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Forest Landscape in Europe: Pattern, Fragmentation and Connectivity

Executive report

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2012

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Forest landscape in Europe: Pattern, fragmentation and connectivity

Executive report

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Abstract

The JRC demonstrated the feasibility to assess and report in a harmonized manner, forest landscape pattern and fragmentation in Europe, on the basis of an easily reproducible set of indices. Results were used in the Forest EUROPE, UN ECE and FAO joint ministerial reporting process on the protection of forests in Europe where data on forest pattern do not exist from national forest inventories. In the EU, 40% of the forest lands are within a 100m distance from other lands, thus potentially less suitable as interior habitat and more likely to be exposed to invasive species, pests and diseases. Forest edges are also mainly (60%) along intensive land uses. In Europe, 40% of woodlands have in their 1km^2 surroundings a mosaic landscape of other natural/semi-natural lands, agriculture and artificial lands, 15% of woodlands are strongly fragmented by mainly intensive land uses. Landscapes with woodlands poorly connected represent 70% of the European territory and are potentially more vulnerable to further fragmentation in the future. National profiles of forest pattern were also provided.

The mitigation of ecosystem fragmentation is also important in new targets of the European Biodiversity strategy to 2020. By affecting ecological processes, fragmentation affects ecosystem services such as habitat provision, pollination, and has also an impact on pest propagation in different ways. Forest area is still increasing in Europe at an annual rate of 0.4% but the JRC assessment showed that new forest areas do not always enhance connectivity. For example, in the Iberian Peninsula, the net forest gain in the 1990-2006 period had no impact on connectivity for nearly 10% of the landscapes. Further, the forest fragmentation processes that were found need to be captured at landscape level. They consist of minor forest losses due to intensive agriculture, transport infrastructures, settlements and fires. These findings support the consideration of forest spatial pattern and fragmentation in sustainable forest management plans for a regional landscape planning of clearings and re/afforestation measures and for habitat provision ecosystem services, particularly in the context of climate change.

Contents

1. Forest landscape in Europe

1.1. Background

In Europe, two opposite landscape processes – anthropization and natural – threaten the provision of ecosystem functions and services. Fragmentation of forest and other natural/semi-natural lands occurs due to the expansion of agricultural areas, transport infrastructures, settlements, and fire occurrence. On the other hand, the increase of woody vegetation follows land abandonment or occurs after re/afforestation. Sustainable forest management should include concerns on landscape pattern and their changes, to address fragmentation and connectivity. Indeed, changes in pattern have impact on ecological processes such as habitat provision, gene flow, pollination, wildlife dispersal, or pest propagation in different ways.

Forest management practices integrate more and more biodiversity aspects such as deadwood, monitoring of threatened species, use of natural regeneration and mixed tree species stands (Forest Europe, 2011). In Europe at large, the increase of forest cover over the last 20 years is at an annual rate of 0.8% (0.4% in the European Union 27 Member States) with differences among regions such as 1.3% for South-West Europe and 0.15% for North Europe. However, nationally aggregated area estimates do not provide an insight into local processes of fragmentation or connectivity due to change in spatial pattern after the cumulative impact of forest losses and gains. Furthermore, expanding forest area, by natural succession or restoration does not necessarily enhance forest connectivity. For example, new forest areas may have no impact on connectivity when they are planted too remotely from other woodlands, or a minor impact when they only enlarge an existing patch. On the contrary, new forest areas in a region can contribute significantly to habitat connectivity (such as woodland islets in the landscape acting as new stepping stones between isolated patches). In Europe, forest fragmentation often consist of only minor forest losses but result in isolation of forest areas within other land use forms (intensive agriculture, artificial surfaces and burnt areas). The typical mixed forest landscape pattern is where forest is intermingled with agricultural and artificial lands; it is expanded in rural lands close to cities. Fragmentation may also be temporary and recoverable within forested areas after forest operations such as cuttings.

The JRC develops research on integrated modeling to assess and report forest landscape pattern and associated fragmentation/connectivity processes in Europe. A standardized and easily reproducible set of indices has been developed on the basis of three conceptual models. Its application European-wide contributes harmonized forest landscape pattern information to the Forest EUROPE, UN ECE and FAO joint ministerial reporting process on the protection of forests in Europe (Forest Europe, 2011) under the biodiversity criteria. Such information is not available from national inventories. Furthermore, the application of indices enables measuring progress towards achieving better ecosystem connectivity and mitigating fragmentation as requested in the European Biodiversity Strategy to 2020 (EC, 2011), in particular for target 2 on maintaining and enhancing ecosystems and their services (in this case, forest habitat provision service) and for target 3 on sustainable agriculture and forestry. The set of indices provides one tool box for strategic landscape planning to measure progress on establishing a green infrastructure approach in land (forest) management and to achieve a European territorial cohesion (ENV, 2012).

1.2. Definitions and models

Forest spatial pattern is defined as the spatial distribution of forest across the landscape. Forest connectivity is based on forest availability and distance between patches; it refers to the degree to which the landscape facilitates or impedes the movement of species with specific dispersal capabilities. Over time, the process of forest (de)fragmentation

relates to three main alterations in the landscape mosaic: pattern: insufficient (sufficient) total forest habitat area, isolation (connectivity) of forest habitat patches, and shift of land uses at edges where forest habitat areas abut modified ecosystems (interface zones).
Table 1 presents the set of standardized indices, organized into five families, which were developed to capture forest (de)fragmentation processes in the landscape. They are based on scientifically well-founded landscape ecological principles (Lindenmeyer et al., 2008) and policy requirements (Kettunen et al., 2007 and ENV, 2012).

2. Forest fragmentation at local scale

Figure 1 illustrates three landscapes with on-going local fragmentation processes. The landscapes showed a decrease in connectivity from 2000 to 2006.

Figure 1. Fragmentation examples due to, from left to right, a fire, a trans-European highway and forest clearance along a riparian area (data: JRC forest maps 2000 and 2006)

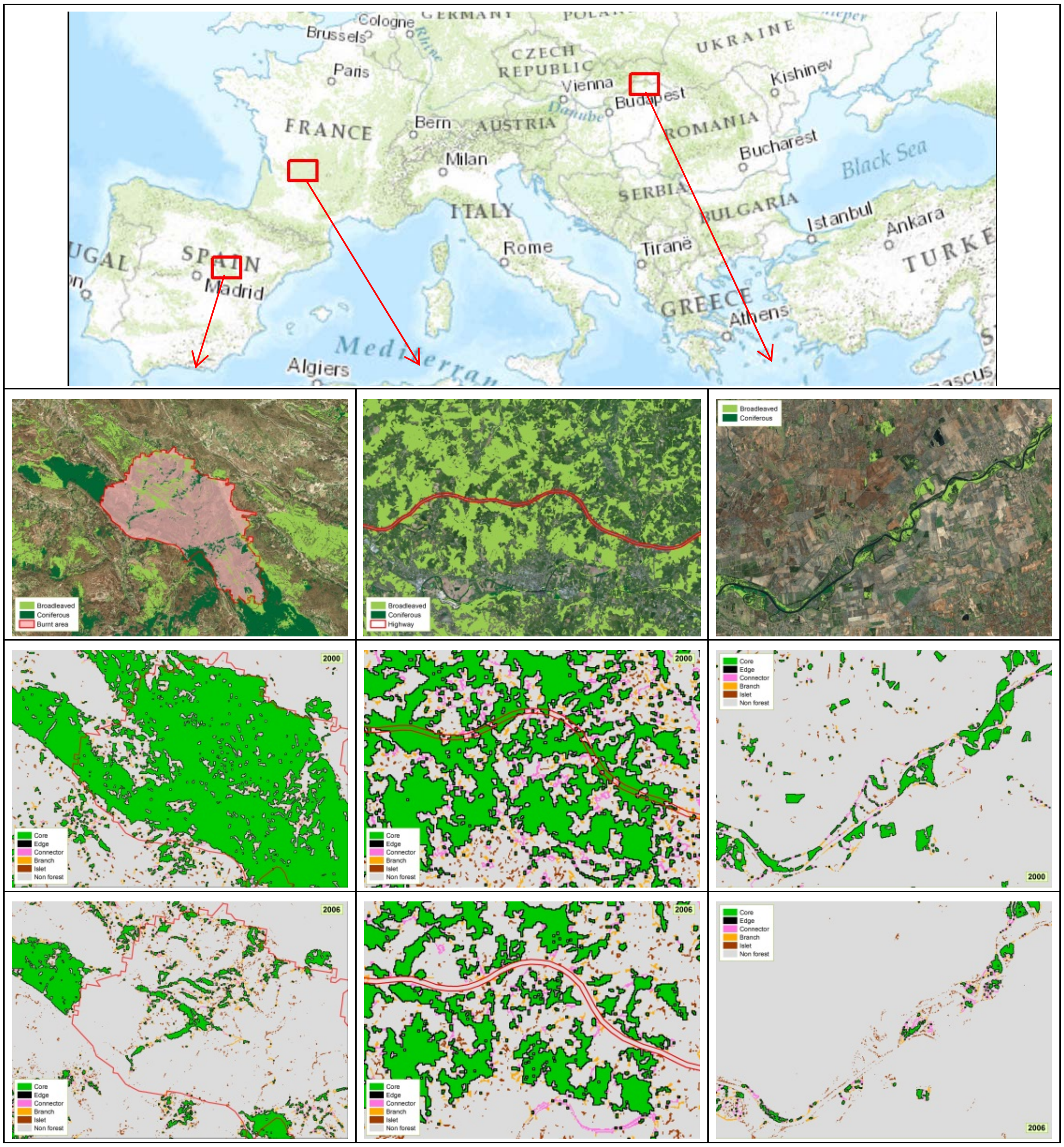
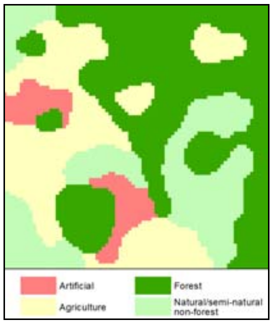


Table 1. Five families of standardised indices

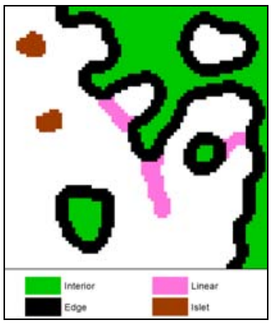


LANDSCAPE COMPOSITION

The land use/land cover of a landscape is simplified into four classes: *Forest*, *Natural non-Forest*, *Agriculture*, *Artificial*.

2 Indices: Forest land proportion; Natural/semi-natural land proportion.

Why?: Fragmentation involves the reduction of total forest habitat area. The presence of natural/semi-natural lands makes it easier for species to adapt to forest habitat losses.

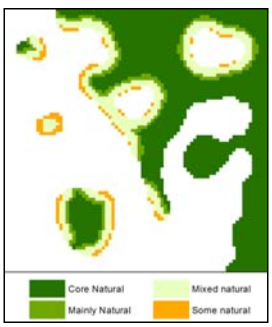


MORPHOLOGICAL SHAPES OF FOREST

The forest cover is described according to 4 classes. *Interior* forest areas are beyond a fixed distance to the border (*Edge* width), *Linear* features (e.g. encroachment of woodlands in pastures) are always connected to interior areas, while *Islets* (e.g. in agricultural fields) are physically isolated.

Indices: Forest share in *Interior*, *Edge*, *Linear feature* and in *Islet*.

Why? Fragmentation relates to the ratio of interior versus non-interior forest. Interior areas provide suitable habitat for interior species. Edges are more exposed to the penetration of invasive species. Linear features and islets are key features for habitat provision services but are often vulnerable to disappear due to their shape and size.

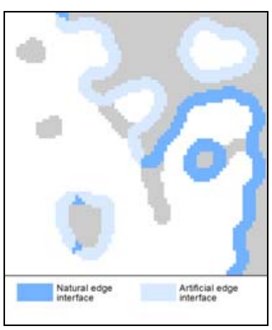


FOREST LANDSCAPE MOSAIC PATTERN

It is based on land uses in the immediate surroundings of forest lands. Forest in a *Core natural* pattern (or *Mainly natural*) are distributed in relatively large patches and/or always adjacent to other natural/semi-natural lands. Forest in a *Mixed natural* pattern are fragmented by agricultural and/or artificial land. Forest in a *Some natural* pattern are embedded in predominant agricultural or artificial context.

4 Indices: Forest shares into *Core natural*, *Mainly natural*, *Mixed natural* and *Some natural* pattern types.

Why? Fragmenting causes are either anthropogenic or natural in origin. They shape the landscape in a variety of mosaic patterns with different effects on forest species. The debate on solving fragmentation is on mitigating isolation (landscape approach by shifting from a *Some natural* pattern to a *Mixed natural* pattern) and mitigating the loss of interior habitat (developing *Core natural* patterns).

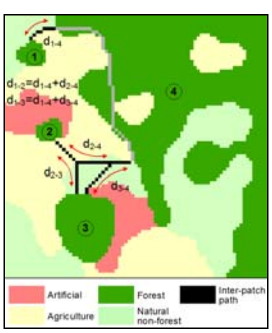


TYPES OF FOREST EDGE INTERFACES

It characterises the type of forest-non forest interfaces depending on the types (intensive/extensive) of land uses at edges. Forest *Edges* with *Core natural* pattern (i.e. along natural/semi-natural lands) are discriminated from forest *Edges* with other more anthropogenic pattern (i.e. along agricultural and/or artificial lands).

2 Indices: Forest Edge proportion along adjacent natural/semi-natural lands (*natural edge interface*) and along anthropogenic lands (*artificial edge interface*).

Why? In temperate regions, fragmentation relates to the shift in land use at forest edges. The permeability of interfaces for species dispersal depends on the similarity of adjacent habitat types to forest and is likely higher in the case of *natural edge interfaces*.



FOREST LANDSCAPE CONNECTIVITY

The probability of forest connectivity in a given landscape is derived on the basis of forest area, forest topology and the landscape permeability for a given species dispersal ability. It relates to functional distances between forest patches.

2 Indices: *Forest connectivity* (intra-patch and inter-forest patch); proxy of landscape permeability (only inter-forest patch functional distance with resistance values for the non-forest lands).

Why? Fragmentation is about isolation due to increased functional distances between patches. The lack or loss of connectivity reduces the capability of organisms to move and can interfere with pollination, seed dispersal, wildlife migration and breeding.

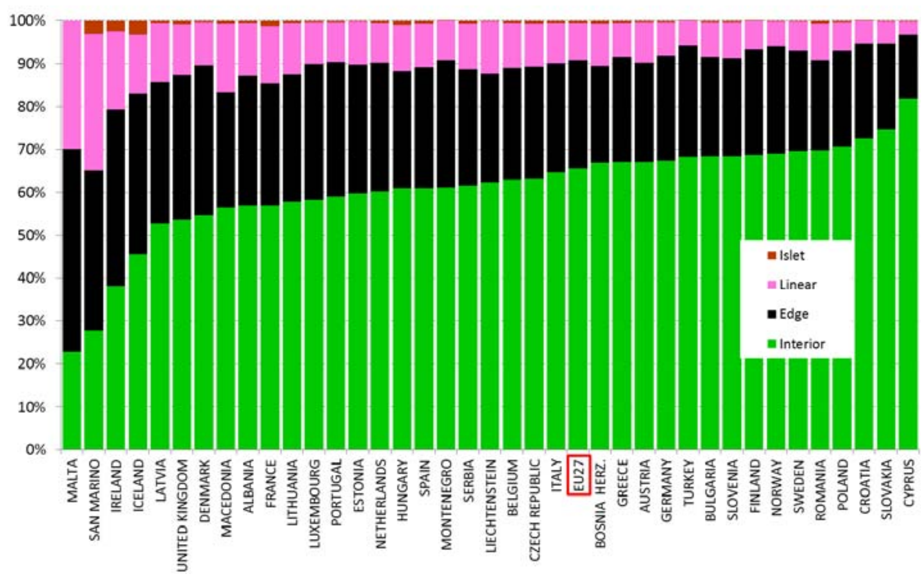
3. European-wide forest landscape pattern

European-wide application of the set of indices are based on the Corine Land Cover map (CLC, years 1990, 2000 and 2006) and the JRC 25 m Pan-European forest map of year 2006 (Kempeneers *et al.*, 2011). The former map provides broad patterns of forest with a minimum mapping unit of 25 ha, while the latter map shows spatial details down to approximately 1 ha, which is relevant for identifying hedgerows, small woodland islets and perforations in large forest patches. Forest includes broadleaved, coniferous and mixed forest. An overview of forest landscape pattern, fragmentation and connectivity for the year 2006 and broad-scale trends for the time period 1990-2000-2006 are illustrated in the next sections.

3.1. Forest morphological shape in Europe

Figure 2 provides the forest cover shares in the four different morphological shapes (Table 1). Countries are ranked per increasing share of *Interior* forest proportion. In the EU, 40 % of woodlands are within a 100m distance from other lands and thus, potentially not suitable as interior habitat and more likely to be exposed to invasive species, pests and diseases. Forest proportion in interior areas (intended as beyond a 100 m to the forest-non forest border) ranges from 20% to 70% when looking at all EU countries. For example in Central-Western Europe, despite France has more forest than Germany (16 million ha compared to 11 million ha), its woodlands are (10%) less in *Interior* areas but the proportion in *Linear* features is double compared to Germany.

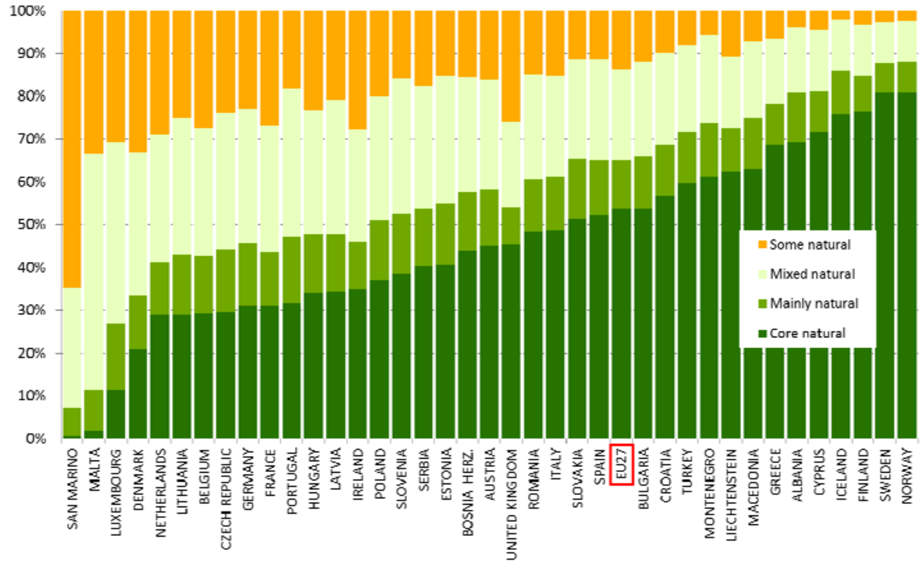
Figure 2. National profile of forest morphological shape in 2006



3.2. Landscape mosaic pattern in Europe

Figure 3 provides the forest cover shares in four pattern types, informing on how much forest is likely ‘unfragmented’ with natural/semi-natural lands in the immediate surroundings (*Core natural* and *Mainly natural* patterns) or fragmented by agriculture and artificial lands (*Mixed natural* and *Some natural* patterns). Countries are ranked per increasing share of *Core natural* pattern. In Europe, 40% of woodlands are intermingled with natural/semi-natural non forested lands, agriculture and artificial lands in their 1 km^2 surroundings; 15% of woodlands showed a strong fragmentation by mainly intensive land uses. In the Northern countries, Finland and Sweden show similar forest landscapes dominated (80% share) by a *Core natural* pattern, but the three other north-eastern countries (Estonia, Latvia, Lithuania) have a different pattern, with more than half of forest lands intermingled with agricultural and/or artificial lands (*Mixed natural* and *Some natural* pattern). Interestingly, Lithuania, Czech Republic and France show similar mosaic pattern although not belonging to the same European regions.

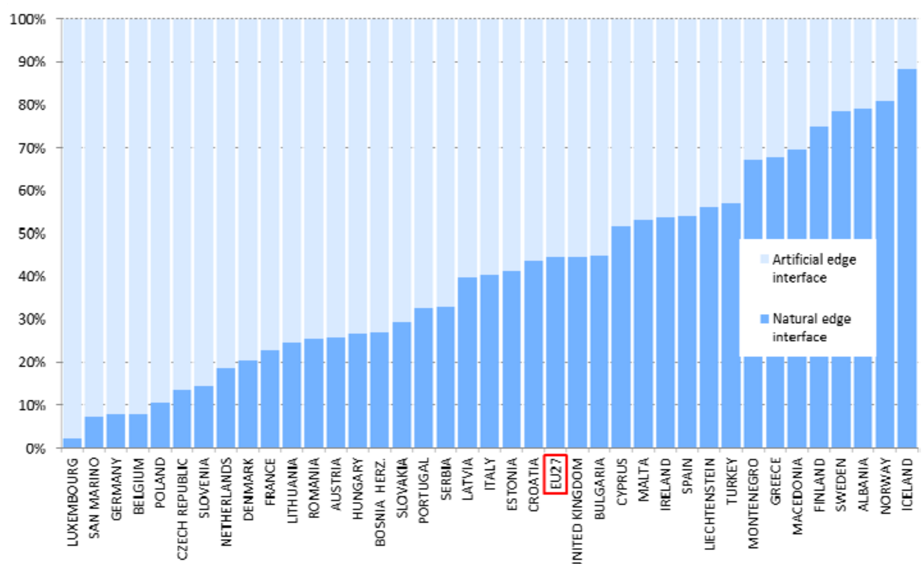
Figure 3. National profile of forest landscape pattern in 2006



3.3. Forest edge interface in Europe

Figure 4 provides the shares of forest edges along more intensive land uses (*artificial edge interface*) and along more extensive land uses (*natural edge interface*). Countries are ranked by increasing share of *natural edge interface*. In the EU, forest edges are mainly (60% share) along intensive land uses. At national level, countries from the same Mediterranean region like Italy, Spain, Portugal and Greece, exhibit different shares of *artificial forest edge interface* (see for example Greece and Portugal which have a similar forest area and forest edge amount).

Figure 4. National profile of forest edge interfaces in 2006



3.4. Landscape forest connectivity in Europe

The European-wide map in figure 5 provides the degree of forest connectivity per landscape unit of 25 km x 25 km and for forest species dispersing in average 1 km. Wooded patches as small as 1 ha were accounted in the connectivity assessment. Landscapes with no woodlands are discriminated with the index value 0% from landscapes including woods which have a forest connectivity index varying from above 0% (few woodlands and highly isolated) to 100% (all woods maximally connected).

Figure 5. European-wide forest connectivity for year 2006 (species dispersing 1 km)

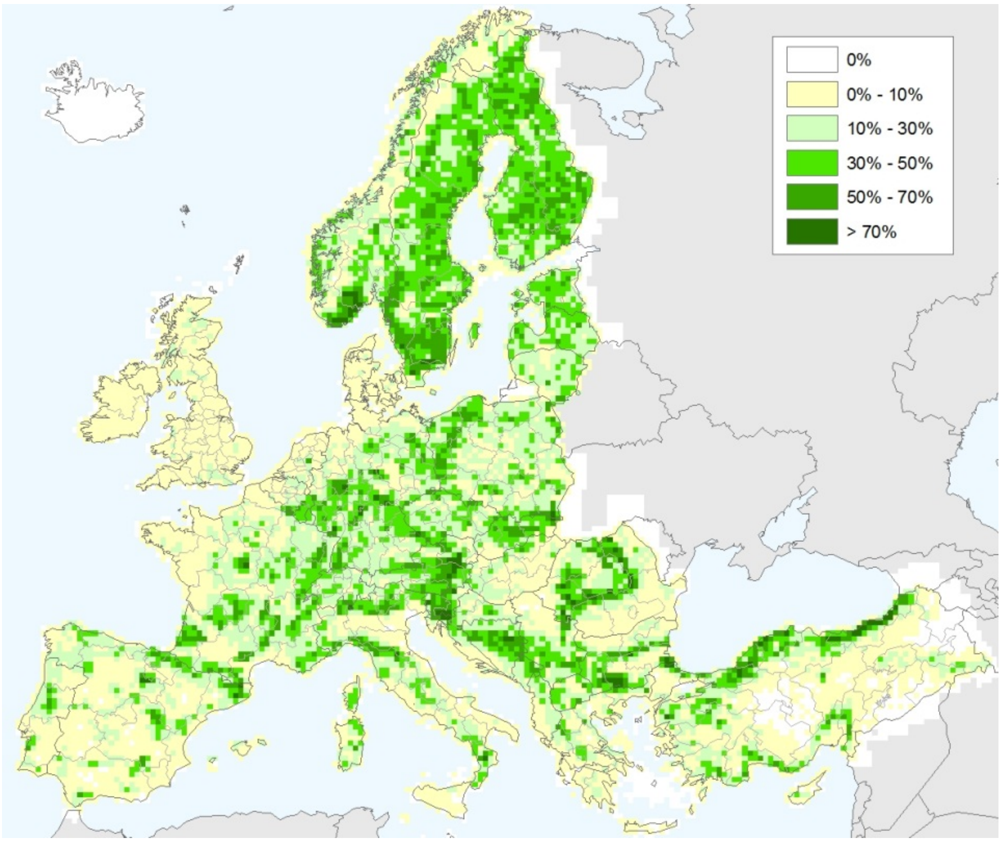
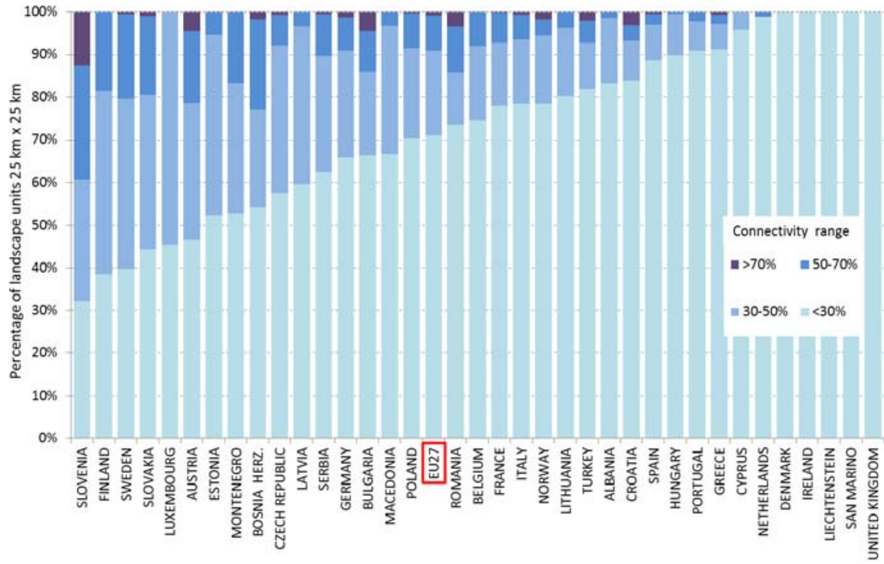


Figure 6 shows per country the shares of landscapes in four different connectivity ranges. Landscapes with poorly connected woodlands (<30%) represent 70 % of the European Union. While causes of isolation may be natural and/or anthropogenic in origin, such landscapes deserve more attention in the future for species particularly vulnerable to fragmentation effects and even more in the context of climate change.

At national level, for example in North-eastern countries like Estonia and Lithuania have the same forest area amount (2.2 million ha) but exhibit a different landscape distribution per connectivity ranges (higher share of poorly connected woodlands in Lithuania). Latvia and Estonia have the same forest land area proportion, forest in the former country is approximately 1 million ha more but less connected. Similar statement can be made for the Czech Republic when compared to Slovakia in central-eastern Europe.

Figure 6. National distribution of forest connectivity for year 2006 (species dispersing 1 km)



4. Forest connectivity trends in the Iberian Peninsula

The Iberian Peninsula was chosen to illustrate the trends in forest connectivity in the 1990-2006 time period for species dispersing 1 km in average. Figure 7 shows if, how much and where forest connectivity has changed per landscape unit of 25 km x 25 km.

Figure 7. Trend in forest connectivity in the Iberian Peninsula, 1990-2006 (insight where blue circle in figure 8)

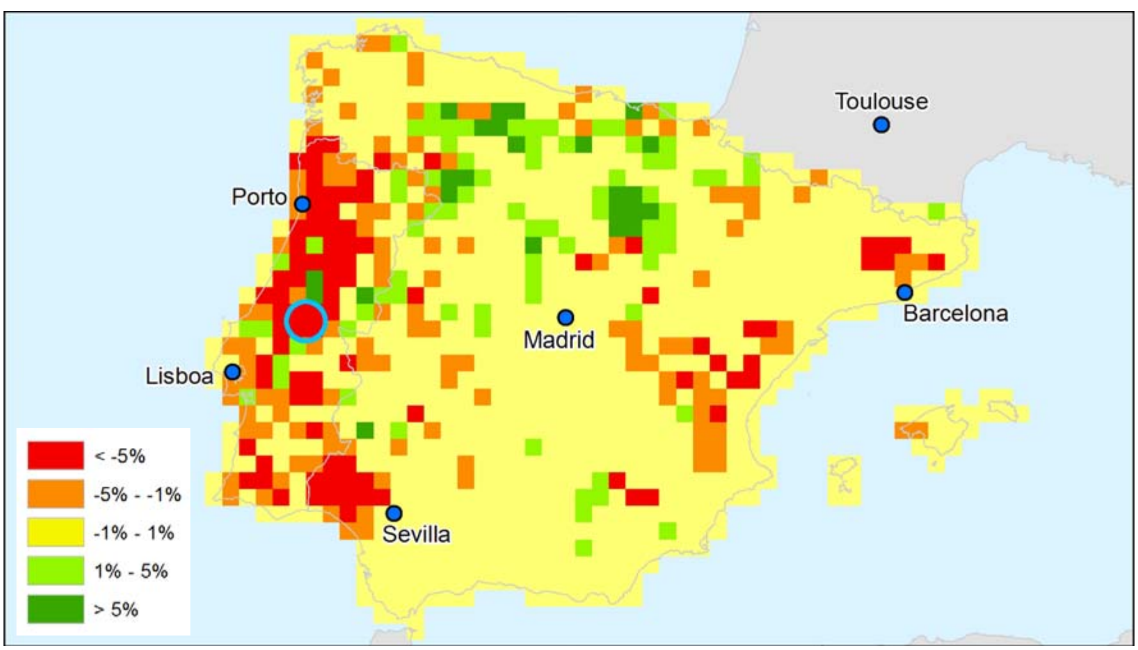


Figure 8. Four landscape units in Portugal where forest areas burnt in the 2000-2006 time period had a significant impact on forest connectivity (decrease below 5%)

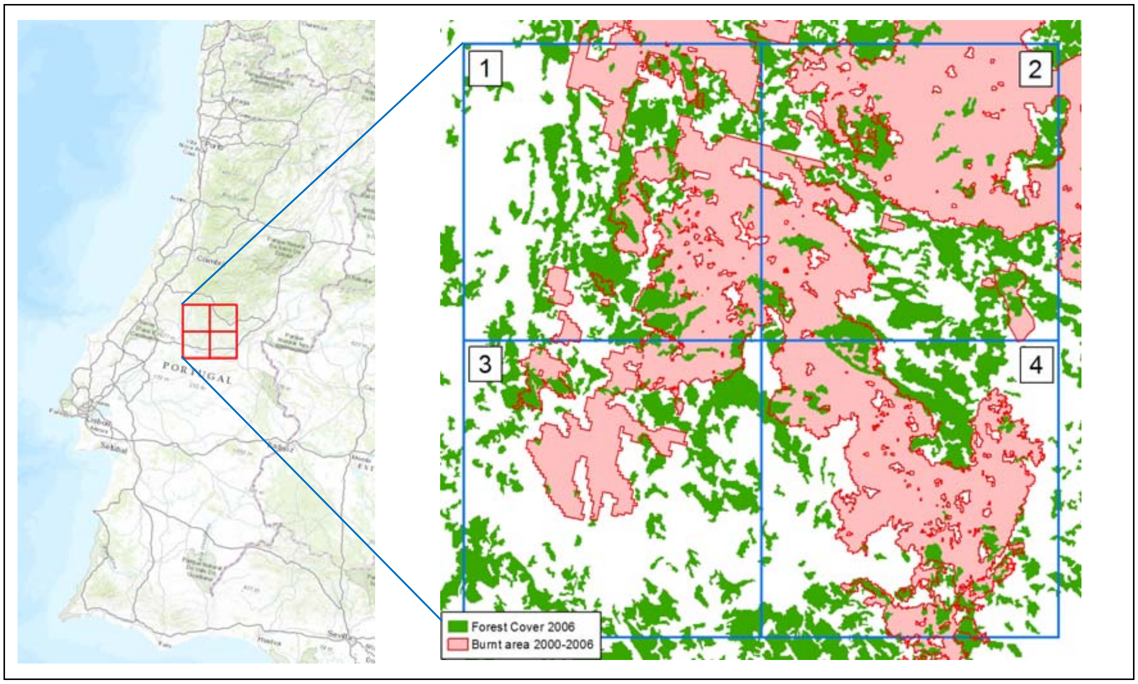


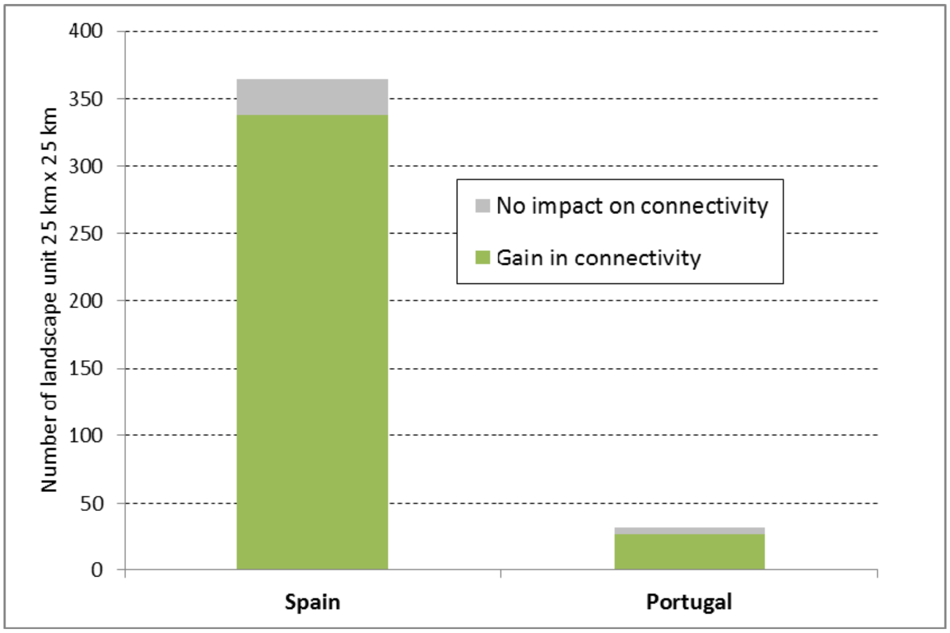
Figure 8 shows the cumulative impact of burnt areas after forest fires in the 2000-2006 period in four landscape units located in Portugal. In addition to the large area of forest burnt (loss in forest cover in Table 2), the spatial distribution of the burnt areas led to a strong isolation of the forest remnants (highest rate of loss in connectivity compared to loss in forest cover in Table 2).

Table 2. Loss in forest cover versus loss in connectivity for four landscapes in Portugal (figure 8)

	Loss in forest cover	Loss in connectivity
Landscape unit 1	-24%	-31%
Landscape unit 2	-29%	-36%
Landscape unit 3	-24%	-27%
Landscape unit 4	-46%	-53%

In the Iberian Peninsula, 38% of the landscapes reported a net forest area increase. As expected, this gain resulted in most cases in an increase in connectivity (Figure 9). However, for nearly 10% of the landscapes, this area gain had no significant impact on connectivity. This occurred when new forest areas were planted too remotely from other woodlands or only enlarged an existing wood patch. This finding supports the consideration of forest spatial pattern in sustainable forest management plans for landscape planning of re/afforestation measures.

Figure 9. Forest connectivity change in 1990-2006 in landscapes with a net forest area gain



5. Conclusions

This research responds to the biodiversity policy needs for improved reporting on European-wide forest landscape pattern and fragmentation. It demonstrates that it is possible to characterise forest landscape pattern and associated fragmentation or connectivity processes in a harmonized and reproducible manner on the basis of a set of indices and derived maps. Preferably, fragmentation processes need to be captured at landscape scale. The selection and number of indices can be streamlined depending on users focus and semantics, and computed to address changes over time and space.
Furthermore, our findings from the trend analysis support the consideration of pattern and fragmentation related issues in sustainable forest management plans for landscape planning of forest operations such as clearings and re/afforestation measures.
Finally, a European-wide forest pattern web map viewer was set up for data viewing and querying from the European Forest Data Centre, and is presented in annexe (EFDAC at http://efdac.jrc.ec.europa.eu).

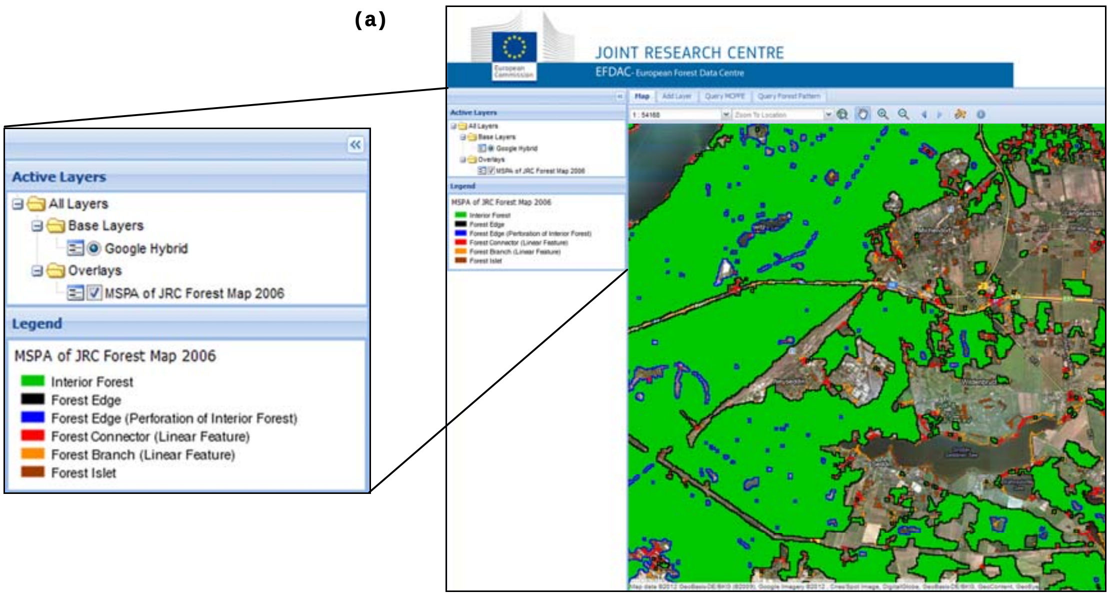
The method and tools that were developed can further be adapted to reporting on fragmentation of open natural lands or inland waters. Also, they can be relevant to address fragmentation issues in the context of ecosystem services (habitat provision and climate mitigation/adaptation) and Green Infrastructure.

6. Annexes: online services and references

A European-wide forest pattern web map viewer was set up on the basis of existing tools, open source software and web standard technologies for data viewing and querying from the European Forest Data Centre (EFDAC at http://efdac.jrc.ec.europa.eu). Layers are two folds: (1) the morphological shape map and the landscape mosaic map that can be overlaid on Google maps, and (2) maps derived from the computation of the indices listed in Table1 that can be queried per different reporting units (landscape, provinces, country) on forest morphology, landscape mosaic patterns, forest edge interfaces and connectivity at year 2006 and on trends in 1990-2006 (figure 10).

Figure 10. European-wide forest pattern web map viewer: (a) morphological shape map 2006, (b) forest connectivity per landscapes year 2006, (c) trend 90-2006 in core natural pattern

(a)



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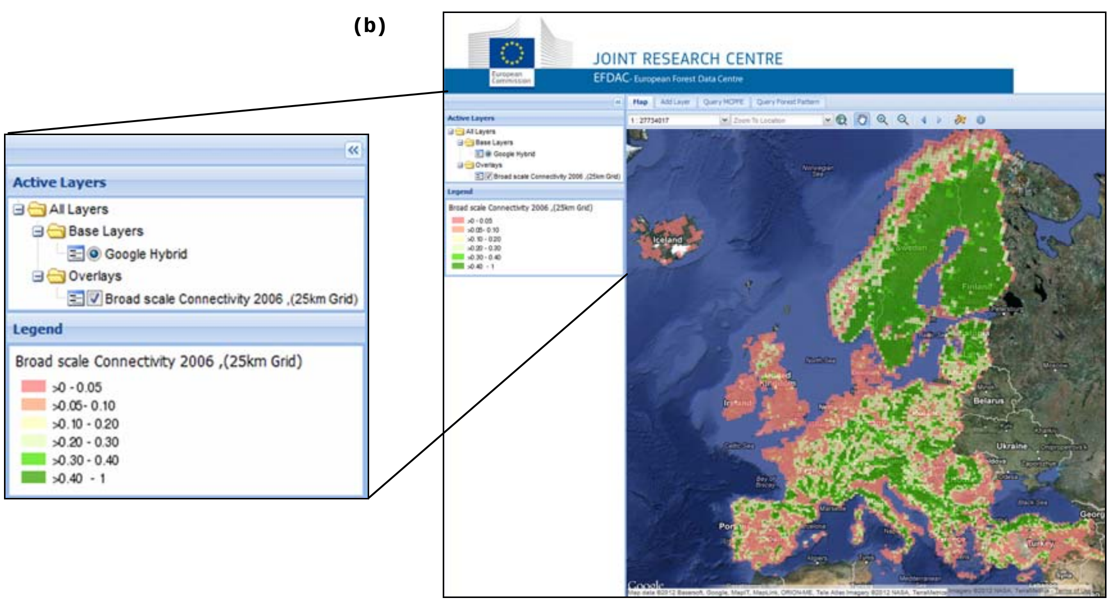

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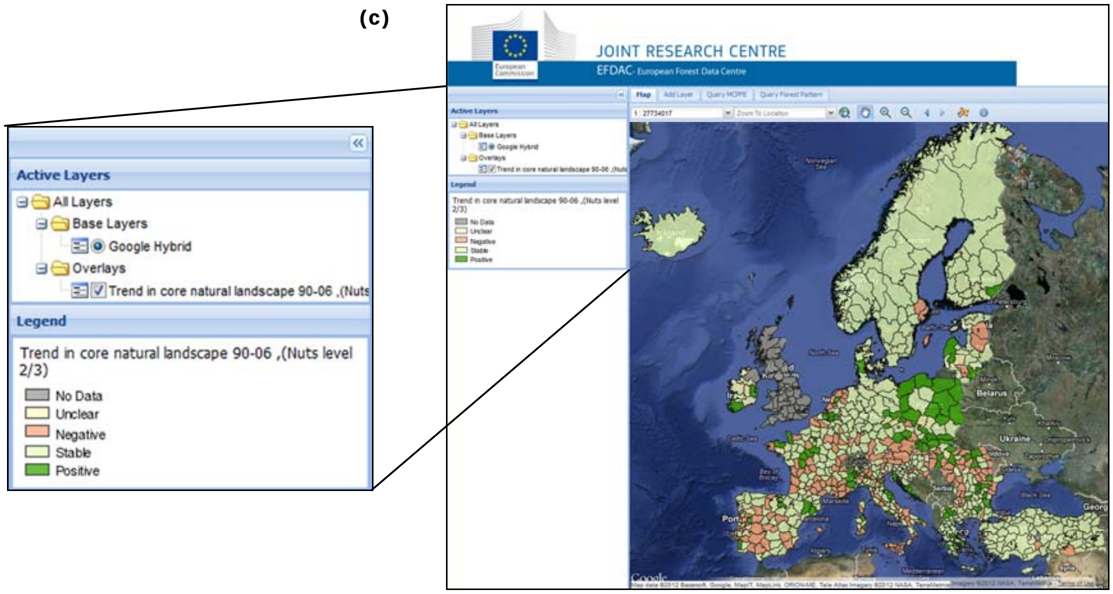

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