Historic land-use changes and implications of management in a small protected island

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Abstract. Land-use changes in a small protected island (Ushant, France) were analysed from historical documentation (1844) and aerial photographs taken in 1952 and 1992. Over 150 years, and especially during the last forty ones, this island has undergone a complete transformation from rural landscape into a vast scrub. Nowadays, there are no longer cultivated areas, grazed areas have moved from the coastal fringe to the island core, and fallow stretches over 40% of the island total area. The relationship between current sheep population distribution and vegetation shows that grazed areas take up meadows close to inhabited areas (at about 150 m in average from villages). These results allowed us to conduct a prospective analysis of land-cover potentialities in accordance to an increase or reduction in sheep livestock. The scenarios highlighted by this method provide one with an objective framework for further land fallow management.

***Keywords**:* agricultural fallow, GIS, potentialities, sheep grazing, vegetation

Introduction

Landscape dynamics rely on complex interactions between several physical, biological and socio-economical parameters that may occur at various temporal and spatial scales (Reid et al. 2000). Human land-use appears as a prior agent of ecosystem evolution (Simpson et al. 1994): human settlement (Douglas 1994) and activities like intensive crops (Hester et al. 1996; Iverson 1988) can produce strong, and sometimes irreversible, changes on landscape, water- or air-quality, populations of endangered plants or animal species… As part of this human impact on environment, agricultural abandonment entails on vegetation dynamics various responses that are insidious and perceptible on longer time-intervals (Foster 1992; Motzkin et al. 1999). So, over the twentieth century, in several countries, the reduction in land cultivation has caused an extension of fallow lands, which has led to a reduction of biodiversity (Baudry 1991). Vegetation succession after agricultural abandonment refers to a secondary succession process (Falinski 1998). Within this context, the limitation of scrubs proliferation can be viewed through management actions. But, this requires to understand the history of landscapes and the impact of particular land-use like pastoralism on the vegetation cover. The impact on vegetation dynamics differs according to the grazing intensity and species of herbivores (Bakker 1989). Many studies have dealt with vegetation succession in relation with a decrease in cattle grazing (Brown & Carter 1998; de Bonte et al. 1999; Treweek et al. 1997; van Wijnen et al. 1997), or with overgrazing impacts on natural vegetation (Barkhadle et al. 1994). For a nature conservation purpose, grazing activity can be considered as an efficient management tool on condition that it is carefully used (de Bonte et al. 1999).

The study reported here deals with Ushant (Figure 1), a small protected island located off the western coasts of Brittany (France, 1550 ha, 48°28’N latitude, 5°5’ W longitude). The whole island has been exploited by man till the early years of the twentieth century. Then, since 1911 its demography has undergone a drastic fall which reduced its population from 2661 inhabitants in 1911 to about 1000 in 1999. This reduction went along with cultivation abandonment, and led to a nearly complete disappearance of crops (Brigand et al. 1990, 1992). Only a traditional and extensive sheep breeding has been maintained in a traditional way. About one thousand sheep (versus 5903 in 1857) freely roam all over the island during the ‘free-range’ period from early September to early February. All over the rest of the year, the sheep are tied up near houses (Brigand & Bioret 1994). Ushant Island is now part of a regional natural park and is designated since 1988 as part of the Mer d’Iroise Biosphere Reserve. Through the international biosphere reserves network, three objectives are stressed by the UNESCO MAB program (Batisse 1986, 1990; Unesco 1996): i) biodiversity conservation, ii) sustainable development in regional units, and iii) logistic including environmental education, training and involvment of local populations. Within this context, knowledge on the vegetation dynamic processes and the consequences of human activities to biodiversity provide the basis for land management recommendations, as well as for wildlife management programs.

This study is aimed at providing one with a better understanding of landscape dynamics while collecting data relevant for the environmental management of Ushant island. So, its specific objectives are: i) to analyse, especially in a quantitative way, the structure of rural landscape at three dates over the period 1844-1992, ii) to implement a comparative analysis of landscape structure changes and grazing pressure decrease, iii) to measure the spatial distribution of the present pastures and their relationships with vegetation and iv) to forecast the potential trends of landscape changes according to sheep livestock.

Methods

As Geographic Information System (GIS) techniques offer effective tools for storing, retrieving, analysing and displaying spatialized data, they show great potentialities for environmental sciences (Haines-Young et al. 1993; Naveh 1993). Many recent studies have used GIS to describe land-cover and vegetation changes through times (Carmel & Kadmon 1998; de Bonte et al. 1999; Duncan et al. 1999; Kadmon & Harari-Kremer 1999; Miller 1994; Turner 1990) or to analyse the relationships between independent environmental parameters (Duhaime et al. 1997; Franklin 1999; Kadmon & Danin 1999). Using a vector-based GIS (Arc/Info), a spatial database has been set up on the Mer d'Iroise Biosphere Reserve. The present study is based on the implementation of several thematic layers dealing with land-uses in 1844, 1952 and 1992 along with sheep grazing and vegetation in 1992.

Data in relation with human land-uses were available from two different types of documents. By taking into account the shape, location and toponymy of land parcels, different land-use types were mapped from the cadastral register of 1844 and historical archives. Land-use patterns for 1952 and 1992 were interpreted from a set of enlarged black and white (1952) and colour (1992) aerial photographic prints (1/10 000). A land-use map was thus drawn up through a classical photo-interpretation work, validated on field for 1992. The same typology was applied to 1844, 1952, 1992 maps. It was based on 7 predominant land-use types: i) coastal vegetation and low heathlands, ii) pastures, iii) crops, iv) scrubs and fallow, vi) European gorse enclosures, vii) wetlands and built-up areas.

Vegetation and sheep land-use data of 1992 were extracted from a mosaic of 1/10 000 colour aerial photographs and field surveys. Seventeen local vegetation types describe 7 main vegetal formations related to mesophilous, hygrophilous and coastal series (Table 1). Heathlands and maritime grasslands are growing on the poorest and hardly cultivable soils of the coastal fringe of Ushant, whereas ancient cultivated areas set on the brown and deeper soils of the inland part are now colonised by mesophilous meadows and shrubs. Former enclosures of cultivated European gorses *Ulex europaeus* tend to be colonised by shrubs. Hygrophilous meadows, locally colonised by reed-grass and willows, are developing on the hydromorphic soils of the two main small valleys and notches that cut the plateau perpendicularly to the sea (Bioret et al. 1994). Over the summer of year 1993 when sheep were tied up, field observations allowed the identification of 3 categories of sheep grazing: i) areas where sheep were effectively grazing or with indices of sheep presence such as faeces, laid down or trampled grass; ii) areas no longer grazed, but still suitable for pasture; iii) unsuitable-for-pasture areas, without any evidence of sheep presence.

Following the manual photo-interpretation of unrectified photo mosaics and ground-truthing of 1992, we transferred the whole interpreted documents to mylar overlays for digital input and co-registration into an Arc/Info GIS package. Five thematical layers concerning land-use patterns (1844, 1952, 1992), sheep land-use (1992) and vegetation types (1992) were thus obtained, then used to produce maps and descriptive statistics. Spatial and temporal changes along with relationship between sheep grazing and vegetation types were analysed by a polygon overlay process through which time-series graphs summarised areas whereas frequency distribution and tables showed areas of transition for each type of land-use. The spatial distribution of pastures was achieved through the generation of buffer zones of 50, 100, 150 and 200 m around each village, or group of built-up land plots, followed by a selective overlay with the ‘sheep land-use’ coverage.

Results and Discussion

1844-1992 land-uses

In 1844 the whole island was exploited by a population of 1983 inhabitants that has grown during the second part of the century to reach 2661 inhabitants at its height in 1911 (Brigand & Le Berre 1994). Around the villages land-use was already organised from the most intensive to the most extensive use; environmental constraints such as soil quality, topography and wind exposure had been taken into account. Ushant Island is constituted of a plateau highly exposed to winds and, in the absence of trees, the only protections are little valleys and low stone walls (Couix & Le Berre 1996). In 1844, more than 50% of the island area were then covered with crops (green vegetable and potatoes) and 20% with pastures mainly located along the shoreline, also covered with low heathlands in the South Eastern part of the island (Figure 2). Wetlands were located at the bottom of small valleys; they covered about 10% of the island area. Though in 1952 the progression of land abandonment was not yet conveyed by the occurrence of shrubs, its consequences were already noticeable in the scattering of cultivated plots to the benefit of meadows and pastures. Thirty percent of lands were still ploughland; scrubs did not yet grow on European gorse-bounded enclosures, and the low heathlands were no longer involved with sheep grazing, but still covered 10% of Ushant soil. In 1992, important changes occurred in landscapes. There were no more crops, low heathlands extended on quite the whole coastal fringe, and more than 40% of the island area were colonised by fallow. Only the level of built-up areas and pastures was comparable to the one observed in 1952.

Changes

Spatial frequency distributions of land-use changes between 1844 and 1952 as well as between 1952 and 1992 were analysed. This showed that landscape changes were the most noticeable over the last forty years (Tables 2 and 3). Over 150 years, the built-up area, wet areas and coastal heathlands remained rather stable despite the disappearance of crops and occurrence of fallow in 1952. The case of pasture is peculiar: even though the involved surfaces significantly were increasing from 21 to 37% between 1844 and 1952, they later stagnated to finally account for 31% in 1992. In fact, our analysis revealed that only 31% of present pastures have been inherited from 1952-pastures, and that 63% of present pastures result from 1952-crops. This change in land-use has been accompanied by a shift of pastures from the coastal fringe to the inland part. In 1952, the pastures on coastal part spread on slightly more than 27 km out of the 50 km of the whole island perimeter, whereas in 1992 they only covered about 6 km. As a consequence, the coastal vegetation being no longer maintained by sheep livestock tends to change into higher heathlands with *Ulex gallii*, excepted in the most exposed coastal parts of the island. The extension of fallow refers to another process. Contrary to nowadays, fallow did not significantly mark landscapes in the mid twentieth century. So, in less than 40 years they have colonized nearly 42% of the island (Gourmelon et al. 1995). This colonization occurs on 1952-pastures (49%) and on 1952-crops (29%). Crops were reduced by 20% in one century (1844-1952) before totally disappearing (only two land plots issued from an agricultural revival experience in 1975 were still cultivated in 1992).

Sheep land-use and vegetation

In order to measure the spatial distribution of the pastures along with the associated vegetation, we process to polygon overlays,on the one hand, between the sheep land-uses coverage and buffers of built-up parcels extracted from the 1992 land-uses coverage and, on the other hand, between the sheep land-uses coverage and the vegetation coverage.

Today, 30% of the island area are effectively grazed, 17% can be considered as suitable for this purpose, whereas 45% are unsuitable. About the vegetation types involved one should note that the *pastured areas* consist of mesophilous meadows (74%), bracken superposition facies (7%), bracken and thick bramble-made substitution plant communities (7%) and maritime grasslands (4%). The *pasturable areas* are composed of mesophilous meadows (50%), maritime grasslands (13%), superposition facies (10%) and substitution plant communities (7%).

A thorough examination of the present sheep pasture map highlights the linear distribution of pastures along three north, median and south axes that correspond to the main communication ways and to the villages location. The spatial analysis performed carried out by a buffer process showed that 68% of *pastured areas* and 51% of *pasturable areas* were within a 150-m radius from houses. An illustration and confirmation of this trend are provided by mesophilous meadows, which correspond to the strongest grazing pressure: 74% of them are found within this radius.

Prediction of landscape changes in the future

The results reported above allowed us to discuss the influence of sheep grazing on the vegetation dynamics in this island. Today, sheep pastures are mainly located on the central part of the island. The coastal area is only grazed during the free-range period, *i.e.* from September to February. It is, thus, likely that coastal pastures will quickly shift into more marked fallow. On the other hand, the land plots close to houses are cared during the summer months through mowing actions associated to sheep grazing, which thus keep the grass short. In July 1993, the sheep livestock was assessed to about a thousand individuals. Taking into account this datum along with general statistics about the spatial distributions of the various types of environment, it turns out that the pasture pressure on the areas involved by this activity was about 2.25 sheep.ha^{-1}, which is equivalent to less than 1 sheep.ha^{-1} at the island scale. The threshold currently accepted to prevent the propagation of shrubs is 2 to 3 ewes with their offspring (Hester & Baillie 1998). Within this context of undergrazing, one may wonder on the efficiency of the present pasture to limit the extension of shrubs and bushes that represent *[sujet de represent,: shrubs and bushes?]* the most evolved stage of fallow dynamics in Ushant Island (Bioret et al. 1994). Indeed, sheep only maintain the pastured areas, whereas places still suitable for pastures in 1992 are now shifting into a strong shrub dynamics.

In order to provide an objective framework for manager decisions through the fallow management scheme, we will now attempt to determine the trends of future change in relation with increase or decrease in sheep livestock. Our predictions are based on three data: i) actual land-cover and sheep livestock, ii) location of pastures near house, iii) threshold of 2-3 sheep.ha^{-1} to maintain meadows. So, from the present situation four scenarios are illustrated (Table 4, Figure 3).

In the event that the situation observed today (*1000 sheep)* would keep stabilized over the coming years, it would maintain 450 ha of mesophilous meadows presently pastured. On the other hand, the areas still accessible today, but no longer involved with sheep grazing activity, would shift into a process of shrub propagation. If so, shrubs would colonise 43% the island territory.

Further reduction in the size of sheep livestock would provide the situations described hereafter. 1) A *700 sheep livestock* would allow one to maintain about 300 ha, which approximately correspond to the mesophilous meadows presently pastured within a 100-m radius from houses. The other vegetation types, not involved with pastoralism, would thus shift towards maritime heathlands, blackthorn bushes (52% of space), or willows. 2) Without pastoralism activity, landscape dynamics reflects the theoretical potentialities of vegetation. By allotting each of the presently-observed type of vegetation to the final dynamic stage of its serie, one can get an insight into potential vegetation (Pedrotti 1998) according to the three classes: coastal heathland, blackthorn bushes (73% of space) and willows. On Breton islands, the present dynamics of vegetation tends to be stuck at the stage of blackthorn bushes (Bioret et al. 1990). The geographical isolation of the island, combined with the absence of seed-bearers and acorn-disseminator birds (*i.e.* magpies and jays), avoid the natural propagation of potential oak woodland that is observed on the mainland (Bioret et al. 1994; Bossema 1979).

Conversely, the environmental impact of a higher pasture pressure may lead to the following situation: a *1400-sheep livestock* would theoretically maintain the mesophilous meadows presently pastured or suitable for pastures in the same stage and on 40% of space, whereas shrub and bush vegetation would cover 30% of the territory.

Conclusion

The dynamic nature of land-uses in Ushant Island is quite remarkable: a complete transformation has taken place from 1844 to nowadays concommitantly to the abandon ofas the agriculture was abandoned. Changes from agriculture to park use have affected vegetation and transformed landscape from a garden-like structure to a vast scrub (Brigand et al. 1992). In this context, traditional sheep grazing appears to be a sustainable management tool. Many studies have strengthened the role of grazing in nature conservation (de Bonte et al. 1999) for instance on entomofauna and nesting-birds (van Wijnen et al. 1997).

In the study reported here the GIS database was useful in landscape analysis and simulation to provide spatially-explicit for testing hypotheses about patterns of change and relationships between independent parameters. Unfortunately, the manual method used to extract data and the lack of geographical reference information cannot provide one with accurate assessments which is a critical parameter for studies of land-cover changes (Lowell 1990). Even though this methodology demonstrates land dynamics-related spatial trends through long time-scales (40 years), it cannot be transferred onto sharper space-time scales. In fact, the insular fallow management scheme requires a map monitoring at 5 to 10 years steps. Within this scope a different methodology must be envisioned to monitor the dynamic processes in fallow areas. The use of automated procedures for the classification of digital orthophotographs should improve both geometrical precision and space resolution (Barrette et al. 2000; Carmel & Kadmon 1998; Duhaime et al. 1997). At a sharp scale, studying the neighbourhood of shrub parcels should allow one to better define the space context of the involved land-cover while foreseeing the ways of extension through the local environmental features. Such a natural process is assessed by coupling GIS and environmental models (Miller 1994). The modelling approach is also of the utmost interest to simulate landscape functioning while integrating all the environmental parameters into a space-time perspective (Turner 1987) to provide predictions of conflicts between land-uses and biotic elements (Crist et al. 2000) or to project observed changes to the future (Duncan et al. 1999).

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	PRESENT SITUATION	SCENARIO 1 SAME TREND	SCENARIO 2 LOWER TREND	SCENARIO 3 NO SHEEP	SCENARIO 4 HIGHER TREND
NUMBER OF SHEEP	1000	1000	700	0	1400
AREAS OF GRAZED MEADOWS (ha)	620	450	300	0	620
GRAZING PRESSURE (sheep.ha^{-1})	1.6	2.25	2.25	0	2.25
LOCALISATION	Meadows	Presently pastured meadows	Presently pastured meadows at less than 100 m from urban parcels		Presently pastured + pasturable meadows
SHRUBS (% of the island area)	42	43	52	73	30

Mapped as 1844	Mapped as 1952
CROPS (824 ha)	**Crops (473 ha)**
	Pastures (258 ha)
	Fallow (3 ha)
	Other (108 ha)
PASTURES (367 ha)	**Pastures (192 ha)**
	Crops (5 ha)
	Fallow (2 ha)
	Other (168 ha)

Mapped as 1952	Mapped as 1992
PASTURES (579 ha)	Fallow (322 ha)
	Pastures (148 ha)
	Crops (0 ha)
	Other (109 ha)
CROPS (525 ha)	Pastures (300 ha)
	Fallow (192 ha)
	Crops (9 ha)
	Other (24 ha)
FALLOW (9 ha)	**Fallow (7 ha)**
	Pastures (1 ha)
	Crops (0 ha)
	Other (1 ha)

Table 1. Vegetation series composition and correspondence with vegetation units and dynamic steps.

Table 2. Spatial frequency distribution of land-use changes between 1844 and 1952 (other includes low heathlands, wet areas and constructed parcels).

Table 3. Spatial frequency distribution of land-use changes between 1952 and 1992 (other includes low heathlands, wet areas and constructed parcels).

Table 4. Scenario for the evolution of the Ushant land-use according to livestock hypothetical evolution.

Figure 1. The location of the study site in Brittany (Western France).
Figure 2. History of land abandon, Ushant Island.
Figure 3. Scenarios for the evolution of mesophilous vegetation versus hypothetical changes in sheep livestock.

Case-study: Beniguet island in the Iroise Sea (Brittany, France)

Small island of 64 ha in the Iroise Sea, Beniguet belongs to the 'Office National de la Chasse'. Its natural heritage and location within the Réserve de Biosphère d'Iroise justify to have priorities in the management of species and habitat conservation; this may sometimes results in the setting up of concrete field operations. Covered with cultures in the past, this island is now colonized by post-cultural fallows that may locally disturb the habitats of some populations of nesting birds responsible for the conservation designation.

It is within the framework of the scientific activities of the 'Réserve de Biosphère de la Mer d'Iroise' (MAB program) that a multi-disciplinary monitoring of all the coastal areas concerned started in 1988. It has produced spatial inventories of natural, physical and anthropic variables stored in a geographical database over nearly the last 10 years. This database mainly deals with terrestrial and intertidal parameters at the local scale (1 : 5 000) (Gourmelon *et al.* 1995) where the regional context of the Iroise Sea is taken into account in another database developed from 1995 (Le Berre 1999). For Beniguet Island the data were acquired from physical parameters (soil, relief), and natural ones (vegetation, nest-building sites of terrestrial birds) in a time-perspective: vegetation (1990, 1996, 2000), colonies of gulls (1988, 1992, 1996, 2000), nest-building sites of some species of birds (every year since 1998). For the intertidal zone, the biosedimentary strates (1992) as well as the location of sea-bird nest-building sites (1992) were stored into the database.
Within the framework of a European Project, administrators have recently decided to perfect techniques to restore grass-covered dunes and fight against the development of shrubs that presently threaten the nest-building sites of birds. The impact of the actions taken over the period 1999-2001 will be assessed through a yearly monitoring of vegetation, terrestrial nesting birds and populations of micro-mammals. Within this context GIS functions are being used to reach the three following aims.

1- *Change detection.* The comparison of the dynamic stages of vegetation in 1990 and 1996 allowed us to highlight the shrubs development. Through the spatial analysis of geographical information it produced a map easily interpreted; this document summarized the changes that had occurred over the period of time considered and, thus, enabled us to localize and determine the nature of stable environments and of those undergoing degeneration or regeneration.
2 *Setting 3-year intervention plan*. The facts established from the above analysis led the administrator to carry out concrete field actions to limit fallow development. GIS allowed us to draw up maps of the sites where the intervention plan could be implemented, *i.e.* areas meeting the required selection criteria with shrub vegetation, no nests within these sites and/or nearby. Four experimental sites were precisely located from the map produced further to the compilation of selected data. In parallel, it has been decided to store the GPS-located nest-building sites of various species of marine and terrestrial birds into GIS for the period 1999-2001.
3 *Analysis of change factors and modeling of ecosystem functioning*. The analysis of information about the characteristics of the fauna and flora in a time prospect should allow one to determine the parameters responsible for vegetation changes and, in the

end, to model the ecosystem functioning. At this level of analysis, simulation will enable one to evidence the environmental impact of spatial and numerical variations undergone by such or such animal population.