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Land-use changes and implications for management of a small protected island off the coast of Bretagne

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Abstract. Over the 20th century, reduced land cultivation has caused an extension of fallow land in several European countries, which has led to a decrease in biodiversity. Knowledge of dynamic vegetation processes and of the impact of human activities on biodiversity provides the basis for land management recommendations, as well as for wildlife management programs. We analysed land-use changes on a small protected island (Ushant, Bretagne, France) using historical documentation (1844) and aerial photographs taken in 1952 and 1992. Over this period, especially during the last 40 yr, Ushant underwent a complete transformation from rural landscape to extensive shrubland. No cultivated area remains, grazed areas were moved from the coastal fringe to the core of the island, while over 40% of the island is fallow land. The relationship between current sheep grazing and vegetation suggests that grazed meadows used to be close to inhabited areas, i.e. 150 m outside the villages. These results allowed us to analyse land-cover potential related to changes in the intensity of sheep grazing. The scenarios highlighted by our method provide an objective framework for further assessment of fallow land management.

Keywords: Fallow land; GIS; Sheep grazing; Time series; Vegetation.

Introduction

Landscape dynamics are based on complex interactions between several physical, biological and socio-economical parameters that may occur on various temporal and spatial scales (Reid et al. 2000). Often, human land-use is a prime agent of ecosystem development (Simpson et al. 1994): human settlement (Douglas 1994) and intensive cropping (Hester et al. 1996; Iverson 1988) can produce strong, and sometimes irreversible, changes in landscape, water- and air quality, as well as populations of endangered plants and animals. Changes in land-use such as agricultural abandonment can have effects on vegetation dynamics at longer time-intervals (Foster 1992; Motzkin et al. 1999). Over the 20th century, reduced cultivation has caused an extension of fallow land in several European countries, which has led to a reduction of biodiversity (Baudry 1991). Vegetation change after agricultural abandonment is called secondary succession (e.g. Faliński 1998). The extension of shrubland can be related to management measures. But this requires an understanding of the history of the landscape and the impact of particular land-use types such as pastoralism on the vegetation. The impact on vegetation dynamics differs according to the grazing intensity and the type of herbivore species (Bakker 1989). Many studies dealt with vegetation succession in relation to reduced cattle grazing (e.g. Brown & Carter 1998; de Bonte et al. 1999; Treweek et al. 1997; van Wijnen et al. 1997), or the impact of overgrazing on natural vegetation (Barkhadle et al. 1994). In nature conservation, grazing can be an efficient management tool if it is carefully used (de Bonte et al. 1999).

The study reported here deals with Ushant or Isle d'Ouessant (Fig. 1), a small protected island (1541 ha) located off the western coast of Bretagne, France (48° 28' N, 5° 5' W). The entire island was exploited until the early 20th century (Péron 1997). Since 1911 the human population underwent a drastic decline from 2661 inhabitants in 1911 to ca. 1000 in 1999. This reduction led to a nearly complete disappearance of crops (Brigand et al. 1990, 1992). Only traditional, extensive sheep breeding was maintained. Only ca. 1000 sheep (versus 5903 in 1857) roam on the island during the 'free-range' period from early September to early February. During the remainder of the year, sheep are concentrated near houses (Brigand & Bioret 1994). Ushant is part of a regional natural park and was designated part of the Mer d'Iroise Biosphere Reserve in 1988. The international biosphere reserves network (UNESCO MAB program) has three main objectives: (1) biodiversity conservation, (2) sustainable use in regional units, and (3) environmental education, training and involvement of the local population (Batisse 1986, 1990; Anon. 1996). In this context, knowledge of dynamic vegetation processes and the consequences of human activities for biodiversity provide the basis for land management recommendations, as well as for wildlife management programs.

This study aims to provide a better understanding of landscape dynamics. It presents relevant data for the environmental management of Ushant Island. The objectives are: (1) to analyse, especially in a quantitative

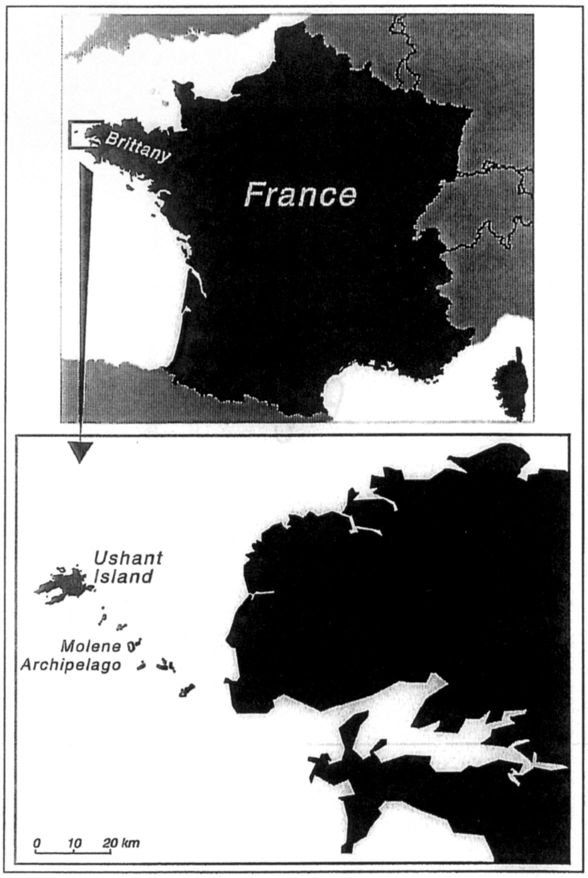

Fig. 1. The location of the study site in Bretagne (Brittany; western France).

way, the structure of the rural landscape at three dates over the period 1844-1992; (2) to implement a comparative analysis of landscape structure changes and grazing pressure decrease; (3) to measure the spatial distribution of the present pastures and their relationships to vegetation; and (4) to forecast the potential trends of landscape changes according to sheep distribution.

Methods

Geographic Information System (GIS) techniques, effective tools for storing, retrieving, analysing and displaying data, have a great potential for environmental sciences (Haines-Young et al. 1993; Naveh 1993). Recent studies used GIS to describe temporal changes in land cover and vegetation (e.g. Carmel & Kadmon 1998; de Bonte et al. 1999; Duncan et al. 1999; Kadmon & Harari-Kremer 1999; Miller 1994; Turner 1990) or to analyse relationships between independent environmental parameters (Duhaime et al. 1997; Franklin 1999; Kadmon & Danin 1999). We used a vector-based GIS (Arc/Info) to establish a spatial database for the Mer d'Iroise Biosphere Reserve. The present study is based on the implementation of several thematic layers, land use in 1844, 1952 and 1992, sheep grazing and vegetation in 1992.

Data in relation to human land-use patterns were derived 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 drawn through classical photo-interpretation and validated in the field for 1992. The same typology was applied to the 1844, 1952 and 1992 maps. It was based on seven predominant land-use types: (1) coastal vegetation and low heathlands, (2) pastures, (3) crops, (4) scrubs and fallow, (5) European gorse (*Ulex europaeus*) enclosures, (6) wetlands and (7) built-up areas.

Vegetation and sheep grazing data from 1992 were extracted from a mosaic of 1:10 000 colour aerial photographs and field surveys. 17 local vegetation types were recognized in seven formations related to mesophilous, hygrophilous and coastal series (Table 1). Heathlands and maritime grasslands grow on the poorest and hardly cultivatable soils of the coastal fringe of Ushant, whereas ancient cultivated areas are found on the deeper loam soils. The loam soils are colonized by mesophilous meadows and shrubs. Former enclosures of cultivated European gorse (*Ulex europaeus*), tend to be colonized by shrubs. Moist meadows, locally colonized by reed-grass and willows, are developing on the hydromorphic soils of the two main valleys (Bioret et al. 1994). During the summer of 1992, when sheep were tied up, we identified three categories of sheep grazing in the field: (1) areas where sheep were effectively grazing or with indices of sheep presence such as faeces, laid down or trampled grass; (2) areas no longer grazed, but still suitable for pasture; (3) unsuitable-for-pasture areas, without any evidence of sheep presence.

Following manual photo-interpretation of unrectified photo mosaics and ground-truthing of 1992, we transferred the 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, and 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 summarized areas whereas frequency distribution and tables showed areas of transition for each type of land-use. The spatial

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

Vegetation series	Main plant formations	Vegetation units	Dynamic steps
Formerly cultivated parcels on mesophilous soils	Secondary meadow	Mesophilous meadow	Initial stage
	Shrubs	Bramble and bracken scrub	Superposition
	Blackthorn bush	Blackthorn shrub	Subfinal stage
Former enclosures of cultivated European gorse	European gorse scrub	European gorse scrub in closed parcels	Initial stage
		European gorse scrub and bracken scrub in closed parcels	Superposition
		Bracken scrub in closed parcels	Substitution
		Heathland	Substitution
Meso-hygrophilous vegetation types	Wet meadows and reed beds	Moist meadow	Initial stage
		Amphibious vegetation	Initial stage
		Molinia caerulea community	Substitution
		Short reed bed	Substitution
		Rush communities	Substitution
		Tall herbs communities	Substitution
		Reed bed	Substitution
	Willow shrubs	Willow shrubs	Subfinal stage
Coastal vegetations	Coastal grasslands and heathlands	Maritime grassland	Initial stage
		Coastal heathland	Initial stage
Others	Cultivated area	Human occupation	—
		Main village, fillup materials, dumps	—

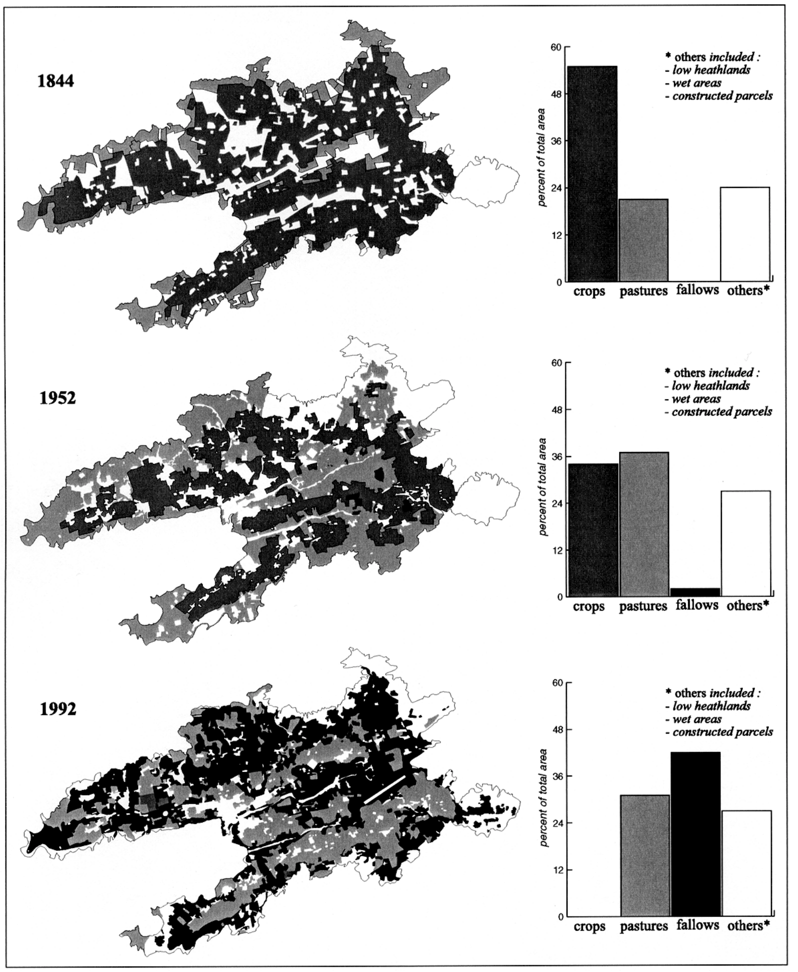

Fig. 2. History of land abandonment, Ushant Island, Bretagne.

distribution of pastures was analysed through the generation of buffer zones of 50, 100, 150 and 200 m around each village, or group of built-up land parcels, followed by a selective overlay with the 'sheep land-use' coverage.

Results and Discussion

Land-use types 1844-1992

In 1844 the entire island was exploited by a population of 1983 inhabitants. By 1911, the population had grown to 2661 inhabitants and was at its peak (Brigand & Le Berre 1994). Around the villages, land use was spatially arranged 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 is a plateau highly exposed to winds. In the absence of trees, the only protection is found in small valleys and behind low stone walls (Couix & Le Berre 1996). In 1844, more than 50 % of the island was covered with crops (green vegetables and potatoes), and 20 % with pastures mainly located along the shoreline, also covered with low heathlands in the southeastern part of the island (Fig. 2). Wetlands were located at the bottom of small valleys, covering ca. 10 % of the island area. Although by 1952 the progression of land abandonment had not yet been followed by shrub succession, the consequences of succession were already noticeable in the scattering of cultivated plots consisting of meadows and pastures. 30 % of the land was still ploughed and the low heathlands were no longer involved in sheep grazing. These low heathlands covered still 10 % of the island. In 1992, important changes had occurred in the landscape. Only two land parcels were still cultivated, low heathlands extended along the entire coastal fringe, and more than 40 % of the island was colonized by shrubs. Only the extension of built-up areas and pastures was similar to the situation observed in 1952.

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

Mapped as 1844	Mapped as 1952
CROPS (842 ha)	Crops (473 ha)
	Pastures (250 ha)
	Other (116 ha)
	Fallow (3 ha)
PASTURES (314 ha)	Pastures (192 ha)
	Other (115 ha)
	Crops (5 ha)
	Fallow (2 ha)
OTHER (385 ha)	Other (196 ha)
	Pastures (136 ha)
	Crops (47 ha)
	Fallow (6 ha)

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 most noticeable over the last 40 yr (Tables 2 and 3). Over 150 yr, the built-up area, wet areas and coastal heathlands remained rather constant despite the disappearance of crops and the occurrence of fallow land in 1952. The case of pasture is peculiar: after the area involved increased significantly from 20 to 37 % between 1844 and 1952, later on some pastures disappeared again and by 1992 they made up only 31 %. In fact, our analysis revealed that only 31 % of the present pastures originated from 1952 pastures, while 63 % of the present pastures was developed on 1952 cropland. This change in land use has been accompanied by a shift of pastures from the coastal fringe to the inland parts. In 1952, the pastures from the coastal fringe extended to ca. 27 km from the 50 km perimeter of the island, whereas in 1992 they only extended to ca. 6 km. Because there was no pruning by sheep grazing any longer, the coastal vegetation changed into taller heathlands with *Ulex gallii*, except in the most exposed coastal parts of the island. The extension of fallow land refers to another process: prior to 1952, fallow did not significantly mark the landscape in the mid-20th century. In less than 40

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

Mapped as 1952	Mapped as 1992
PASTURES (579 ha)	Fallow (322 ha)
	Pastures (148 ha)
	Other (109 ha)
	Crops (0 ha)
CROPS (526 ha)	Pastures (300 ha)
	Fallow (192 ha)
	Other (25 ha)
	Crops (9 ha)
FALLOW (9 ha)	Fallow (7 ha)
	Pastures (1 ha)
	Other (1 ha)
	Crops (0 ha)
OTHER (427 ha)	Other (257 ha)
	Fallow (141 ha)
	Pastures (29 ha)
	Crops (0 ha)

yr, fallow land increased to nearly 42 % of the island (Gourmelon et al. 1995). This abandonment occurs on 1952-pastures (49 %) and on 1952-cropland (29 %). Crops were reduced by only 20 % between 1844 and 1952, but then almost disappeared.

Sheep grazing and vegetation

To measure the spatial distribution of the pastures along with the associated vegetation, we processed polygon overlays between the sheep-grazing areas and buffer zones of built-up parcels extracted from the 1992 land-use cover map and between the sheep-grazing land and vegetation cover.

In 1992, 31 % of the island was effectively grazed and 17 % would be considered suitable for this purpose, whereas the rest is unsuitable. The *pastured areas* consisted of mesophilous meadows (74 %), bracken superposition facies (7 %), bracken and thick bramble secondary succession 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 %).

An examination of the present sheep pasture map highlighted the linear distribution of pastures along three axes: north, median and south that correspond to the main communication corridors and village locations. We used a 150-m buffer around houses that showed that 68 % of pastured areas and 51 % of pasturable areas were within the buffer. This trend was confirmed since 74 % of the moist meadows corresponding to the strongest grazing pressure were found within the 150-m buffer.

Prediction of landscape changes in the future

Today, sheep pastures are mainly located in the central part of the island. The coastal area is only grazed during the free-range period, i.e. from September to February. Thus it is likely that coastal pastures will quickly become more fallow-marked through secondary succession. On the other hand, the lots which are situated close to houses are cared for during the summer months through mowing in order to support sheep grazing which keeps the grass short. In July 1992, the sheep population was ca. 1000 individuals. Given this estimate and the spatial distribution of pasture this means a grazing pressure of 2.25 sheep/ha, and less than 1 sheep/ha for the entire island. The threshold currently accepted to prevent the succession of shrubs is 2 to 3 ewes/ha with their offspring (Hester & Baillie 1998). One may wonder if the present grazing pressure is sufficient to limit the extension of shrubs into the fallow areas of Ushant Island (Bioret et al. 1994). Indeed, sheep only maintain the pastures, whereas places still suitable for pastures in 1992 were involved in scrub succession.

To provide an objective framework for management decisions through the fallow management model, we predict the trends of future change in relation to increased or decreased in numbers of sheep. Our predictions are based on three data: (1) actual land cover and sheep distributions, (2) location of pastures near houses, and (3) a threshold of 2-3 sheep/ha to maintain meadows. Given the present situation, four scenarios were derived (Table 4, Fig. 3).

Under current conditions, 1000 sheep would maintain 450 ha of moist meadows presently used as pasture. The areas accessible today, but no longer subject to sheep grazing, would be involved in scrub succession. In that case shrubs would colonize 43 % of the island.

A reduction in the numbers of sheep to 700 would allow the maintenance of ca. 300 ha, corresponding to the moist meadows presently pastured within a 100-m radius of the houses. An idea about the potential vegetation (Pedrotti 1998) can be obtained according to the presumed vegetation succession of the actual types. It would shift towards maritime heathlands, blackthorn (*Prunus spinosa*) bushes (52 % of space), or willows. Without pastoralism, landscape succession reflects the theoretical potential of the vegetation. To permit each of the presently-observed vegetation types to reach finally the successional stage, we can expect three classes: coastal heathland, blackthorn bushes (73 % of the area) and willows. On Breton islands, the present climax

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

	Actual situation	Scenario 1 Same trend	Scenario 2 Lower trend	Scenario 3 No sheep	Scenario 4 Higher trend
Number of sheep	1000 sheep	1000 sheep	700 sheep	0 sheep	1400 sheep
Areas of grazed meadows	620 ha	450 ha	300 ha	0 ha	620 ha
Grazing pressure	1.6 sheep/ha	2.25 sheep/ha	2.25 sheep/ha	0 sheep/ha	2.25 sheep/ha
Localization	Meadows	Actual pastured meadows	Actual pastured meadows at less than 100 m from urban parcels		Actual pastured + pasturable meadows
Scrub (% of the island area)	42 %	43 %	52 %	73 %	30 %

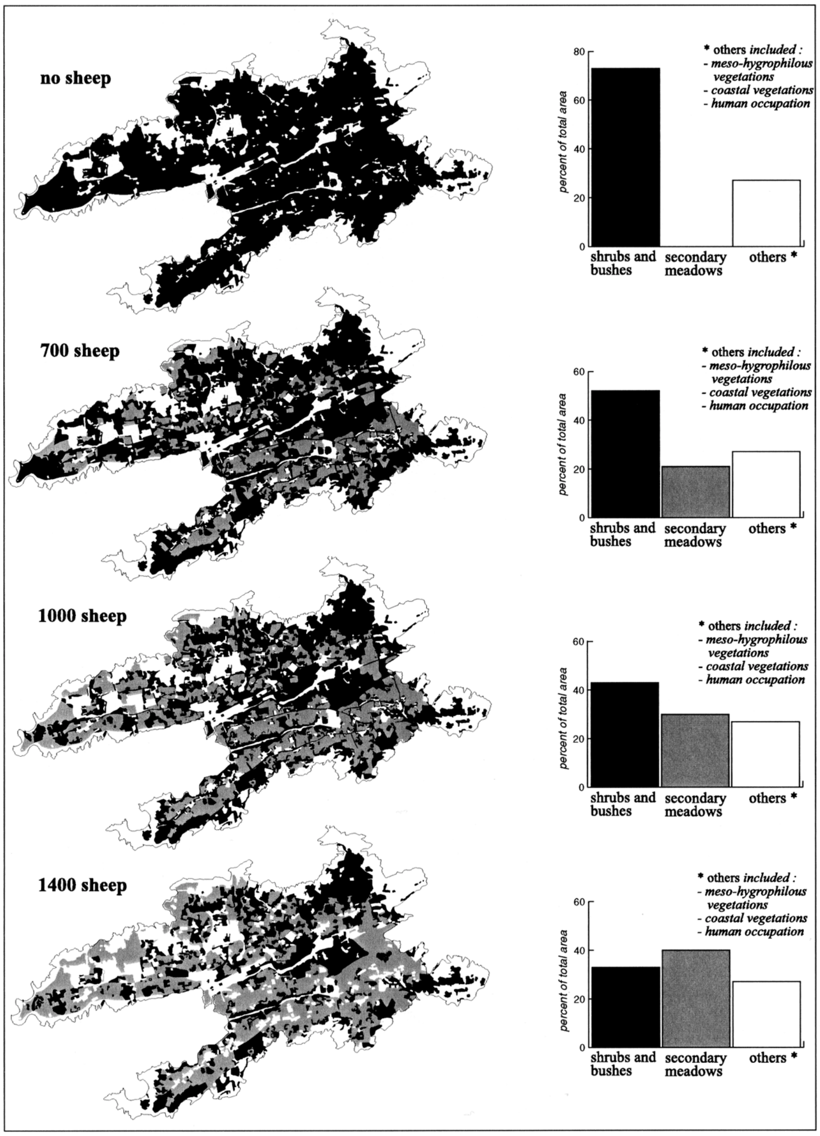

Fig. 3. Scenarios for the evolution of mesophilous vegetation versus hypothetical changes in sheep livestock.

vegetation tends to be blackthorn bushes (Bioret et al. 1990). The geographical isolation of the islands, combined with the absence of seed-bearers and acorn-disseminating birds (i.e. magpies and jays), limit natural propagation of potential oak woodland that is observed on the mainland (Bioret et al. 1994; Bossema 1979).

Conversely, 1400 sheep could maintain the moist meadows presently pastured and suitable pastures in the same successional stage keeping 40% of the island open whereas shrubs would cover 30% of the island.

Conclusions

The complete transformation of the dynamic nature of the land-use pattern on Ushant Island that has taken place since 1844 is remarkable, particularly the abandonment of traditional crop agriculture. Changes from agricultural use to park use in the Biosphere Reserve have affected vegetation and transformed the landscape from garden-like to a vast expansion of scrub (Brigand et al. 1992). In this context, traditional sheep grazing appears to be a sustainable management tool. Several studies support the role of grazing in nature conservation (de Bonte et al. 1999) and in maintaining entomofauna and nesting birds (van Wijnen et al. 1997).

With our GIS study we were able to provide spatially explicit hypotheses testing patterns of change and relationships between independent parameters. Unfortunately, the manual method used to extract data and the lack of geographical reference information does not provide accurate assessments which is a critical parameter for studies of land-cover changes (Lowell 1990). Our approach demonstrated spatial trends through long time-scales (40 to 100 yr) related to land-use dynamics. This cannot be resolved at finer space-time scales. In fact, given the insular fallow management scheme and rates of vegetation succession, monitoring at 5 to 10 yr intervals is required and a different methodology must be developed to monitor the dynamic processes in fallow areas. The use of automated procedures for the classification of digital orthophotographs will improve geometrical precision and space resolution (Barrette et al. 2000; Carmel & Kadmon 1998; Duhaime et al. 1997). At a finer scale, the study of the neighbourhood of shrub parcels should permit a better definition of the spatial context of land cover, while incorporating local environmental features. Miller (1994) recommended to link GIS to environmental models. This modelling approach is necessary to simulate landscape functions while (1) integrating environmental parameters into a space-time perspective (Turner 1987), (2) providing predictions of conflicts between land-use and biotic elements (Crist et al. 2000), and (3) projecting observed changes into the future (Duncan et al. 1999).

References

Anon. 1996. *Biosphere reserves. The Seville Strategy and the Statutory Framework of the world network.* MAB program, Unesco, Paris.

Bakker, J.P. 1989. *Nature management by cutting and grazing*. Kluwer Academic Publishers, Dordrecht.

Barkhadle, A.M.I., Ongaro, L. & Pignatti, S. 1994. Pastoralism and plant cover in the lower Shabelle region, Southern Somalia. *Landscape Ecol.* 9: 79-88.

Barrette, P., August, P. & Golet, F. 2000. Accuracy assessment of wetland boundary delineation using aerial photography and digital orthophotography. *Photogramm. Eng. Remote Sens.* 66: 409-416.

Batisse, M. 1986. Biosphere reserves: developing and focusing the concept. *Nature Resour.* 22: 2-11.

Batisse, M. 1990. Development and implementation of the biosphere reserve concept and its applicability to coastal regions. *Environ. Manage.* 17: 111-116.

Baudry, J. 1991. Ecological consequences of grazing extensification and land abandonment: Role of interactions between environment, society and techniques. *Options Méditer.* 15: 13-19.

Bioret, F., Bouzillé, J.-B. & Godeau, M. 1990. Quelques problèmes posés par l'étude phyto-écologique de deux îles du Ponant (Ouessant et Groix, France): réflexions méthodologiques. In: *Approches comparatives de méthodologies d'étude et expression des résultats de recherche relatifs aux systèmes micro-insulaires en Méditerranée et en Europe du Nord*, pp. 17-23. MAB Unesco, Paris.

Bioret, F., Gourmelon, F. & Le Berre, I. 1994. Analyse spatiale du processus d'enfrichement sur l'île d'Ouessant. *Norois* 164: 547-558.

Bossema, I. 1979. Jays and oaks: an eco-ethological study of a symbiosis. *Behavior* 70: 1-117.

Brigand, L. & Bioret, F. 1994. Réflexions sur l'influence du mouton dans les modes de gestion des milieux insulaires: Ouessant (France) et Clare Island (Irlande). *Norois* 164: 559-564.

Brigand, L. & Le Berre, I. 1994. L'usage de l'espace à Ouessant au milieu du XIXe siècle. *Norois* 164: 535-545.

Brigand, L., Bioret, F. & Le Démézet, M. 1992. Landscapes and environments on the island of Ouessant (Brittany, France): from the traditional maintenance to the management of abandoned areas. *Environ. Manage.* 16: 613-618.

Brigand, L., Fichaut, B. & Le Démézet, M. 1990. The changes that have affected the Breton Islands (Brittany - France). A study based on three examples: Batz, Ouessant, Groix. In: *Sustainable development and environmental management of small islands*, pp. 197-213. Man and Biosphere series, Paris.

Brown, J.R. & Carter, J. 1998. Spatial and temporal patterns of exotic shrub invasion in an Australian tropical grassland. *Landscape Ecol.* 13: 93-102.

Carmel, Y. & Kadmon, R. 1998. Computerized classification of Mediterranean vegetation using panchromatic aerial photographs. *J. Veg. Sci.* 9: 445-454.

Couix, G. & Le Berre, I. 1996. L'espace agricole à Ouessant du milieu du XIXème siècle à nos jours : organisation et évolution. *Mappemonde* 4: 27-30.

Crist, P.J., Kohley, T.W. & Oakleaf, J. 2000. Assessing land-uses impacts on biodiversity using an expert systems tool. *Landscape Ecol.* 15: 47-62.

de Bonte, A.J., Boosten, A., van der Hagen, H.G.J.M. & Sýkora, K.V. 1999. Vegetation development influenced by grazing in the coastal dunes near The Hague, The Netherlands. *J. Coastal Conserv.* 5: 59-68.

Douglas, I. 1994. Human settlements. In: Meyer, W.B. & Turner, B.L. (eds.) *Changes in land-use and land-cover: a global perspective*, pp. 149-169. Cambridge University Press, Cambridge.

Duhaime, R.J., August, P.V. & Wright, W.R. 1997. Automated vegetation mapping using digital orthophotography. *Photogramm. Eng. Remote Sens.* 63: 1295-1302.

Duncan, B.W., Boyle, S., Breininger, D.R. & Schmalzer, P.A. 1999. Coupling past management practice and historic landscape change on John F. Kennedy Space Center, Florida. *Landscape Ecol.* 14: 291-309.

Faliński, J.B. 1998. Deciduous woody pionier species (*Juniperus communis*, *Populus tremula* (*Salix* sp. div.) in the secondary succession and regeneration. *Phytocoenosis* 10: 1-151.

Foster, D.R. 1992. Land-use history (1730-1990) and vegetation dynamics in central New England, USA. *J. Ecol.* 80: 753-772.

Franklin, J. 1999. Predicting the distribution of shrub species

in Southern California from climate and terrain-derived variables. *J. Veg. Sci.* 9: 733-748.
Gourmelon, F., Bioret, F. & Brigand, L. 1995. S.I.G. et évolution paysagère: l'île d'Ouessant de 1952 à 1992. *Mappemonde* 4: 6-10.
Haines-Young, R., Green, D.R. & Cousins, S.H. 1993. *Landscape ecology and Geographic Information Systems.* Taylor & Francis, London.
Hester, A.J. & Baillie, G.J. 1998. Spatial and temporal patterns of heather use by sheep and red deer within natural heather grass mosaics. *J. Appl. Ecol.* 35: 772-784.
Hester, A.J., Miller, D.R. & Towers, W. 1996. Landscape-scale vegetation change in the Cairngorms, Scotland, 1946-1988: implications for land management. *Biol. Conserv.* 77: 41-51.
Iverson, L.R. 1988. Land-use changes in Illinois, USA: the influence of landscape attributes on current and historic land-use. *Landscape Ecol.* 2: 45-61.
Kadmon, R. & Danin, A. 1999. Distribution of plant species in Israel in relation to spatial variation in rainfall. *J. Veg. Sci.* 10: 421-432.
Kadmon, R. & Harari-Kremer, R. 1999. Landscape-scale regeneration dynamics of disturbed Mediterranean maquis. *J. Veg. Sci.* 10: 393-402.
Lowell, K.E. 1990. Differences between ecological land type maps produced using GIS or manual cartographic methods. *Photogramm. Eng. Remote Sens.* 2: 179-184.
Miller, D. 1994. Coupling of process-based vegetation models to GIS and knowledge-based systems for analysis of vegetation change. In: Michener, W.K., Brunt, J.W. & Stafford, S.G. (eds.) *Environmental Information Management and Analysis: ecosystem to global scales*, pp. 497-509. Taylor & Francis, London.
Motzkin, G., Wilson, P., Foster, D.R. & Allen, A. 1999. Vegetation patterns in heterogeneous landscapes: the importance of history and environment. *J. Veg. Sci.* 10: 903-920.
Naveh, Z. 1993. Some remarks on recent developments in landscape ecology as a transdisciplinarity ecological and geographical science. *Landscape Ecol.* 5: 65-73.
Pedrotti, F. 1998. La cartographie géobotanique des biotopes du Trentin (Italie). *Ecologie* 29: 105-110.
Péron, F. 1997. *Ouessant, l'île sentinelle, vie et tradition d'une île bretonne*. Editions Ar Men - Le Chasse-Marée, Douarnenez.
Reid, R.S., Kruska, R.L., Muthui, N., Taye, A., Wotton, S., Wilson, C.J. & Mulatu, W. 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. *Landscape Ecol.* 15: 339-355.
Simpson, J.W., Boerner, R.E.J., DeMers, M.N., Berns, L.A., Artigas, F.J. & Silva, A. 1994. Forty-eight years of landscape change on two contiguous Ohio landscapes. *Landscape Ecol.* 9: 261-270.
Treweek, J.R., Watt, T.A. & Hambler, C. 1997. Integration of sheep production and nature conservation: experimental management. *J. Environ. Manage.* 50: 193-210.
Turner, M.G. 1987. Spatial simulation of landscape changes in Georgia: a comparison of 3 transition models. *Landscape Ecol.* 1: 29-36.
Turner, M.G. 1990. Landscape changes in nine rural counties in Georgia. *Landscape Ecol.* 56: 379-386.
van Wijnen, H.J., Bakker, H.J. & de Vries, Y. 1997. Twenty years of salt marsh succession on a Dutch coastal barrier island. *J. Coastal Conserv.* 3: 9-18.

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