# Assessing land use change in Europe's protected areas through time

## Evaluación del cambio de uso del suelo en las áreas protegidas de Europa a través del tiempo

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### Abstract

Protected area status has become more important than it used to be. Today, protected areas have a crucial role in society, environment and economy. Land use change has become a major issue submitting protected areas to pressures which trigger a number of problems such as biodiversity loss and enhancing global warming, which affects their nature and our livelihoods. The land use/cover change per decade was studied for Europe's oldest protected areas from 1900 to 2000, within their limits and outside a 10km radio. The land use change was also compared between historic time steps defined by major historic events in Europe's protected areas history. The study addressed if the protected areas were actually working in limiting or enhancing land use/cover change through time and find if there were substantial differences between time periods. Additionally, it also addressed if the IUCN categorization was affecting land use change within the protected areas. Despite increases in the rate of change of human settlements outside the protected areas, which could lead to negative interactions, protected areas have been effective in limiting the land use change within their boundaries. Based on historic events, 3 time lapses were established. Significant differences were found between time lapses in the rate of change of land cover category

### Resumen

El estatus de área protegida debe ser mas importante que para lo que se usa actualmente. En la actualidad las areas protegidas tienen un rol crucial en la sociedad, el medio ambiente y la economia. El cambio de uso del suelo, ha sido el factor que mayor presion ejerce sobre las areas protegidas con un gran numero de problemas ocasionados como el calentamiento global y la perdida de biodiversidad afectando a todos los involucrados. El cambio de uso del suelo por decada, ha sido estudiado por las mas antiguas areas protegidas de Europa, desde los años 1900 hasta el 2000 con un radio de 10 kilometros a su alrededor.El cambio de uso tambien fue comparado con los mas grandes sucesos historicos definidos en el tiempo. Este estudio se dirige a visualizar las diferencias substanciales en periodos de tiempo, con el fin de estudiar si las areas protegidas mejoran y limitan ese cambio de uso del suelo en distintos periodos historicos. Adicionalmente tambien se estudiara si la categorizacion IUCN afecta el cambio de uso del suelo en las areas protegidas. Se establecen entonces tres periodos de tiempo en los que se estudiara que tan efectivo es el establecimiento de areas protegidas en cuanto al cambio en el uso del suelo y si existe un respeto de ese limite para los asentamientos humanos.


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(Settlements, Cropland and Forest) and in total area. Since the introduction of the IUCN categories, the total areas inside the protected areas is less for the Settlements and Cropland categories and more for the Forest one compared to other historic time lapses. Protected areas are effective in limiting the area of settlements and cropland within their limits..

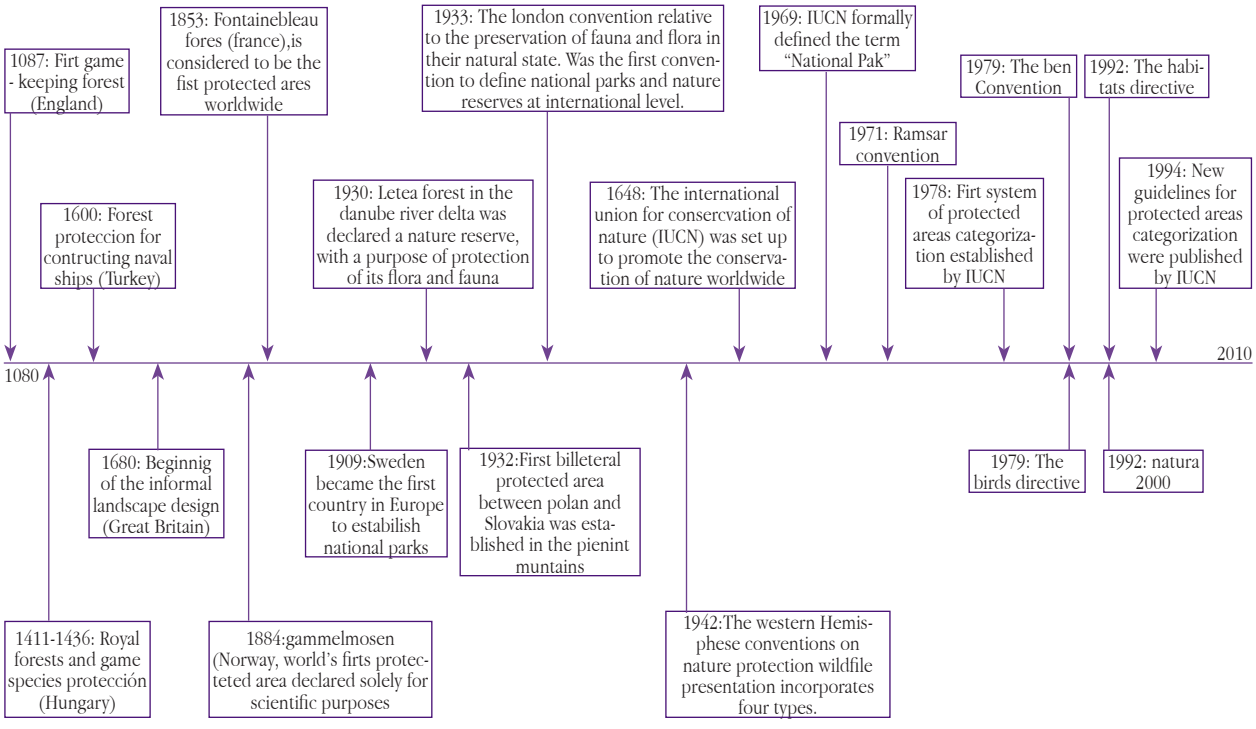
**Keywords:** Resiliencia urbana, ciudades sustentables, infraestructura multifuncional, recurso pluvial.

**Palabras clave:** Resiliencia Urbana, Ciudades Sustentables, Infraestructura multifuncional, recurso fluvial.

# Introduction

The status of Protected Area (PA), is given to a region due to its ecological, social and economic importance (Watson et al, 2014). These areas are at the core of efforts towards conserving nature and the services they provide to people (IUCN, 2013). There is evidence that the concept of protected area has been in Europe for several thousand years and regarding of their purpose, Europe has been establishing them since 1080 (Walters, 2013). IUCN defines PA as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural value"(IUCN, 2008).

*Figure 1.*



Time lapse of major events in Europe's protected areas history. It goes from 1080 to 2010, with a gap between 1087 and 1411due to the lack of relevant events.

The first major event in Europe's PA's history was in 1087 with the introduction of the first game-keeping forest in England (Walters, 2013). Almost 400 years later, in 1411 Hungary declares royal forests for the protection of game species; and in 1600 Turkey, begins protecting forest that were used for the construction of naval ships (Walters, 2013). Since 1087 and the next 800 years, forests in Europe were protected for the use of their natural resources and recreation value. There is a major change in 1844, in Gammelmosen, Norway; an area is declared solely for scientific purposes. Just years after, in 1853 the Fontainebleau Forest in France is given the status of protected area and is considered the first PA worldwide (Walters, 2013). Major changes start to take place in the last century; in 1909 Sweden became the first country in Europe to establish National parks and in 1930 the Latea forest in Rumania was declared nature reserve, with the purpose of protecting flora and fauna.

As new protected areas were established around Europe, an effort to categorize them and clarify terminology began. In 1933 at the International Conference for the Protection of Fauna and Flora, in London, four protected areas categories were established (National Park; Strict Nature Reserve; Fauna and Flora reserve; and Reserve With Prohibition for Hunting and Collecting)(Dudley, 2008). In 1942, the Convention on Nature Protection and Wildlife Preservation In The Western Hemisphere, also incorporated four types: National Park; National Reserve; Nature Monument; and Strict Wilderness Reserve (Holdgate 1999). The IUCN categories were introduced in 1978, but it was not until 1994 when new guidelines for categorizing PA's were approved by the IUCN. As a result, PA's were divided into categories (Ia Strict Nature Reserve, Ib Wilderness Area, II National Park, III Natural Monument or Feature, IV Habitat/Species Management Area, V Protected Landscape/ Seascape, VI Protected area with sustainable use of natural resources).

***Table 1.*** *IUCN Categories*

| Category | Main purpose |
|---|---|
| Ia | Strict Nature Reserve: managed mainly for science |
| Ib | Wilderness Area: wilderness protection |
| II | National Park: Ecosystem protection and re-creation |
| III | Natural Monument: conservation of specific natural features |
| IV | Habitat/Species Management Area: Conservation through management intervention |
| V | Protected landscape/Seascape: Conservation and recreation |
| VI | Sustainable use of natural resources |

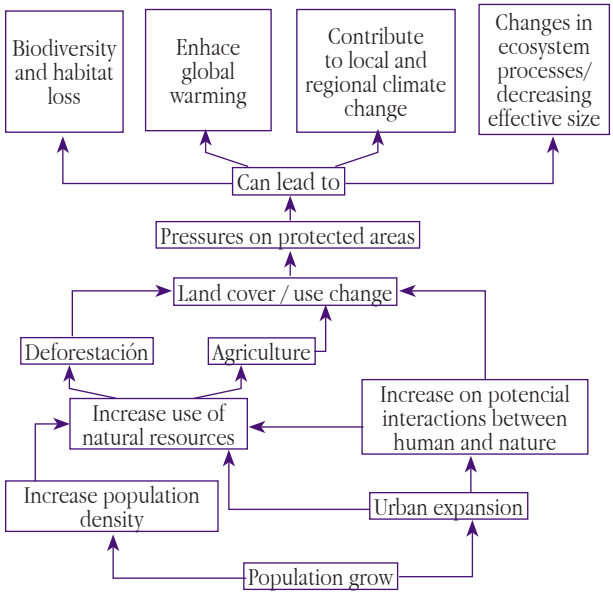
*Table 1 displays the seven IUCN categories and their main purpose. (IUCN, 2008)*

Today there is a strong linkage between society and PA's, which is vital for our livelihoods (Treves et al, 2005). In addition to conserving biodiversity (La Saout et al, 2013), well-managed protected areas can provide crucial ecosystem services and now PA's are also seen as crucial component of global climate change mitigation efforts (Watson et al, 2014). PAs are submitted to different types of pressures such as land use change, land conflicts (use vs adequate use), increase in population, etc. It is expected that in the coming decades, pressures on protected areas will increase depending on the land use and socioeconomic dynamics of the region in which they are located (Defries et al, 2007). Land use and land cover change are among the major problems that prevent PA's to achieve their socioeconomic and conservation purposes.

Land cover change is one of the most important factors leading to biodiversity and habitat loss (Falcucci et al, 2007). Also land use changes are so pervasive that, when aggregated globally, they significantly affect key aspects of Earth System functioning (Lambin, 2001), having a direct impact on biodiversity, contributing to local and regional climate change and enhancing global climate warming (Ellis, 2008). It is well known that changes in land cover are mostly generated by human activities; deforestation, agriculture and urban expansion are major causes leading to land cover change (Ellis, 2008). Scientists recognize that the magnitude of change is large. One estimate holds that the global expansion of croplands

since 1850 has converted 6 million km2 of forests/ woodlands and 4.7 million km2 of savannas, grasslands and steppes (Lambin, 2001). Some studies assure that the effectiveness of PA's in preventing anthropogenic land cover/use change (especially in sites of objectively defined biodiversity value) remain uncertain (Cambridge Conservation Initiave , 2010).

*Figure 2.*




Cause effect diagram. Possible resulting effects from the pressures that protected areas are submitted due to population grow. Population grow is the main cause. Each level is and effect of the level behind it. Each level is also the cause for the next level.

As land cover change is driven by human activities, the population growth will enhance the change in the coming years. In the next half century population is expected to continue growing (2-4 billion people) (Cohe, 2003). As population increases, the pressure for natural resources does too. Human land use is expanding and intensifying on the land surrounding PA's, and in some areas population density is leading to more rural settlement in previous Wild areas (Hansen et al, 2007). As proximity between urban areas and PA's increases, so does the potential for interactions ( Mcdonalds et al, 2009). Population settlements on the edges of PA's can have negative consequences that may result in changes in ecosystem processes and biodiversity within the PA (Hansen et al, 2007). Studies in Latin America, United States and Africa suggest that PA's attract human settlements (Wittemyer et al, 2008), resulting on changes in land cover. Other studies show that housing growth in and near PA's in Unites States is decreasing their effective size, and national forests are even threatened by habitat loss due to housing grow within their boundaries (Radeloff et al, 2010).

Deforestation agriculture and interaction between humans and nature lead to a land cover/use change which places pressures on PA's. These pressures on PA's can lead to different consequences. A potential change in forest area can lead to habitat loss for animals resulting in a decrease of biodiversity. Deforestation release the carbon stored in the trees into the atmosphere which can enhance global warming. Deforestation can also affect the CO2, N, and water cycle, leading to regional and local climate change. As ecosystem needs to have an effective area for natural processes (Naeem et al, 1999), pressures can reduce these areas and interrupt the process of them.

As stated before, population growth is resulting in land cover change, which threatens protected areas and its conservation purposes. This research purpose is to analyze the land use change over time in and around Europe's oldest PA's and compare them between different historic times. It hypothesized that there is no difference between historic periods of time regarding land use change inside PA's. McDonalds (2009) stated that potential interactions between humans and protected areas increase with less distance between them. Wittemyer and company (2008) suggested that PA's attract human settlements. This research also wants to determine if these potential interactions due to potential urban area grow close to the PA's are submitting them to pressures and resulting in potential changes in land cover/use within the PA's over time.

# Methodology

## Data

### Land cover data

The land cover/use data set was obtained from model results of the Historic Land Dynamics Assessment (HILDA) version 2.0 (date of the version 27-3-14). The

data set was developed by the Laboratory of Geo-information Science and Remote Sensing, Wageningen University (NL) under the lead of Richard Fuchs & Martin Herold for the GHG-Europe project (Fuchs et al, 2014a)( Fuchs et al, 2014b)(Fuchs et al, 2013). The land cove/user data set has a spatial resolution of 1 km by 1 km. It contains the land cover/use from Europe per decade from 1900 to 2010. The thematic resolution is divided into six classes.

- Settlements, including green urban area, with three density classes: low, medium and high.
- Cropland, including orchards and agro-forestry.
- Forest, including transitional shrub and woodland, tree nurseries, reforested areas for forestry purposes.
- Grassland, including natural grassland, wetlands, pasture and Mediterranean shrub vegetation.
- Other Land, including glaciers, sparsely vegetated areas, beaches, bare soil.
- Water, including water bodies, Ocean, streams.

### Protected areas data

The data for protected areas was obtained from the European Environmental Agency (EEA) (date of the version 31-10-2014). It displays the boundaries of PA's located in Europe. This data set is best known as nationally designated areas. The inventory began in 1995 under the Coordination of Information of the Environment (CORINE) programme of the European Commission (European Environmental Agency, 2014).

## Sample

The land use change inside protected areas and their surroundings was compared within different historic time periods. These were selected according to Europe's PA's time line. Due the time threshold from the Hilda data set (1900-2010), the historic time steps were taken into account from 1900. The historic time lapses were divided according to major historic events that represent a major impact in PA's history. The major events and the historic time lapses are named below.

- Establishment: This period of time goes from 1900 to 1930, refers to the time lapse were the PA's were established before the official designation work began, which according to Walters (2014) began in 1933.
- Transition: it goes from 1930 to 1970, in this period, the categorization work began, and several conferences took place were they established different categories for protected areas (Dudley, 2008) (Holdgate 1999).
- Official: the last time lapse comprehends from 1970-2000, in these decades the IUCN official categories were published (1974) and the new guidelines that we use today were approved in 1994 by the IUCN.

37 PA's from Europe were evaluated during the study, each PA had to meet 4 requirements in order to be considered as part of the sample.

1. Protected areas established between 1900 and 1930, and the study wanted to assess PA's before the categorization work began in 1933 (Walters, 2014).
2. PA's must be bigger than 1km2 because the spatial resolution from the land cover/use data set is 1km2.
3. The study excluded marine PA's. The vast majority of Europe's marine protected areas are established within the ocean. The rate of change for the land use categories important for this study cannot be evaluated, therefore were excluded.
4. PA's that are mostly covered by water bodies (e.g. lakes) were excluded because the change cannot be evaluated.

*Figure 3.*

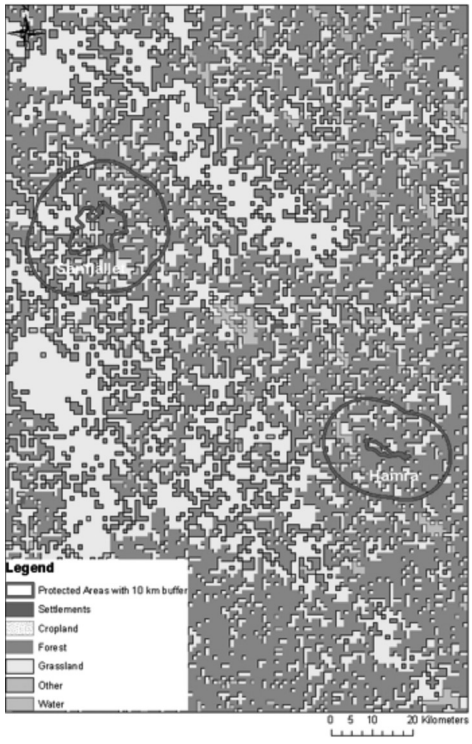
Europe map with PA's. The location of the 37 PA's across Europe are displayed in red, due to limit data access some countries are not displayed, this does not affect the study. The PA's sample is located in Denmark, Germany, Czech Republic, Sweden, Slovenia, Latvia, Italy, Slovakia and Switzerland

## Procedure

Both Data sets were intercepted to obtain the extent of area for each land cover category, this process was repeated once per decade. To detect if a PA is limiting or enhancing the land use change within their limits, it must be compared with its surroundings, which receives less protection (Nagendra, 2008). A 10 km buffer was generated outside the limits of each PA and the process was repeated per decade.

With the area data for each land cover class within the boundaries of the park and outside the 10 km buffer, the rate of change was calculated. As a result the rate of change for each class per decade was obtained for the sample and its buffer. Subsequently each rate of change was calculated for each time lapse.

*Figure 4.*




Example of PA's with their buffer. Hamra and Sanjallet are two protected areas located in the north of Sweden. For this example, the land cover data from 1910 was used. Each color represents a land cover category.

## Data analysis

The analysis was divided into two different steps. In the first step the 1900 to 2000 period of time was analyzed, while the second one involves the historic time steps.

For the purpose of this study, the land cover classes Other land and Water were left out from analysis (They did not vary in the whole time period).

### Analysis 1900-200

To identify possible trends in land use, each land cover class area was standardized with the area from the sample (Total area of all PA's within boundaries). The same process was repeated for the 10 km buffer data (Total area from the 10 km buffers sample) and then plotted.

To assess the effectiveness of PA's in limiting land cover changes and support the trends found, the inside rate of change per decade was compared with the surroundings rate of change. If the rate of change is lower than the outside, this means that the PA's are effective in lowering the land cover change of that class. On the other hand if the rate of change is bigger, this means that the PA's enhanced the land cover change. A nonparametric sign test ($p>0.05$) was used to assess the difference in rate of change.

A second sing test ($p>0.05$) was performed between land cover categories, with the purpose of determining which category had the faster rate of change and which one the slower inside the PA's

### Analysis Historic time steps

The total area and rate of change was calculated for each land cover category within each historic step. A Kruskal-Wallis (KW) ($p>0.05$) test was implemented to determine possible differences between the historic time steps regarding the total area from each class. A third sing test ($p>0.05$) was performed for each historic time step,

the average rate of change per PA inside and outside was tested for each class. And the rates of changes were also comparted with each other.

According to Nagendra (2008) the effectiveness of a PA can be assessed by comparing rates of change from inside the PA to their surroundings, "If the rate of land-cover change is lower within the protected area's boundaries than outside, this indicates that the protected area has been successful in limiting land-cover change". Following the same order of ideas, if the rate of change inside the PA is bigger than outside, this indicates that the PA's are enhancing land cover change. This effectivens was also evaluated and compared for each historic time step.

# Results

## 1900-2000

***Table2.*** *Percentages of land cover class within the boundaries of the PA's sample per decade*

| Years | Settlements (%) | Cropland (%) | Forest (%) | Grassland (%) |
|---|---|---|---|---|
| 1900 | 0.311 | 4.493 | 18.456 | 35.945 |
| 1910 | 0.311 | 4.493 | 18.456 | 35.945 |
| 1920 | 0.311 | 4.308 | 18.351 | 36.235 |
| 1930 | 0.304 | 3.932 | 18.382 | 36.587 |
| 1940 | 0.300 | 3.396 | 18.980 | 36.529 |
| 1950 | 0.277 | 3.107 | 18.324 | 37.497 |
| 1960 | 0.263 | 3.097 | 21.476 | 34.369 |
| 1970 | 0.228 | 3.025 | 22.390 | 33.562 |
| 1980 | 0.228 | 3.067 | 22.997 | 32.913 |
| 1990 | 0.214 | 3.039 | 23.623 | 32.328 |
| 2000 | 0.202 | 2.108 | 24.680 | 32.215 |
| Mean | 0.262 | 3.348 | 20.9 | 34.695 |

The sum of all the percentages is not 100 %, due to the missing values from the other two land cover categories that were not evaluated for this study.

Size of Grassland category revealed to be the one covering most area within the PA's (mean=34.695%) from 1900 to 2000, followed by Forest (mean=20.9%), Cropland (mean=3.348%) and Settlements (mean=0.262%). The area from Settlements is reducing in size through time, while in the beginning of last century, covered 0.311% at the beginning of the present century covers 0.202%, showing a reduction of 0.109% (equivalent of changing 7.301 km2 of land). Cropland is also decreasing a cross time, with a total reduction of land cover of 2.385% (equivalent of changing 159.512 km2 of land). Forest class shows a different behavior in the hundred years period, increasing the total area per decade, acquiring a total area of 416.241 km2 from 1900 to 2000. In contrast, there is no a clear behavior for the Grassland class, it increases its area for the first half of the century but then it decreases.

***Table 3.*** *Percentages of land cover class outside (10 km buffer) the boundaries of the PA's sample per decade*

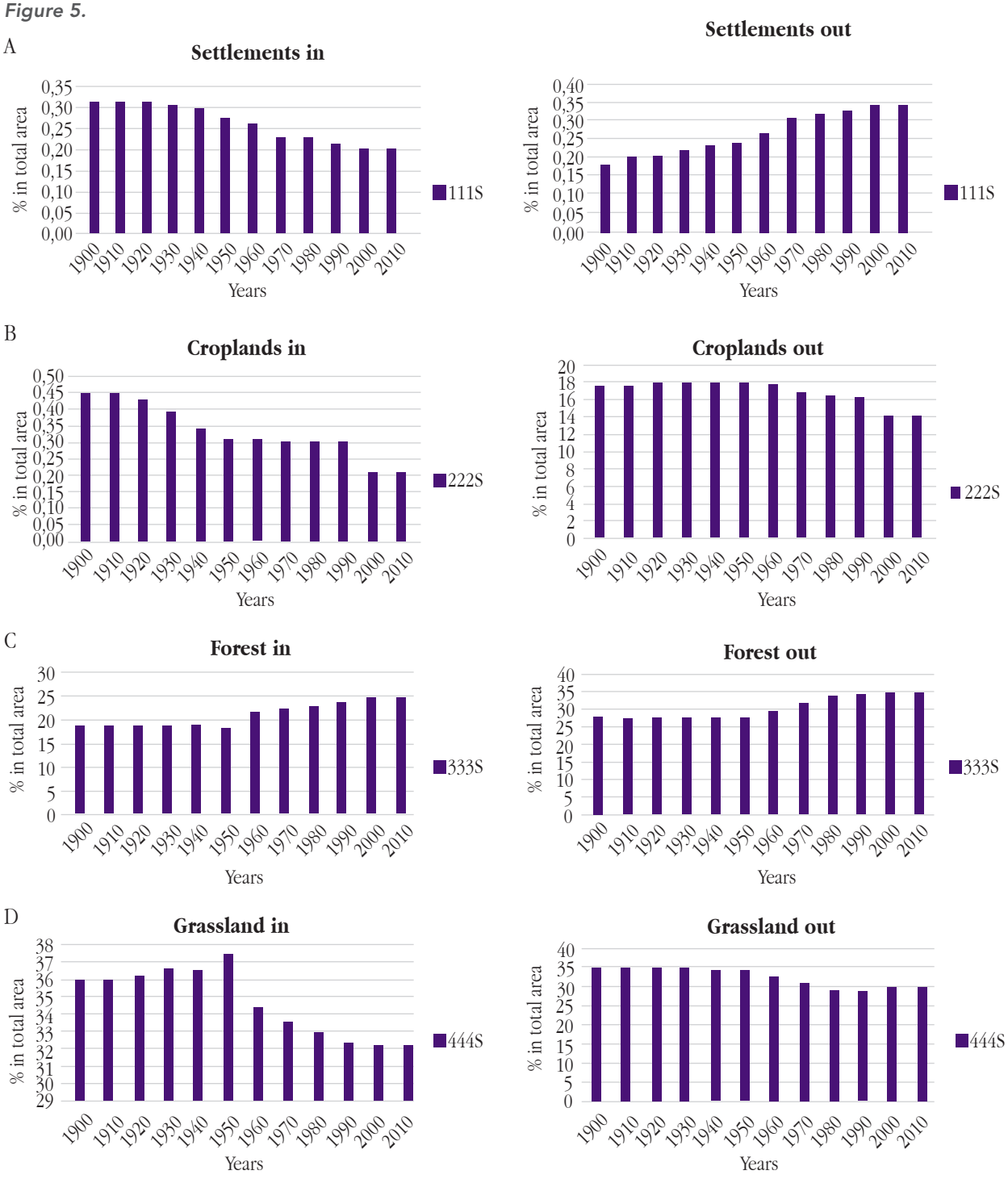
| Years | Settlements (%) | Cropland (%) | Forest (%) | Grassland (%) |
|---|---|---|---|---|
| 1900 | 1.820 | 17.773 | 27.868 | 35.195 |
| 1910 | 2.019 | 17.680 | 27.578 | 35.377 |
| 1920 | 2.020 | 18.124 | 27.461 | 35.050 |
| 1930 | 2.183 | 18.071 | 27.443 | 34.959 |
| 1940 | 2.362 | 18.100 | 27.772 | 34.422 |
| 1950 | 2.408 | 18.096 | 27.786 | 34.366 |
| 1960 | 2.688 | 17.883 | 29.466 | 32.618 |
| 1970 | 3.141 | 16.819 | 31.788 | 30.907 |
| 1980 | 3.236 | 16.587 | 33.852 | 28.981 |
| 1990 | 3.339 | 16.286 | 34.271 | 28.760 |
| 2000 | 3.451 | 14.169 | 34.983 | 30.052 |
| Mean | 2.676 | 16.980 | 30.437 | 32.562 |

The sum of all the percentages is not 100 %, due to the missing values from the other two land cover categories that were not evaluated for this study.

Table 2 illustrates the behavior from the land cover classes area outside the boundaries from the PA's. The order of size outside the protected areas is the same as inside. Grassland demonstrates to be covering more area outside the boundaries of the PA's (mean=32.562%)

for the entire period, followed close by forest (mean=30.437%), Cropland (mean16.980%) and Settlements (mean 2.676%). While Settlements and Forest are gaining area per decade, and showed a total change of 1.631% (equivalent of gaining 410.813 km$^2$) and 7.115% (equivalent of gaining 1,792.688 km$^2$) respectively, Cropland and Grassland shows a reduction of 907.773 km2 (reduction of 3.604%) and 1,295.729 km$^2$ (reduction of 5.143%) respectively. In the las part of the century, Forest class becomes the bigger in size outside the PA's, while inside the PA's Grassland is the biggest class in the whole century.

*Figure 5.*



Percentage of each land cover category within and outside the PA's per decade. On the y axis are standardized values and the x axis the time. A Settlements, B Cropland, C Forest and D Grassland

Settlements (A) show a clear trend of reducing area inside the sample, this category is reduced in almost 1/3 of its size (0.1%), while outside is growing on time and duplicates its size. Boundaries seem to be effective in protecting these areas for this class. McDonalds (2009) stated that potential interaction between humans and PA's increase with less distance between them, this graph shows that even if PA's surrounding could be attractive for developing Settlements, the limits are effective in controlling the change within the park.

Cropland (B) size shows a trend of reduction within the PA's, while outside there is not a clear trend. The graph suggest that the PA's are effective in reducing the size of cropland within the PA's sample, which is reduced in more than 50%. In the last decades, there is also a reduction from the Cropland area outside the PA's.

Forest (C) illustrates the same trend for inside and outside the sample. In both cases, the land cover class is gaining area, Forest is an important category for determining the effectiveness of protected area, and theoretically they should enhance reforestation or limit deforestation. As outside is behaving the same as inside, the boundaries are not being effective in showing a clear difference trend improving more reforestation or reducing it more than outside.

The trend of Grassland (D) inside the sample is irregular, it slowly gains area in the first decades, while then dramatically drops down. The trend outside is steady. There is no clear suggestion regarding on how are the limits of the PA's affecting this category. It is impossible to tell whether the boundaries of the sample are enhancing or limiting the change in the Grassland class.

***Table 4.*** *Rate of change per decade in % in vs out, Settlements and Cropland classes*

| Decades | Forest in (%) | Forest out(%) | Difference in vs out | Grassland in (%) | Grassland out (%) | Difference in vs out |
|---|---|---|---|---|---|---|
| 1910-1900 | 0.00000 | 0.19935 | Inside < Outside | 0.00000 | -0.09243 | Inside <Outside |
| 1920-1910 | 0.00007 | 0.00020 | Inside < Outside | -0.18525 | 0.44432 | Inside <Outside |
| 1930-1920 | -0.00724 | 0.16289 | Inside < Outside | -0.37601 | -0.05360 | Inside >Outside |
| 1940-1930 | -0.00390 | 0.17926 | Inside < Outside | -0.53637 | 0.02892 | Inside >Outside |
| 1950-1940 | -0.02304 | 0.04644 | Inside < Outside | -0.28855 | -0.00419 | Inside >Outside |
| 1960-1950 | -0.01404 | 0.27968 | Inside < Outside | -0.01016 | -0.21251 | Inside <Outside |
| 1970-1960 | -0.03474 | 0.45267 | Inside < Outside | -0.07184 | -1.06375 | Inside <Outside |
| 1980-1970 | 0.00000 | 0.09530 | Inside < Outside | 0.04163 | -0.23242 | Inside <Outside |
| 1990-1980 | -0.01383 | 0.10293 | Inside < Outside | -0.02730 | -0.30127 | Inside <Outside |
| 2000-1990 | -0.01246 | 0.11191 | Inside < Outside | -0.93160 | -2.11626 | Inside <Outside |

Comparison between rates of change from inside the PA's with their surroundings for the Settlements and Cropland class. A positive rate of change means that the class is gaining area, while a negative one is the opposite

Table 3 corroborates with graph A, while outside the PA's settlements class increase, inside they decrease, showing the effectiveness of PA's in lowering the settlements within their boundaries for the 100 years period (sign test, p=0.002).

The comparison between Cropland rates of change is not as clear as the Settlements one. In almost all the decades Cropland is being reduced inside and outside. In 6 decades the rate of change is bigger outside than inside, proving that the outside is losing cropland much faster than inside. In just 3 decades the rate of change was bigger inside. There is no significant difference between the rates of change in this class (sign test, p=3.44)

***Table 5.*** *Rate of change per decade in % in vs out, Forest and Grassland classes*

| Decades | Forest in (%) | Forest out(%) | Difference in vs out | Grassland in (%) | Grassland out (%) | Difference in vs out |
|---|---|---|---|---|---|---|
| 1910-1900 | 0.00000 | -0.28946 | inside<Outside | 0.00000 | 0.18255 | Inside <Outside |
| 1920-1910 | -0.10493 | -0.11778 | inside<Outside | 0.29011 | -0.32674 | Inside <Outside |
| 1930-1920 | 0.03108 | -0.01760 | inside>Outside | 0.35217 | -0.09170 | Inside >Outside |
| 1940-1930 | 0.59819 | 0.32890 | inside>Outside | -0.05791 | -0.53708 | Inside <Outside |
| 1950-1940 | -0.65575 | 0.01375 | inside>Outside | 0.96734 | -0.05600 | Inside >Outside |
| 1960-1950 | 3.15197 | 1.68014 | inside>Outside | -3.12778 | -1.74731 | Inside >Outside |
| 1970-1960 | 0.91386 | 2.32243 | inside<Outside | -0.80728 | -1.71135 | Inside <Outside |
| 1980-1970 | 0.60676 | 2.06341 | inside<Outside | -0.64839 | -1.92629 | Inside <Outside |
| 1990-1980 | 0.62586 | 0.41898 | inside>Outside | -0.58472 | -0.22064 | Inside >Outside |
| 2000-1990 | 1.05771 | 0.71288 | inside>Outside | -0.11364 | 1.29147 | Inside <Outside |

Comparison between rates of change from inside the PA's with their surroundings for the Forest and Grassland class. A positive rate of change means that the class is gaining area, while a negative one is the opposite

In almost all the decades the rate of change for Forest is positive, which means that both for inside and outside, this class is gaining area. The rate of change is negative in the first 3 decades outside the sample, and there are two decades (1910-1920 and 1940-1950) when the class is losing area inside the parks (deforestation).It cannot assure that PA's are enhancing reforestation or limiting deforestation within their boundaries for the 100 years period, even if in 6 decades the rate of change is bigger inside than outside. There is no significant difference between the rates of change (sign test, $p=0.754$).

Furthermore, Grassland does not show a clear behavior in rates of change, most of the decades are losing area inside and outside the PA's, with an exception in the first decades. Grassland like Forest and Cropland don't show significance between rates of change (sign test, $p=0.754$).

From 1900 to 2000, Settlements category, showed to be the one changing with the slower rate inside the PA's and had significant difference with all the other categories (sign test, $p<0.05$), this means that in the 10 decades the rate of change from the settlements class was smaller than the rate of change of the other categories. On the other hand, Grassland and Forest categories are the ones with the biggest rate of change per decade, which means that they are changing faster than the other ones. There is no significance difference between these two categories, because there is only one decade when the Grassland is changing faster than Forest, but no statistical significance was found between these categories (sign test, $p>0.05$).

## Historic time steps

***Table 6.*** *Mean area for each class per period inside the PA's*

| Time lapse | Inside km² | | | |
|---|---|---|---|---|
| | Settlements | Cropland | Forest | Grassland |
| Establishment | 20.665 | 287.975 | 1,231.123 | 2,419.180 |
| Transition | 17.837 | 211.045 | 1,356.948 | 2,373.111 |
| Official | 14.346 | 183.080 | 1,589.251 | 2,172.265 |

Mean area for each category per historic time lapse.

There is a strong difference in mean area between historic time steps for the Settlements, Cropland and Forest category. The difference in mean area for the Grassland category between historic time steps is not as significant as the other categories (taking into account the change within the category). The historic time step that differ most form each other is the Establishment against the Official, there is a reduction of 6 km² for the Settlements class, 104 km² reduction for the Cropland category and a gain of 385 km² in Forest mean area. Significant difference was found between Establishment and Official historic time steps for the settlements category ($p=0.011$), between the other historic time periods there is no significant difference (Establishment-Transition $p=0.61$, Transition-Official $p=0.232$). Cropland and Forest also present a significant difference in mean area between historic time steps Establishment and Official ($p=0.021$ and $p=0.03$), but not among the other ones ($p>0.05$). On the contrary the mean area from Grassland doesn't present a significant difference between historic time steps ($p>0.05$).

***Table 7.*** *Mean area for each class per period outside the PA's*

| Time lapse | Outside km² | | | |
|---|---|---|---|---|
| | Settlements | Cropland | Forest | Grassland |
| Establishment | 506.507 | 4,512.682 | 6,950.252 | 8,854.372 |
| Transition | 667.545 | 4,465.429 | 7,357.238 | 8,333.600 |
| Official | 841.929, | 3,950.521 | 8,658.661 | 7,372.701 |

Mean area for each category per historic time lapse.

There are also strong differences in mean area between historic time steps for the land cover classes outside

the PA's. The Settlements class shows a gain of 300 km² in mean area from the Establishment time lapse to the Official one ($p=0.009$). In contrary from inside the PA's, Settlements gain area between historic time steps. Cropland shows to be changing not significantly between historic time steps (taking into account the change within the category) ($p>0.05$), but the category is reducing the mean area over time. Forest and Grassland differ significantly between Establishment and Official historic time steps ($p=0.017$ and $p=0.009$), while forest is gaining more than 1700 km², Grassland loses more than 1400 km². Establishment-Transition and Transition-Official historic time steps are not showing significant difference in area one from each other, suggesting to be not changing significantly in all the land cover classes ($p>0.05$).

***Table 8.*** *Mean rate of change per historic time step for each land cover class*

| Time lapse | Outside km² | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Settlements | | Cropland | | Forest | | Grassland | |
| | in | out | in | out | in | out | in | out |
| Establishment | 0,015 | 0,1931 | 0,6297 | 0,8011 | -0,0361 | -0,0995 | -0,5952 | -0,8946 |
| Transition | -0,2269 | 0,3264 | -0,4024 | -0,1500 | 1,9089 | 1,0998 | -1,2796 | -1,2771 |
| Official | -0,007 | 0,147 | -2,728 | -1,473 | -0,776 | 0,6462 | 3,5099 | 0,6795 |

Mean rate of change for each category per historic time lapse.

The mean rate of change for each time lapse was calculated for each land cover class, according to what stated before by Nagendra (2008), the green color symbolizes a positive difference while the red one a negative. In the Official historic time step Forest, the rate of change is negative inside the sample (deforestation) while it is positive outside (reforestation). Establishments historic time step, showed a lower rate of change inside than outside for the Forest category, even if deforestation is taking place, the limits are effective in preventing faster changes than outside. Transition provides a different panorama; the rate of reforestation is bigger within the PA's. Settlements, Croplands and Grassland show similar results in the 3 historic time steps, always with a positive difference. For the Settlements class, Transition has the best difference in mean rates of change, while outside the area is increasing in 0.327, inside is decreasing in 0.2269. On the other hand, the Official historic time step proves to have the best difference in mean rate of changes for Cropland, decreasing twice fast within the boundaries of the sample.

When the rate of change data is evaluated in historic time steps instead of a 100 years period different results are obtained. For the Establishment period, there is significance in the 4 classes (sign test, $p<0.05$), which means that the rate of change was lower inside the boundaries of the PA's than outside. Similar results were obtained for the Transition and Official time step, they proved to be having lower rate of change within the PA's for the Settlements and Cropland class (sing test, $p<0.05$). For the Forest and Grassland category, there is no significance (sing test, $p>0.05$) between values from inside and outside the sample, even if the mean values had a positive difference in the Grassland class. There is a substantial difference between time steps.

For the Establishment period, Settlements had the slowest rate of change inside the PA's, all the categories had statistical significance (sing test, $p<0.05$), except for the Grassland-Forest test. Forest showed to be the one with the faster rate of change. In the Transition time step, Settlements was the category with the slower rate of change and Grassland was tied with Forest for the fastest one, also the Forest-Grassland test was not statically significant. Additionally for the Official period, Settlement was changing with the slowest rate and Forest with the fastest, all categories proved to be statistically significant with each other ($p>0.05$) except for the Cropland-Forest test.

***Table 9.*** *Summary of PA's with effective protection*

| Protected areas | | % of PA's with effective protection | % of PA's with uneffective protection | % of PA's with no difference |
|---|---|---|---|---|
| Establishment 1900-1930 | Settlements | 60 | 0 | 40 |
| | Cropland | 48 | 22 | 30 |
| | Forest | 44 | 43 | 3 |
| | Grassland | 54 | 46 | 0 |
| Transition 1930-1970 | Settlements | 58 | 3 | 39 |
| | Cropland | 51 | 19 | 30 |
| | Forest | 62 | 38 | 0 |
| | Grassland | 59 | 41 | 0 |
| Official 1970-2000 | Settlements | 56 | 3 | 41 |
| | Cropland | 54 | 22 | 24 |
| | Forest | 59 | 41 | 0 |
| | Grassland | 76 | 24 | 0 |

The effectiveness of the protected areas for each land cover class per time lapse is illustrated in Table 9. In all the 3 time steps, PA's have an effective protection regarding Settlement class; only in the last two periods there is an ineffective protection of 3 percent (equivalent to one PA). In the Establishment period, the number of effective PA's in the protection of the Forest class is almost the same as the number with Ineffective protection (44% vs 43%). This behavior changes in the next two time periods, when more PA's become effective in protecting this category. It must be taken into account that for this table that only the number of PA's were taken into account, instead in Table.8 the mean value was from the sum of all PA's per time lapse. Grassland also shows an increasing number of effectiveness, while in Establishment 54% of the sample is effective, in Transition 51% and in Official 76%. Cropland doesn't change considerable in the 3 time lapses; the difference between them is small.

## Discussion

The HILDA data set is a reliable source of information according to Fuchs and company (2014), "our model has improved quality of land change trends over the whole period as we have more measured data sources available to rely on. Spatial data streams also provide detailed information about where land changes happened, which improves the allocation of land cover change information in our model… Our model takes more accurate quantification methods of land changes into account." The high quality of the data set gives confidence that the results found are reliable.

The findings suggest that PA's are effective, especially in limiting and reducing the area of settlements within their limits. The results also propose that they are effective in reducing the use of cropland and enhancing reforestation for a hundred year period. Wittemyer and compay (2008) stated that PA's in Sout America, United States and Afria attract human settlements. The change in the sorroundings of the PA's sample was drastic, a major increase in human settlements was found since they were established, suggesting that in Europe, the PA's also could attract human settlements. Even if PA's seems to be attracting human settlements, the boundaries of them are effective in avoiding negative land use changes for the Settlements (increase), Cropland (increase) and Forest (decrease) uses.

The results also suggest that since the IUCN categories were introduced, the PA's have decrease the area of settlements and cropland within their limits, and increase the forests area, this suggests that the official designation and categorization of PA's was useful not only for establishing a worldwide common language, but also for assuring that PA's are being effective in achieving their purposes and limiting the land use change within their limits. It is important to underline that PA's and the IUCN categories are being effective tools to prevent the land use change in zones where the biodiversity and natural elements need protection.

The results in area show a trend for Settlements, Cropland and Forest categories through the time steps, this proposes that the Transition historic time step is truly a period of change that links the other two, suggesting that the land use changes obey a trend and events that could affect dramatically the area of a category (for example a wild fire inside a PA) did not occur.

Some PA's had a big difference in area from other ones inside the sample, this difference may have influenced the results, and the trend of few big PA's could have affected the changes in total area and rates of change. Above suggestion can be the explanation of the major drop in area for the Grassland category in the 1950-1960 decade. Additionally, this also can be the reason of the negative mean rate of change of Forest for the Official historic time lapse.

It is interesting to compare the results with similar studies. The results are similar to the ones found by Nagendra (2008), 65% of the PA's studied by them were effective in limiting deforestation since the PA's were established, while our study showed that 62% and %59 of the PA's in the Transition and Official historic time steps were effective in limiting the land use change of forest, even though similar criteria was implemented. In other study, Bruner and company (2001) reported that only 3% of the 93 protected areas they studied were in the same or worse condition compared to the surrounding landscape (regarding to forest category). This differ with our study, we found bigger percentage of ineffective PA's for the 3 historic time steps, even if the criteria used for the methodology was similar.

The comparison between rates of change within the limits of PA's and their surroundings is a good method to establish the effectiveness of PA's, but it must be taken into account that lower rates of change inside PA's can not only be attributed to the limits of them. The lower rates of change of some PA's can be consequence of other variables such as the location of them. It is inadequate to attribute that differences in time step were only cause of major historic events, which is why more variables such as location, social and economic dynamics should be taken into account for further studies.

These type of studies can be used as basis to determine possible future land use changes within the PA's and their surroundings. With the continue increase in population and expected global warming, PA's may arise as an effective tool to contra rest land use changes that enhance global warming and contribute to a sustainable use of the land. Even if PA's suggest to be effective in limiting land use change, not all of them are meeting their goals and further investigation and measures should be taken to assure all of them perform as they should.

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