

Landscape Change in a Mountainous Area in Northeastern Portugal: Implications for Management

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Abstract: - In this paper we analyzed changes in landscape composition and structure over the 1958-2005 period in the França Parish (Bragança, northeastern Portugal). Agriculture decreased from 22% to 5% of the area of study. Forests and shrublands became the dominant land uses occupying together 73% of the area of study in 2005. Structurally the landscape became more homogeneous. We speculate that the types of change observed and the tendency for their magnification in the near future will have functional effects on this landscape, namely the creation of condition for the occurrence of catastrophic disturbance events such as wildfires.

Key-Words: - Landscape change, landscape management, wildfires, Parque Natural de Montesinho, Montesinho/Nogueira Natura 2000 Site, Portugal

1 Introduction

Landscape change is a fundamental component of landscapes dynamics [1]. Marginal areas in Mediterranean regions have been under landscape change, both in terms of structure and function, as a consequence of land abandonment for a considerable period of time [2]. Although a familiar process in many countries in the Mediterranean basin, in Portugal this is a relatively new phenomenon that became more evident by the end of the XX century. Currently, most of the landscapes in Portugal which are marginal to larger urban centers, namely mountain landscapes, show clear evidence of advanced land abandonment, such as few agriculture areas located around villages, dominance of forest and shrublands land uses and a general homogenization of the landscape.

Changes in mountainous areas are critical because they provide ecosystem and landscape services essential to the society as a result of regulation, habitat, production and information functions, i.e. carbon sequestration, water quality and supply, biodiversity and natural resources, just to mention a few. It is therefore important to report and analyze changes in these systems as well as to evaluate their implications on landscape functions, namely on the processes related to the major landscape and ecosystem services, which hasn't been done in Portugal. It is important in addition, to consider management practices at the landscape level that can contribute to maintain landscape function and dynamics.

In this research we analyzed changes over a period of 50 years in landscape composition and configuration of major land use /land cover classes in the França Parish (Bragança County, northeastern Portugal), a typical marginal mountain landscape. Additionally, we infer on possible effects of the observed changes on landscape processes that affect goods and services of these landscapes.

2 Methods

2.1 Area of Study

The area of study is the França Parish (Bragança County) located in the North-East of Portugal. This is a 5600-ha area mostly comprised of a granite plateau above 1000m (maximum elevation 1481m). It includes also part of a larger flat valley of metamorphic geology. Average annual precipitation is above 1200mm reaching 1600mm at the higher elevations. Mean annual temperature is 8°C or less.

The Parish includes 3 villages whose population totalled 275 inhabitants (4.9/km²) in 2001 of which only 101 are active. Agriculture (including animal husbandry and forestry) is the most important activity in the parish (40% of the active population) followed by tourism (18%). Within the period of study the populations has decreased from 834 inhabitants in 1960 to the 275 in 2001.

The França Parish is part of the Montesinho/Nogueira Natura 2000 Site (PTCON0002), and part of the Montesinho Natural Park, a protected area established in 1979 by the Portuguese government.

2.2 Data

We used digitized aerial photographs taken in 1958, 1968, 1980, 1993 (Instituto Geográfico do Exército) and 2005 (Câmara Municipal de Bragança). These coverages were originally obtained at the scales 1:26 000, 1:28 000, 1:30 000, and 1:22 000, respectively. The images were orthorectified based on ground points. On average we considered 40 points for each photo. The photographs were interpreted based on the COS'2005 land use/land cover system of the Instituto Geográfico Português [3]. Each land unit above 0.25 ha was classified according to the most detailed level of the COS'2005 hierarchical system in a GIS. Field confirmations were done when necessary for the most recent coverages.

Landscape structure for each of the dates above was quantified based upon landscape metrics calculated for major land cover classes using FRAGSTATS software [4].

3 Results and Discussion

3.1 Composition

There were noticeable changes over the 1958-2004 period of study in terms of the major land use classes (Fig.1; Fig. 2; Table 1). Agriculture dropped from 1174ha (22% of the parish area) to 260ha (5%) (Fig.2; Table 1). In the same period forests increased from 741 ha (14% of the area) to 1118 ha (21%). Shrublands is the dominant land cover in any of the dates (Table 1). It represented 47% of the parish area in 1958 and 52.5% of the Parish in 2005. Semi-natural pasturelands also increased considerably representing, however, just a residual percentage of the area (Fig. 2; Table 1). Most of the changes described above resulted from abandonment of agriculture areas that became dominated by shrubs in a short period of time. New forest plantations were established mostly in shrublands.

Table 1. Major land uses / land covers (percentage of the area) in the França Parish from 1958 to 2005.

| | 1958 | 1968 | 1978 | 1993 | 2005 |
|---------------|------|------|------|------|------|
| Shrublands | 47,4 | 47,9 | 52,4 | 51,8 | 52,5 |
| Forests | 13,8 | 15,0 | 14,7 | 18,7 | 20,8 |
| Rock Outcrops | 14,2 | 14,2 | 14,3 | 14,3 | 14,4 |
| Pasturelands | 2,0 | 1,8 | 2,7 | 4,4 | 5,8 |
| Agriculture | 21,8 | 20,4 | 14,9 | 9,2 | 4,8 |
| Urban | 0,7 | 0,8 | 0,9 | 1,0 | 1,2 |
| Water Bodies | 0,0 | 0,0 | 0,0 | 0,6 | 0,6 |

3.2 Landscape Structure

Landscape structure in the França Parish also suffered relevant modifications over the nearly 50-year period. Landscape metrics considering major land use classes indicated that there was a decrease in heterogeneity at

the landscape level. Diversity as measured by the Shannon's, Simpson's and Modified Simpson's indices decreased during that time interval (Table 2) in spite of the new land cover established in the 1990's and part of the 1993 and 2005 data only. There were also decreases in the Number of Patches and in the Largest Patch Index which represents the percentage of the landscape occupied by the largest patch of all the land classes (Table 3). Edge Density decreased maintaining, however, the initial value of around 166m/ha although there were strong variations within the period of study.

Table 2. Measures of landscape diversity for the França Parish from 1958 to 2005.

| Year | SHDI | SIDI | MSIDI | SHEI | SIEI | MSIEI |
|------|--------|--------|--------|--------|--------|--------|
| 1958 | 1,3509 | 0,688 | 1,1648 | 0,754 | 0,8256 | 0,6501 |
| 1968 | 1,3477 | 0,6864 | 1,1597 | 0,7522 | 0,8237 | 0,6472 |
| 1978 | 1,3256 | 0,6607 | 1,081 | 0,7398 | 0,7929 | 0,6033 |
| 1993 | 1,3662 | 0,666 | 1,0966 | 0,7021 | 0,777 | 0,5635 |
| 2005 | 1,3364 | 0,6551 | 1,0645 | 0,6868 | 0,7643 | 0,547 |

SHDI-Shannon's Diversity Index; MSIDI-Modified Simpson's Diversity Index; SHEI- Shannon's Evenness Index; SIEI- Simpson's Evenness Index; MSIEI-Modified Simpson's Evenness Index.

Table 3. Measures of overall landscape heterogeneity for the França Parish from 1958 to 2005.

| Year | Number of Patches (#) | Largest Patch Index (%) | Edge Density (m/ha) |
|------|-----------------------|-------------------------|---------------------|
| 1958 | 836 | 23,9 | 166,1 |
| 1968 | 906 | 14,6 | 170,3 |
| 1978 | 764 | 19,1 | 168,3 |
| 1993 | 766 | 14,9 | 164,5 |
| 2005 | 751 | 15,7 | 166,6 |

Considering the major land uses/land covers individually (Figure 3) agriculture decreased slightly in Number of Patches and strongly in Mean Patch Area, Largest Patch Index and Edge Density (Figure 3). Forests and shrublands decreased in Number of Patches and increased strongly in Mean Patch Area. The Largest Patch Index increased for forests and decreased for shrublands. Edge Density for these classes increased slightly during the 1958-2005 period. In summary, forests and shrublands became more aggregated in the landscape therefore creating fewer but larger homogeneous landscape units. Agriculture became extremely fragmented and located in the vicinity of villages or in very high fertility sites.

3.3 Effects of Landscape Change

Considering the trend in landscape change observed for the França Parish with the trend in population shown in Table 4, it is reasonable to admit that forests and shrublands will increase further their dominance

in the landscape and that landscape structure will also reflect this dominance by these two major classes. For the most recent date of the time series, these land classes together represented over 73% of the landscape (Table 5; Figure 4). The landscape pattern of these two classes together was becoming more aggregated and the tendency is for aggregation to increase (Table 5; Figure 4).

Table 4. Population in the França Parish for the 1960-2001 period.

| Year | 1960 | 1970 | 1981 | 1991 | 2001 |
|-------------------|------|------|------|------|------|
| Total Population | 834 | 714 | 609 | 331 | 275 |
| Active Population | 283 | 248 | 173 | 150 | 101 |

Table 5. Structure of shrublands and forest considered together from 1958 to 2005 as indicated by selected landscape metrics

| Year | Percentage of Landscape (%) | Number of Patches (#) | Largest Patch Index (%) | Edge Density (m/ha) |
|------|-----------------------------|-----------------------|-------------------------|---------------------|
| 1958 | 61,2 | 1126 | 53,0 | 136,6 |
| 1968 | 62,9 | 1161 | 58,0 | 137,7 |
| 1978 | 67,1 | 930 | 64,1 | 130,8 |
| 1993 | 70,5 | 870 | 67,6 | 123,3 |
| 2005 | 73,2 | 841 | 70,3 | 117,1 |

This pattern is theoretically favorable to some landscape functions such as hydrological functions, particularly in terms of water quality, and soil loss given the role of shrublands and forest stands in decreasing runoff. In terms of water yield there is a potential decrease at the watershed level since large biomass vegetation types (forests and shrublands) will increase evapotranspiration and decrease water yield.

In terms of biodiversity, change of the type described will be favorable, at least for a certain period of time, to large mammals both in terms of cover and landscape connectivity it provides. However, since most of the species in Mediterranean landscapes are dependent to a certain level of open and/or cultivated areas [2], the changes observed in this work are likely to cause a decrease in species richness and diversity in the area, stronger after abandonment of the few agriculture fields still spread over the landscape.

A major reason of concern is the potential this trend represents for the occurrence of catastrophic disturbance events such as wildfires. Landscape change of the same type (but less pronounced) observed in another region of Portugal were predicted to result in a higher fire risk in the landscape [5]. The França Parish already presents a high or very high fire frequency (Table 6) and the occurrence of relatively large wildfires. For favorable temperature, moisture, and wind the landscape will show a very

high risk for the occurrence of intense and large scale wildfires. Additionally, vegetation encroachment, particularly in younger forest stands, will further increase the fuel in the landscape that with the high connectivity of flammable land uses will favor large scale intense wildfires. Several key functions can be affected by these disturbances, namely hydrological (flooding, soil loss, water contamination), biological (habitat impoverishment; landscape simplification), and cultural (aesthetics).

Table 6. Wildfires in the França Parish from 1990 to 2006.

| | Number | Area | |
|------|--------|--------|------|
| | | (ha) | (%) |
| 1990 | 4 | 969,5 | 17,3 |
| 1991 | 3 | 46,8 | 0,8 |
| 1992 | 0 | 0 | - |
| 1993 | 0 | 0 | - |
| 1994 | 6 | 1631,7 | 29,1 |
| 1995 | 6 | 213,3 | 3,8 |
| 1996 | 18 | 553,4 | 9,9 |
| 1997 | 1 | 57,5 | 1,0 |
| 1998 | 25 | 1617,1 | 28,9 |
| 1999 | 14 | 63,0 | 1,1 |
| 2000 | 17 | 1282,7 | 22,9 |
| 2001 | 28 | 237,7 | 4,2 |
| 2002 | 10 | 55,6 | 1,0 |
| 2003 | 12 | 227,0 | 4,1 |
| 2004 | 3 | 38,1 | 0,7 |
| 2005 | 13 | 58,6 | 1,0 |
| 2006 | 1 | 15,0 | 0,3 |

One of the advantages of conducting landscape change studies is the possibility of avoiding some of their negative effects. Landscape management is therefore a requirement in marginal lands such as the França Parish in order to prevent the tendency of landscape homogenization and to prevent the development of a landscape structure that is less favorable to large scale fires.

4 Conclusion

During the 1958-2005 period, the França Parish went through important changes. There was a strong decrease in agriculture and a regular increase in forests and shrublands. The resulting landscape is less diverse and more aggregated. Considering the population tendency it is likely that the landscape change tendency will be maintained. We expect that these changes are likely to cause change in terms of landscape functioning and in terms of hydrological and biological processes. The major functional change, however, is the possible increase in proneness to fire which can have significant impacts on the ecosystem and landscape services and goods.

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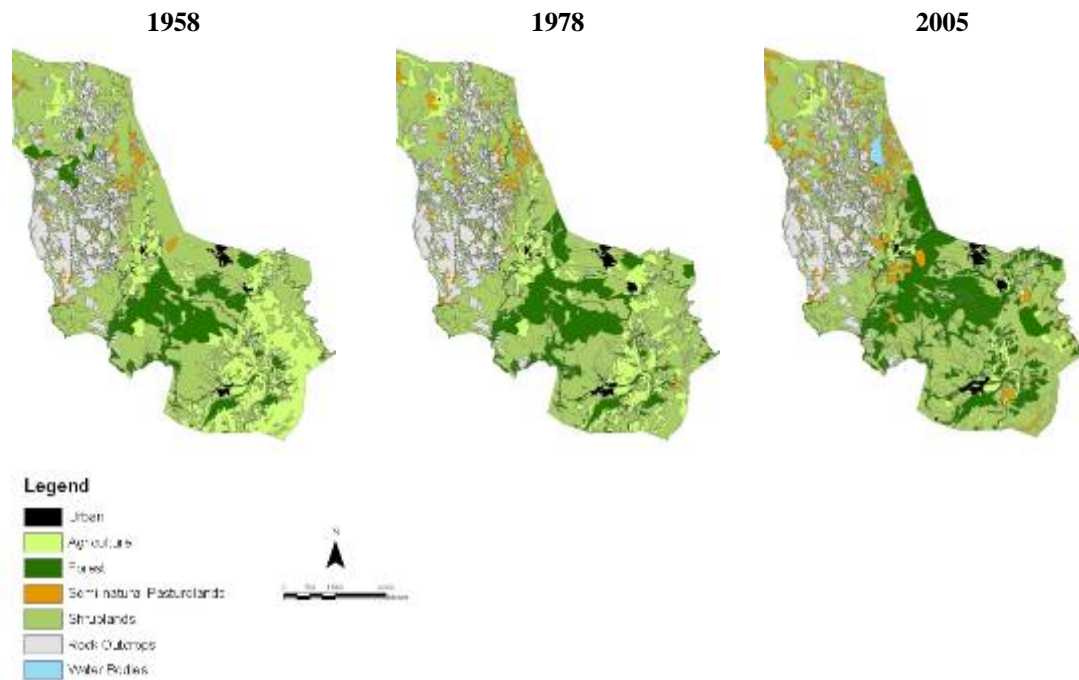


Figure 1. Land use / land cover in the França Parish in three dates of the period of study.

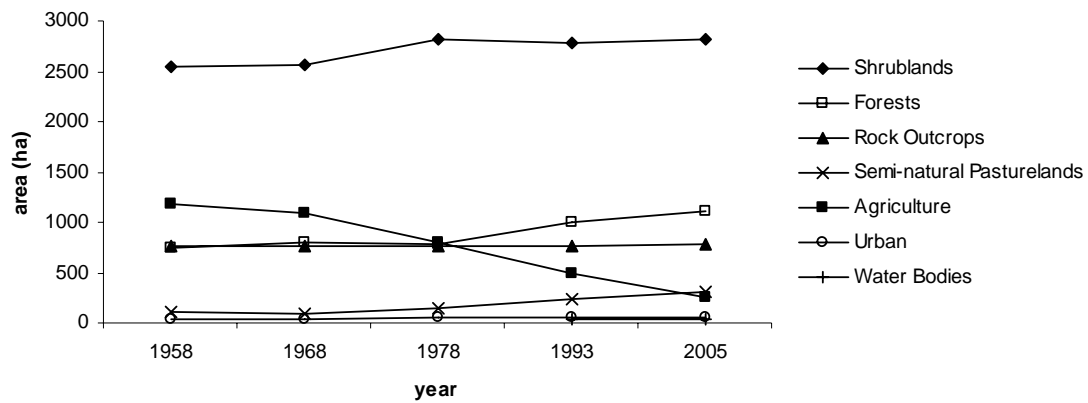


Figure 2. Changes in area for major land uses / land covers between 1958 and 2005 in the França Parish.

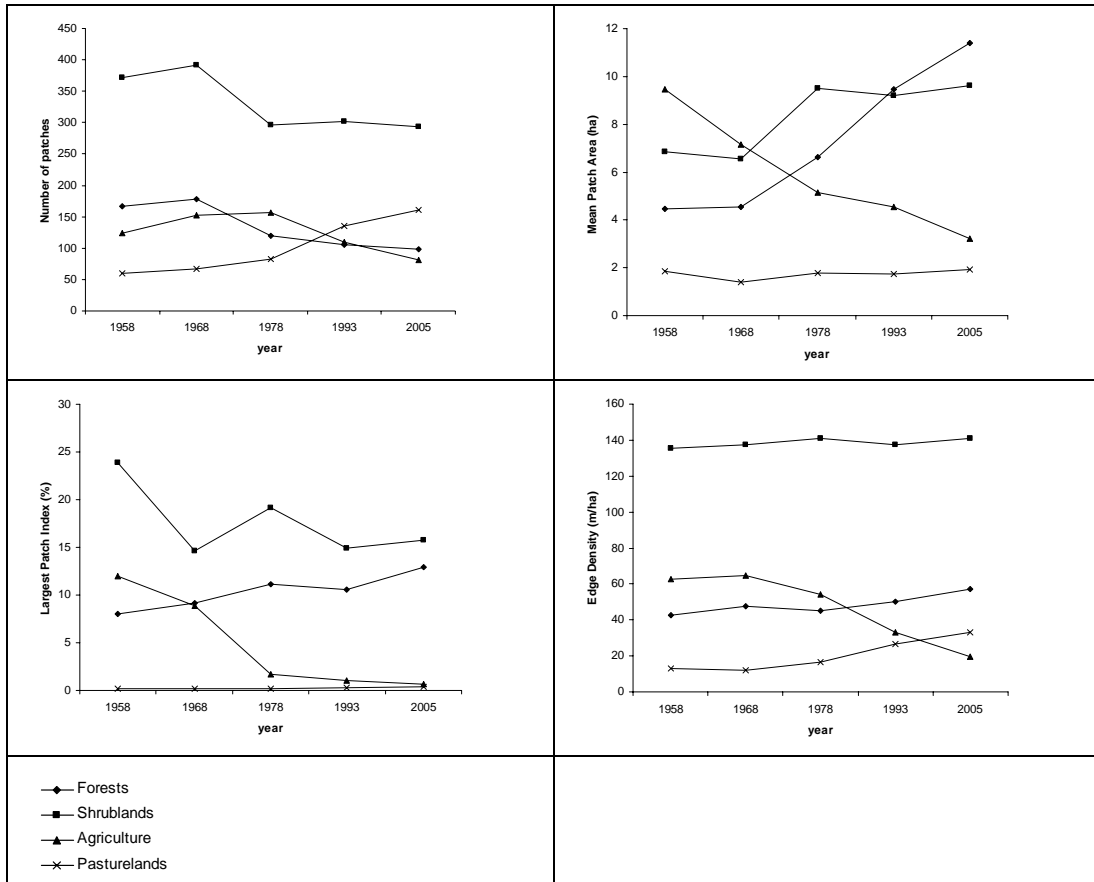


Figure 3. Landscape structure change over the 1958 - 2005 period according to landscape metrics for the major general land uses

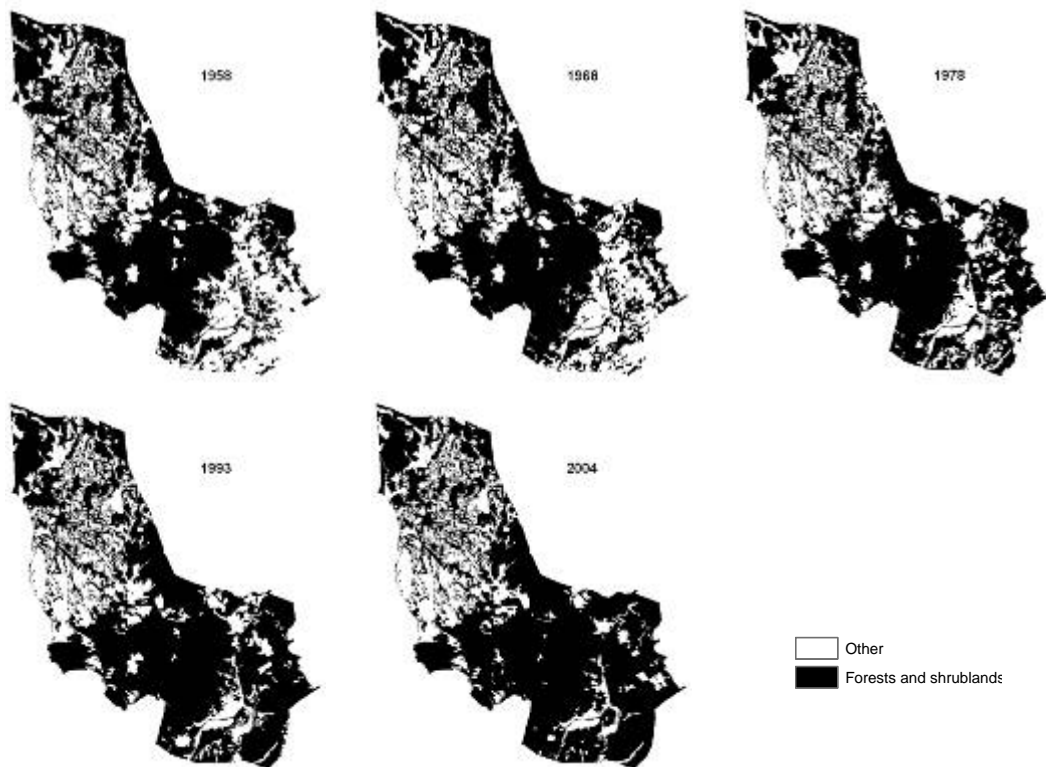


Figure 4. Change in shrublands and forest considered together over the 1958-2005 period of study.