natural areas	Broad leaved forests	9,84	18,67	26,24	9,19	18,45	33,06	21,65	32,77	44,42	53,75	53,94	31,69	75,92	42,79
24	Forest and semi natural areas	Coniferous forests														
25	Forest and semi natural areas	Mixed forests														
26	Forest and semi natural areas	Natural grasslands														
27	Forest and semi natural areas	Moors and heathland														
28	Forest and semi natural areas	Sclerophyllous vegetation														
29	Forest and semi natural areas	Transitional woodland shrub														
30	Forest and semi natural areas	Beaches, dunes, sands	0,08	0,13	0,25	0,13	1,33	0,55	0,27	0,03	3,60	2,20	8,19	28,85	3,30	42,68
31	Forest and semi natural areas	Bare rocks														
32	Forest and semi natural areas	Sparsely vegetated areas														
33	Forest and semi natural areas	Burnt areas														
34	Forest and semi natural areas	Glaciers and perpetual snow														
35	Wetlands	Inland marshes	4,98	3,37	1,90	3,09	2,24	1,73	6,53	1,99	2,82	1,33	1,32	4,45	14,86	9,77
36	Wetlands	Peat bogs														
37	Wetlands	Salt marshes														
38	Wetlands	Salines														
39	Wetlands	Intertidal flats														
40	Water bodies	Water courses														
41	Water bodies	Water bodies														
42	Water bodies	Coastal lagoons														
43	Water bodies	Estuaries														
44	Water bodies	Sea and ocean	0,08	0,04	0,08	0,03	0,05	0,02	0,08	0,05	0,08	0,05	0,08	0,01	0,07	0,33
		Number of regions	29	32	21	41	97	81	52	18	97	171	56	56	30	27
		Percent of Europe	0,22	1,38	1,20	3,57	11,89	10,82	5,48	2,05	15,24	17,75	7,09	4,60	12,89	5,81
			Urban cores and metropolitan areas	Suburban areas	Suburban or peri-urban areas	Arable land in peri-urban and rural areas	Arable land and pastures in predominantly rural areas	Rural arable land with permanent crops and some forest	Rural mix dominated by pastures with some arable land	Rural pastures and complex cultivation paaterns	Diverse land use in rural areas	Diverse rural forest coverage with dispersed areas of permanent crops, pastures and arable land	Arid mixed forest	Sparse vegetation with some forest and pasture	Rural forest	Sparsely vegetated areas

Table 19 The Distribution of the CLC classes in 2000 among the regional and use types

	CLC classes		CL15	CL16	cl20	CL02	CL07	CL03	CL-05	CL09	CL04	CL6	CL12	CL11	CL01	CL10
			Cluster Numbers													
1	Artificial surfaces	Continuous Urban Fabric	51,27	17,68	12,66	4,58	3,92	3,77	3,75	2,33	2,87	1,75	3,03	1,13	0,62	0,32
2	Artificial surfaces	Discontinuous urban fabric														
3	Artificial surfaces	Industrial or commercial units														
4	Artificial surfaces	Roads and rail networks and associated land	10,55	2,59	2,88	0,74	0,54	0,58	0,51	0,32	0,37	0,35	0,43	0,19	0,14	0,11
5	Artificial surfaces	Port areas														
6	Artificial surfaces	Airports														
7	Artificial surfaces	Mineral extraction sites														
8	Artificial surfaces	Dump sites														
9	Artificial surfaces	Construction sites														
10	Artificial surfaces	Green urban areas														
11	Artificial surfaces	Port and leisure facilities														
12	Agricultural areas	Non-irrigated arable land	11,13	32,95	28,31	72,19	52,58	40,56	23,19	8,23	11,96	15,36	28,56	16,97	2,22	0,71
13	Agricultural areas	Permanently irrigated land														
14	Agricultural areas	Rice fields														
15	Agricultural areas	Vineyards														
16	Agricultural areas	Fruit trees and berry plantations	12,08	24,49	27,80	10,01	20,82	19,62	43,97	54,33	27,55	18,99	17,13	16,77	2,87	3,29
17	Agricultural areas	Olive groves														
18	Agricultural areas	Pastures														
19	Agricultural areas	Annual crops ass. With permanent crops														
20	Agricultural areas	Complex cultivation														
21	Agricultural areas	Agriculture with sign. Areas of natural vegetation														
22	Agricultural areas	Agro-forestry areas														
23	Forest and semi natural areas	Broad leaved forests	9,83	18,70	26,10	9,24	18,50	33,16	22,01	32,75	53,68	53,95	44,33	31,69	75,92	42,79
24	Forest and semi natural areas	Coniferous forests														
25	Forest and semi natural areas	Mixed forests														
26	Forest and semi natural areas	Natural grasslands														
27	Forest and semi natural areas	Moors and heathland														
28	Forest and semi natural areas	Sclerophyllous vegetation														
29	Forest and semi natural areas	Transitional woodland shrub														
30	Forest and semi natural areas	Beaches, dunes, sands	0,08	0,12	0,26	0,13	1,33	0,56	0,26	0,04	2,18	8,18	3,58	28,79	3,30	42,68
31	Forest and semi natural areas	Bare rocks														
32	Forest and semi natural areas	Sparsely vegetated areas														
33	Forest and semi natural areas	Burnt areas														
34	Forest and semi natural areas	Glaciers and perpetual snow														
35	Wetlands	Inland marshes	4,97	3,44	1,91	3,09	2,28	1,74	6,23	1,99	1,34	1,34	2,85	4,45	14,86	9,77
36	Wetlands	Peat bogs														
37	Wetlands	Salt marshes														
38	Wetlands	Salines														
39	Wetlands	Intertidal flats														
40	Water bodies	Water courses														
41	Water bodies	Water bodies														
42	Water bodies	Coastal lagoons														
43	Water bodies	Estuaries														
44	Water bodies	Sea and ocean	0,08	0,03	0,08	0,03	0,03	0,02	0,08	0,01	0,05	0,08	0,08	0,00	0,07	0,33
		Number of regions	29	32	21	41	97	81	52	18	97	171	56	56	30	27
		Percent of Europe	0,22	1,38	1,20	3,57	11,89	10,82	5,48	2,05	15,24	17,75	7,09	4,60	12,89	5,81
			Urban cores and metropolitan areas	Suburban areas	Suburban or peri-urban areas	Arable land in peri-urban and rural areas	Arable land and pastures in predominantly rural areas	Rural arable land with permanent crops and some forest	Rural mix dominated by pastures with some arable land	Rural pastures and complex cultivation paaterns	Diverse land use in rural areas	Diverse rural forest coverage with dispersed areas of permanent crops, pastures and arable land	Arid mixed forest	Sparse vegetation with some forest and pasture	Rural forest	Sparsely vegetated areas

5.4 Cluster Results for the Land Use Change Typology

Table 20 Statistical results of the cluster procedure used to identify and interpret the Land use change types – 1990-2000

1990-2000	Percentage of the total area of NUTS273 regions corresponding to each Land Cover Flow									
Land Cover Flow Type	**Cluster 10**	**Cluster 7**	**Cluster 9**	**Cluster 8**	**Cluster 2**	**Cluster 3**	**Cluster 6**	**Cluster 4**	**Cluster 1**	**Cluster 5**
Number of regions	2	4	17	32	103	70	88	102	111	43
LCF1 Urban Land Management	0,04	0,01	0,26	0,09	0,09	0,05	0,05	0,02	0,01	0,02
LCF2 Urban residential sprawl	0,11	0,07	0,51	0,63	0,24	0,14	0,10	0,05	0,02	0,02
LCF3 Sprawl of economic sites and infrastructures	0,03	0,28	0,68	0,52	0,33	0,25	0,17	0,08	0,06	0,05
LCF4 Agriculture internal conversions	0,00	0,01	0,16	0,26	0,39	0,42	0,83	0,72	0,60	1,59
LCF5 Conversion from other land cover to agriculture	0,01	0,04	0,11	0,09	0,09	0,14	0,17	0,08	0,04	0,04
LCF6 Withdrawal of farming	0,00	0,00	0,06	0,08	0,06	0,09	0,17	0,10	0,13	0,26
LCF7 Forests creation and management	0,00	0,00	0,11	0,62	0,45	0,81	1,37	1,53	1,08	1,16
	Percentage of each Land Cover Flow accounting for the total land change in regions									
LCF1 Urban Land Management	21,72	2,05	12,89	3,60	4,94	2,58	1,67	0,67	0,52	0,54
LCF2 Urban residential sprawl	58,40	17,57	25,79	25,04	13,78	6,87	3,18	1,81	1,19	0,77
LCF3 Sprawl of economic sites and infrastructures	15,95	68,35	34,10	20,74	18,51	12,24	5,62	3,05	2,85	1,53
LCF4 Agriculture internal conversions	0,00	1,97	8,17	10,33	22,20	20,67	27,68	26,88	29,92	49,57
LCF5 Conversion from other land cover to agriculture	3,13	10,07	5,49	3,73	4,88	6,87	5,81	2,83	2,10	1,17
LCF6 Withdrawal of farming	0,00	0,00	2,91	3,11	3,28	4,61	5,73	3,73	6,29	8,16
LCF7 Forests creation and management	0,00	0,00	5,73	24,57	25,06	39,72	45,71	56,90	53,97	36,25
Land Use Change Type	**1**	**1**	**2**	**3**	**3**	**5**	**6**	**6**	**6**	**7**
Average percent of change urban (LCF 1-3)	92,02		72,78	43,30		21,69	6,85			2,84
Average change in intensity for each land change	3,69		1,98	1,30		0,72	0,21			-0,35
Average amount of change (%) (LCF 1-7 only)	0,30		1,98	2,15		2,04	2,56			3,21

Table 21 Statistical results of the cluster procedure used to identify and interpret the Land use change types – 2000-2006

2000-2006	Percentage of the total area of NUTS273 regions corresponding to each Land Cover Flow									
Land Cover Flow Type	Cluster 10	Cluster 9	Cluster 7	Cluster 5	Cluster 6	Cluster 4	Cluster 3	Cluster 2	Cluster 1	Cluster 8
Number of regions	2	10	16	48	107	72	148	123	198	17
LCF1 Urban Land Management	0,00	0,05	0,05	0,06	0,12	0,04	0,04	0,02	0,01	0,09
LCF2 Urban residential sprawl	0,00	0,07	0,11	0,11	0,22	0,08	0,05	0,03	0,01	0,01
LCF3 Sprawl of economic sites and infrastructures	0,02	0,37	0,22	0,27	0,28	0,17	0,11	0,08	0,04	0,06
LCF4 Agriculture internal conversions	0,00	0,01	0,04	0,06	0,04	0,07	0,10	0,08	0,13	0,35
LCF5 Conversion from other land cover to agriculture	0,00	0,00	0,06	0,03	0,02	0,03	0,05	0,04	0,02	0,02
LCF6 Withdrawal of farming	0,00	0,00	0,01	0,02	0,02	0,02	0,02	0,03	0,04	0,32
LCF7 Forests creation and management	0,00	0,01	0,09	0,14	0,16	0,31	0,46	0,80	1,25	0,72
	Percentage of each Land Cover Flow accounting for the total land change in regions									
LCF1 Urban Land Management	0,00	10,07	8,12	7,21	12,61	5,43	4,50	1,80	0,96	5,27
LCF2 Urban residential sprawl	0,00	13,42	17,79	13,68	23,96	10,07	5,30	2,77	0,56	0,58
LCF3 Sprawl of economic sites and infrastructures	100,00	72,19	35,17	34,83	30,79	20,29	12,16	7,18	2,81	3,55
LCF4 Agriculture internal conversions	0,00	1,00	7,12	7,19	4,63	8,32	11,49	6,87	8,67	19,54
LCF5 Conversion from other land cover to agriculture	0,00	0,05	10,16	3,82	2,61	3,99	5,63	3,94	1,06	1,24
LCF6 Withdrawal of farming	0,00	0,00	0,96	2,67	2,40	2,81	2,45	2,81	2,84	17,79
LCF7 Forests creation and management	0,00	2,47	14,58	17,38	17,55	38,12	51,86	71,24	81,59	40,33
Land Use Change Type	**1**	**1**	**2**	**2**	**3**	**4**	**5**	**6**	**6**	**7**
Average percent of change urban (LCF 1-3)	97,84		58,41		67,36	35,79	21,96	8,04		9,40
Average change in intensity for each land change	3,75		1,93		1,30	0,95	0,64	0,19		-0,35
Average amount of change (%) (LCF 1-7 only)	0,27		0,71		0,92	0,82	0,88	1,32		1,78

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