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Structural dynamic of a hedgerow network landscape in Brittany France

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Abstract

Changes in agricultural systems since the 50's led to considerable changes in rural hedgerow network landscapes. In these landscapes, ecological processes depend on the spatial structure of the network (length of hedgerows, connectedness, grain size). This paper reports on a study of the dynamics of such a landscape at four periods of time (1952, 1961, 1972, 1985) done on 26 contiguous 16 ha quadrats. A correspondence analysis of the data matrix yields a gradient of change from dense highly connected networks to heterogeneous landscapes with few hedgerows. The study of individual trajectories of the quadrats allowed them to be regrouped in various types of changes. It is possible for a quadrat to go through several pathways. Rates of change varied through time, the 1961– 1972 period had most changes. The use of supplementary elements in correspondence analysis proves to be a useful way to approach spatial hierarchy and allows a better understanding of the differentiation of landscape units.

Introduction

Change in landscape structure is of concern in landscape ecology (Burgess and Sharp 1981; Baudry and Burel 1982, 1985; Romme and Knight 1982; Shugart 1984; Forman and Godron 1986; Turner 1987; O'Neill *et al.* 1988). Baker (1989) points out that we frequently have a 'lack of knowledge of how and why the landscape changes, as well as empirical data on landscape processes'. Turner and Rusher (1988) asked about the ecological relevance of variable and the scale at which they are studied.

Most studies of landscape changes are based on the number or the area of various elements such as forest, farmland, urban areas, small biotopes. If spatial characteristics (e.g. contiguity, connectedness . ..) are measured, they are dealt with separately (e.g. Fahrig and Merriam 1985; Turner 1987). Few investigators attempt to give an integrated view of the whole landscape structure. Phipps *et al.* (1986) use a multivariate approach to deal with environmental variables that constrain land-use, and do not consider landscape structures.' The multivariate descriptions of Danish landscapes by Agger and Brandt (1988) consider only landscape composition *(i.e.* the type of landscape elements that are present), not its structure (the way the elements are related in space).

This paper reports onchanges in a hedgerow network landscape in Brittany, France between 1952 and 1985. During this period dramatic changes in landscapes occurred everywhere in Europe (Leonard and Cobham 1977; Braekevelt 1988; Agger and Brandt 1988). However, by the end of the 70's, new environmental regulations in France decreased changes subsidized by the administration and caused rural planners to take the ecological value of the landscapes (Baudry and Burel 1984) into account.

The ecology of hedgerow network landscapes has been widely studied (Pollard *et al.* 1974; INRA *et al.* 1976; Forman and Baudry 1984; Burel and Baudry 1989, 1990) and the information is sufficient to identify the spatial variables having a role in the sustainability or change in ecological processes. We used these variables to study landscape structure dynamics; employing a multivariate analysis that allows interpretation of the trajectories in time. First, we focus on methods of landscape description, the usefulness of the descriptors, their complementarity, and the relative change of their value through time. Then we link them with possible factors of change.

Forman and Baudry (1984) identified some structural features of hedgerows such as, length, distance to woodlots, connections among hedgerows, and field size, which influence their ecology. Hedgerows are a refuge for many biotic species in farmland. Some species are confined to hedgerows, others spend part of their life cycle in fields. Examples include small mammals (i.e. Apodemus, (Constant *et al.* 1976a), carabid beetles (Lyngby and Nielse 1980), bumble bees (Fretault 1977) and many birds (Constant *et al.* 1976b)). Hedgerow length is a measure of the available habitat, although there are considerable differences in habitat quality according to hedgerow vegetation structure (Constant *et al.* 1976b; Yahner 1983; Osborne 1984; Burel 1989). Parallel hedgerows bordering lanes (Burel and Baudry 1989), are of special importance.

Grain size means the density of hedgerows within a landscape. This is probably the first structural characteristic recognized as important by ecologists. It has special importance to bird populations (Constant *et al.* 1976b). Dense hedgerow networks can sustain more species (up to 40 per 10 ha) and more pairs of passerine birds than can a landscape with a few scattered hedgerows. There is also a similar effect on carabid populations (Deveaux 1976). Solar radiation interception is greater and wind speed is reduced in fine grain networks (Guyot and Seguin 1976).

The effect of connections between hedgerows and/or woodlots on plant species composition has been described by Baudry (1985, 1989a; Burel and Baudry 1989, 1990) in New-Jersey, U.S.A. and Brittany, France. Similar results were obtained by Burel (1988, 1989) for ground beetles. Merriam (1984; Fahrig and Merriam 1985) points out the role of connections for the survival of populations of small mammals.

A connected network also allows a better control of water fluxes (Baudry 1989b; Burel and Baudry 1989).

Study area

The research was carried in Lalleu, a 1500 ha municipality, 50 km south of Rennes, France. This administrative unit is a level of decision for planning operations such as road enlargement, urbanization and reallotment programs. Interactions among farmers are also more intensive within a municipality. Hence, it is a relevant unit for the study of landscape dynamics in a rural area,

The Lalleu landscape is farmland (grassland, cereals, maize) with most of the fields surrounded by hedgerows. Hedgerows are mainly composed of pruned oaks, pollarded every nine years, according to the local rules. There are no woodlots. Roads between small villages are an important landscape structure. The bedrock of the municipality is an alternation of shale supporting gently rolling landscapes and sandstone, which forms steep slopes. The stripes of bedrock are oriented east-west.

Agriculture has traditionally mixed dairy cattle husbandry with cereal cultivation. During the study period, there have been four agricultural censuses (1955, 1970, 1979, 1988) which indicate an increase in the average farm size (from 11.8 ha to 18.2 ha in 1979 and 26 ha in 1988). Twenty to fifty ha farms (none was larger in 1979) occupied 75% of the land in 1979. This was an increase from 50% in 1970. There has been a linear increase in the stocking rate, from 1.05 cattle unit per ha of fodder production in 1955 to 1.70 in 1979, this figure did not change thereafter. Maize produced for silage appeared in the late 60’s and occupied 9% of the area in 1979.

The trend of intensification is also shown by the ploughing of permanent grassland (38% of farmland to 1979 and 17% in 1988); it led to an increase in field size to allow machinery movement. This was accomplished by removing hedgerows.

In 1985 the total hedgerow length in the municipality was 250 km (161.5 m/ha). This amount is above the average for eastern Brittany (100 to 125 m/ha).

Method

Landscape descriptors were chosen according to their known relationships with ecological processes. They were:

hedgerow length (LEN)

connectedness: number of connections among hedgerows (CON). Depending on the type of intersection, the number of interconnected hedgerows varies. In a T intersections there are 6 connections (each hedgerow is connected with the other two), in a L intersection there are only two connections.

number of 'no-connections' (COO), when the end of a hedgerow is not connected to any hedgerow.

number of connections with hedgerows along lanes (CLA)

grain size heterogeneity (HT);

Sampling method

The area was divided into 16 ha square quadrats. This size was chosen because it was the average farm size. The 1985 landscape map was made by a field survey prior to a reallotment program (CERESA 1985). Data for 1952, 1961 and 1972 were collected from air photos (Institut Géographique National, scale ~ 1/30,000). The measures were made by hand.

Using the 1985 data we selected a sample of 26 contiguous 16 ha quadrats as representative of the whole territory. All the analyses are based upon data collected for this area at the four periods of time (Fig. 1).

Grain size heterogeneity was measured on perpendicular transects of 100 m. Grain size was the distance (Di) between two hedgerows on the transect; Distances were aggregated into classes DCj, with Pj being the frequency of a given class, then

$$HT = -\Sigma \, Pj \ln Pj$$

We used five classes of distance (0-30 m, 30-60, 60-120, 120-225, >225). (see Baudry and Burel 1985 for details).

Data analysis

Data from the 26 quadrats and 4 periods (104 units) were analyzed with correspondence analysis (Benzecri 1973, 1984), followed by a cluster analysis on the scores of the first 3 axes (Jambu and Lebeaux 1978). We used programs of the ADDAD library (Lebeaux 1985) to do this.

Correspondence analysis (CA) is a convenient tool because it does not require any specific data distribution and/or relationships between variables. Generally, the output is efficient for gradient analysis (Austin 1985; Balent *et al.* 1988).

We first coded the variables into classes to run a multiple correspondence analysis, which allows a better understanding of the structure of the factorial space (Lebart *et al.* 1977), especially when relationships between variables are not linear (Gower 1987). Furthermore this gives each sample and each variable the same weight in the analysis. Coding was done according to the frequency distribution of the variables. Each variable was coded into four classes, having approximately the same number of quadrats.

Five variables (length of hedgerow, heterogeneity, number of connections, number of connections with lanes, number of no- connections) were used as active variables.

Aggregated quadrats were used as supplementary elements (*i.e.* they do not affect the structure of the factorial space, but are mapped in it). In correspondence analysis an aggregate of elementary elements has a profile equal to the sum of the profiles of elementary elements (Benzecri 1984). The aggregate is mapped at the center of mass of the elementary quadrats in the factorial space. This means that the

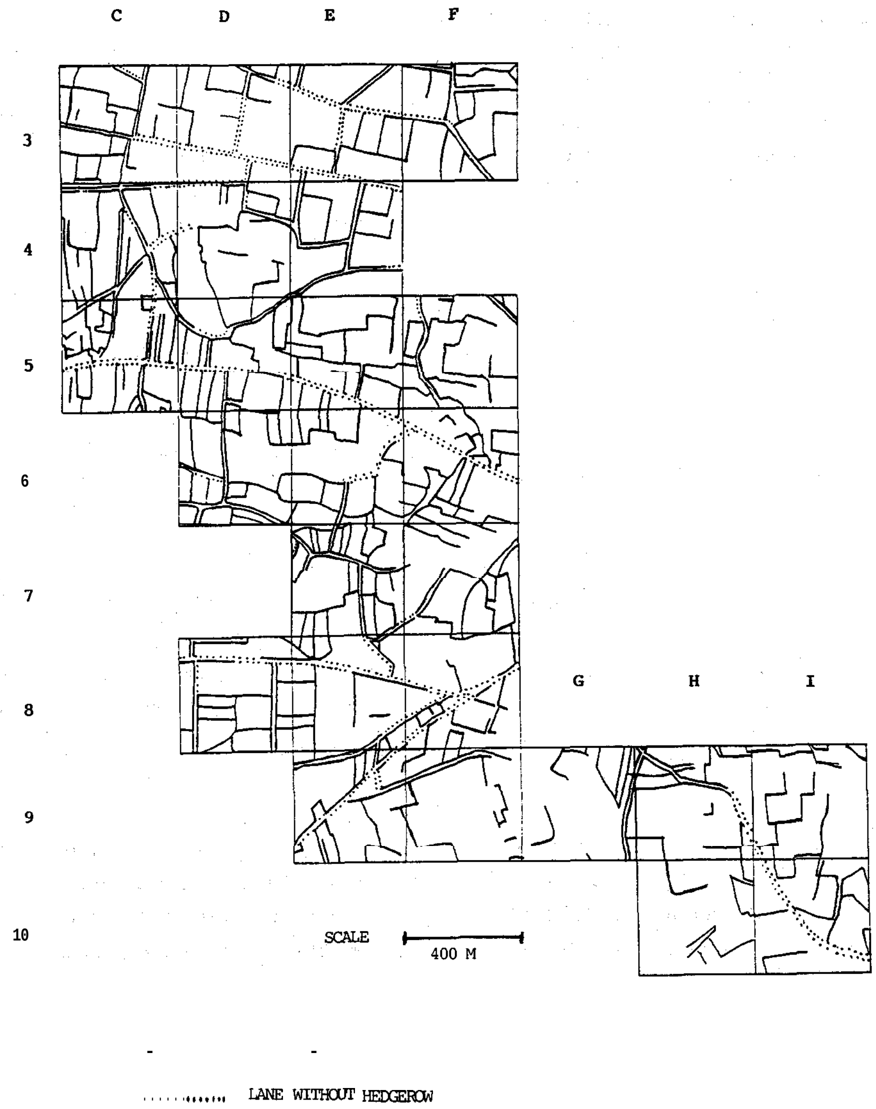


Fig. 1. Hedgerow network of the sampled area in 1985.

aggregate is seen at the resolution scale of the elementary quadrats and not at its own scale, as when it is described by the mean value of the variables of the elementary quadrats. The value of COS^2 of the angle formed by one axis and the line between the point and the center of mass of the factorial space gives the importance of the link between this axis and the point. A high COS^2 means that the point is closed to the axis. This technique was also used to test the representativity of the sample for the whole 1985 landscape. The entire area was studied with quadrats. When these were added as supplementary elements in the analysis, their center of mass was very close to the sample center.

Results

Global changes

Many changes occurred between 1952 and 1985 (Table 1), total hedgerow length of the 416 ha sample area decreased from 96 km to about 62 km, connectedness went from 4166 connections to 1768,

Table 1. Global changes of the descriptors values between 1952 and 1985.

id	LEN (m)	CLA	HT	CON	NCO
1952					
total	96030	319	3432	4166	142
mean	3693.6	12.27	132	160.23	5.46
std	630.93	7.02	6.39	47.10	4.81
1961					
total	89300	250	3439	3218	151
mean	3434.62	9.62	132.27	123.77	5.81
std	665.70	5.89	6.53	48.39	4.22
1972					
total	69300	202	3680	2276	204
mean	2665.38	7.77	141.54	87.54	7.85
std	669.74	5.41	8.70	42.42	4.63
1985 (sample)					
total	61850	193	3817	1768	209
mean	2378.85	7.42	146.81	68	8.04
std	786.66	4.67	6.10	36.09	4.99
1985 (total)					
total	195300	573	12163	4938	571
mean	2325	6.82	144.80	58.79	6.80
std	688.87	4.49	8.86	31.01	4.24

connections with lanes dropped from 319 to 193 and the average quadrat heterogeneity increased. It should be noted that some increase in hedgerow length occurred in a few quadrats. Hedgerows were removed to enlarge roads, but afterward, shrubs and trees were allowed to grow again.

Results of the analysis of the structural gradient

The plan of CA formed by axes 1 and 2 explains 33% of the total variance. Axis 1 was determined on the negative end by LEN4 (> 3600 m hedgerow/quadrat), CLA4 (> 12 connections with hedgerow lane), and CON4 (> 160 connections among hedgerows); on the positive end important variables are LEN1 (< 2400 m hedgerow/quadrat) and HT4 (grain size heterogeneity < 14). The fact that neither low connectedness nor connections with lanes have a significant contribution to the positive end of axis 1 emphasize the poor correlation among variables. Along this axis, quadrats vary from a dense hedgerow network with lanes to a landscape with few hedgerows around fields of heterogeneous size (see examples Fig. 5).

Connectedness (variables CON1 -4) contributes to 41 % of the variance of axis 2. This measure contrasts highly connected dense hedgerow networks with networks with intermediate number of connections. Along this axis the progressive enlargement of fields lead to some non-connected hedgerows. In fact there are various pathways for change between a dense network and a very open one. At intermediate steps along the gradient there are many possibilities for heterogeneity or connectedness. This appears when quadrats and variables are ranked according to their score on the first axis; there is a relative homogeneity of structure at both ends, but in the center, classes of value are mixed. For example **G9–1952** and **F8–1961** have both 3400 m of hedgerows, but connectedness for the first is 154 and 104 for the second, HT values are 134 and 128.

Axis 3 does not explain a significant part of the global variance (tested according to Lebart *et al.* 1977), yet, it was used for the cluster analysis to keep the information it contains for some quadrats.

Table2. Landscape diversity and mean **quadrat** heterogeneity at the four periods.

Year	Distance of **quadrats** to the center of mass of the year		Mean **quadrat** heterogeneity
	mean	std	HT
1952	861	301	132
1961	895	312	132
1972	708	436	141
1985	621	337	147

Landscape diversity at each period

On the plan of CA the quadrats were not grouped by periods, at each period there is a large diversity of situations. Situations existing in 1952 can still be found in 1985. A way to assess landscape diversity for a given year, is to compute the mean Euclidean distance between each quadrat and the center of mass of the year on the factorial plan. The more the quadrats are scattered, the more they are different, and the higher is the landscape diversity. This overall landscape diversity can be compared with the quadrat heterogeneity, which is a measure of diversity at a different scale. Table 2 shows that landscape diversity was almost the same in 1952 and 1961, then declined. This means that the landscape quadrats tended to be more similar. In the meantime quadrat heterogeneity increased, field size within quadrats becoming more dissimilar.

Cluster analysis

The cluster analysis split the 104 quadrats into 6 classes-. The mean value of each descriptor, by classes is given in Table 3. Cells in classes **1,2,3** have a low hedgerow length, they differ by their heterogeneity (high for 1 & 2) and their connectedness (specially low for 3). Cells in classes 5 & 6 have a long hedgerow length, a low heterogeneity and a high connectedness (specially 6). Class 4 is intermediate between 1,2,3 and 5,6.

The descriptors do not vary in the same way between classes; they give different information. The same length of hedgerow can be associated with different values of heterogeneity or connectedness, indicating a different spatial arrangement of hedgerows. Maps of the distributions of quadrats into classes at the four periods are given in Fig. 2. Globally there has been a shift from classes **5,6** toward classes 1,2,3. But rates of changes of individual quadrats are not monotonous nor do they occur at the same time. This is consistent with the distribution of quadrats in the factorial space.

Trajectories of changes

To describe and understand changes, it is important to find out if trajectories of changes can be classified into types, and to look at differences between types. Classification was done by a cluster analysis

Table 3. Characteristics of the classes yielded by the cluster analysis.

class		LEN (m)	CLA	HT	CON	**NCO**
1	mean	2187.50	3.17	147.08	77.67	7.08
	std	423.80	3.33	7.66	21.52	2.71
2	mean	1946.67	5.80	147.93	55.60	8.73
	std	527.28	2.46	9.03	23.51	4.98
3	mean	2400	7.13	143.88	41	6
	std	504.98	3.04	4.29	12.51	1.85
4	mean	2875	6.35	138.50	84.60	5.85
	std	336.98	4.46	5.84	21.55	3.05
5	mean	3459.66	10.52	133.24	128.69	8
	std	318.35	3.92	7.24	24.84	6.16
6	mean	4200	17.50	129.95	195.50	4.65
	std	379.75	4.87	4.03	29.71	4.69

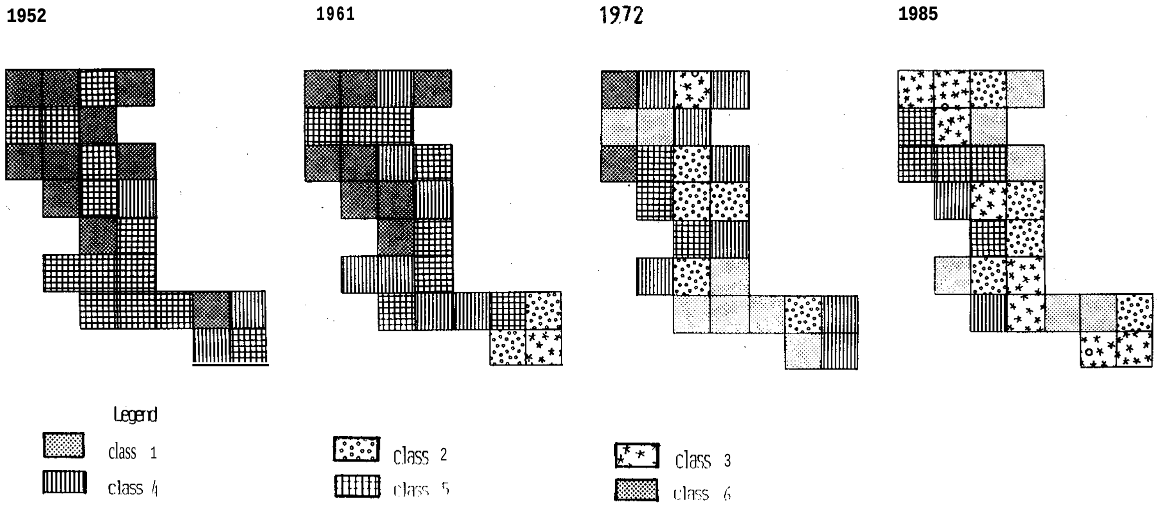


Fig. 2. Maps of the **quadrats** at the 4 periods, according to the cluster analysis (see Table 3 for the characteristics of classes).

where each **quadrat** was characterized by its factorial scores on the two first axes for the four sampled years. This gave four types of **quadrats** with different average characteristics (Fig. 3).

Type 1 is composed of 5 **quadrats** having constantly the highest hedgerow length (mean length: 4460 m in 1952 and 3360 in **1985),** as opposed to type 4 (9 quadrats), with a low hedgerow length (3155 m in 1952 and 1778 in 1985). Types 2 and 3 (6 **quadrats** each) are intermediate. The patterns are similar for heterogeneity, but not for connectedness nor for no-connections. If in 1952 type 4 had the lowest connectedness **(120),** in 1985 it is type 2 that have the lowest **(42, 57** for group 4). This is because not only do the types differ by the average starting and ending points, but also by the rates of change. For most of the variables, type 2 changed faster than any other (Fig. 3). Type 1 remained almost unchanged between 1952 and 1961, as did type 3 between 1972 and 1985. In 1952 and 1961, type 1 and 4 had the same number of no-connections; a divergence took place afterward, so that in 1985 type 1 is similar to type 3 and type 4 to type 2. On the average, in 1952 type 2 was very similar to type 1, in 1985 it was similar to type 4. **Quadrats** in type 2 are fast changing ones and traverse almost the entire factorial space. ***This implies that the knowledge of the characteristics of a type at any given time gives no information on its future behavior.*** One example of each type of trajectory is given on Fig. 4.

The mapping of types (Fig. 5) shows that there is some spatial auto-correlation, **quadrats** of types 3 and 4 are more abundant in the south, and type 1 in the north. This will be discussed later in the study of geographic zones.

Rate of changes

The rate of change of one **quadrat** is measured by the distance of its positions between two periods divided by the time lag (Smith and Urban 1988). These rates have been computed for all **quadrats** for the three time intervals **(1952–** 1961, **1961–** 1972, 1972-1985). The mean rate of change is maximum between 1961 and 1972 (156 score units/annum) and practically the same for the two other periods (about 50 score units/annum). During the 60’s the French government gave subsidies to remove hedgerows to speed up the modernization of agriculture, this may explain the higher rates. Data on rates of changes are supported by the cluster analysis (Fig. 3): in 1961 there were only 3 **quadrats** in classes 1-3 (low hedgerow length), while 16 **quadrats** were in classes 5-6 (high hedgerow length), in 1972 13 **quadrats** were in classes 1 – 3 and 5 in classes 5-6.

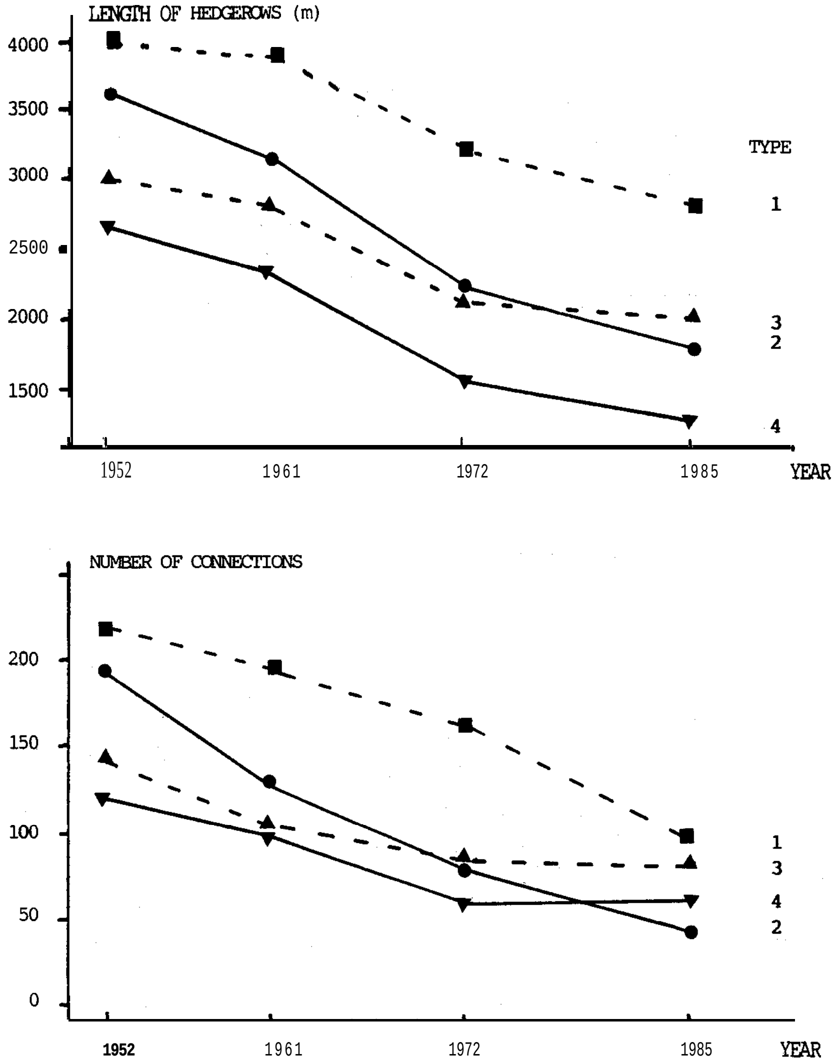


Fig. *3a.* Average characteristics of the 4 types of trajectories of changes of quadrats between 1952 and 1985.

Predictability of changes

Predictability of a phenomenon is requisite to build and use models of change. The results show that the landscape is not changing as a whole; individual quadrats have their own behavior. We tested the predictability of changes in two ways: first by comparing the relationships between scores on the first axis at the different periods (correlations among scores), and second, by the probability of a quadrat in a given class being in another at the next sampling period (test on a contingency table). None gave any positive result. We concluded that change cannot be predicted from the knowledge of current state of a quadrat alone. Therefore, we changed the level of investigation.

Patterns of changes at other scales

To evaluate the effect of the position of the quadrats in geographic space, they were aggregated into five zones: North, Center, South, Village, Large farm. The first three zones are coherent with the geomorphological stripes of the area; the others are determined by a specific type of human occupation:

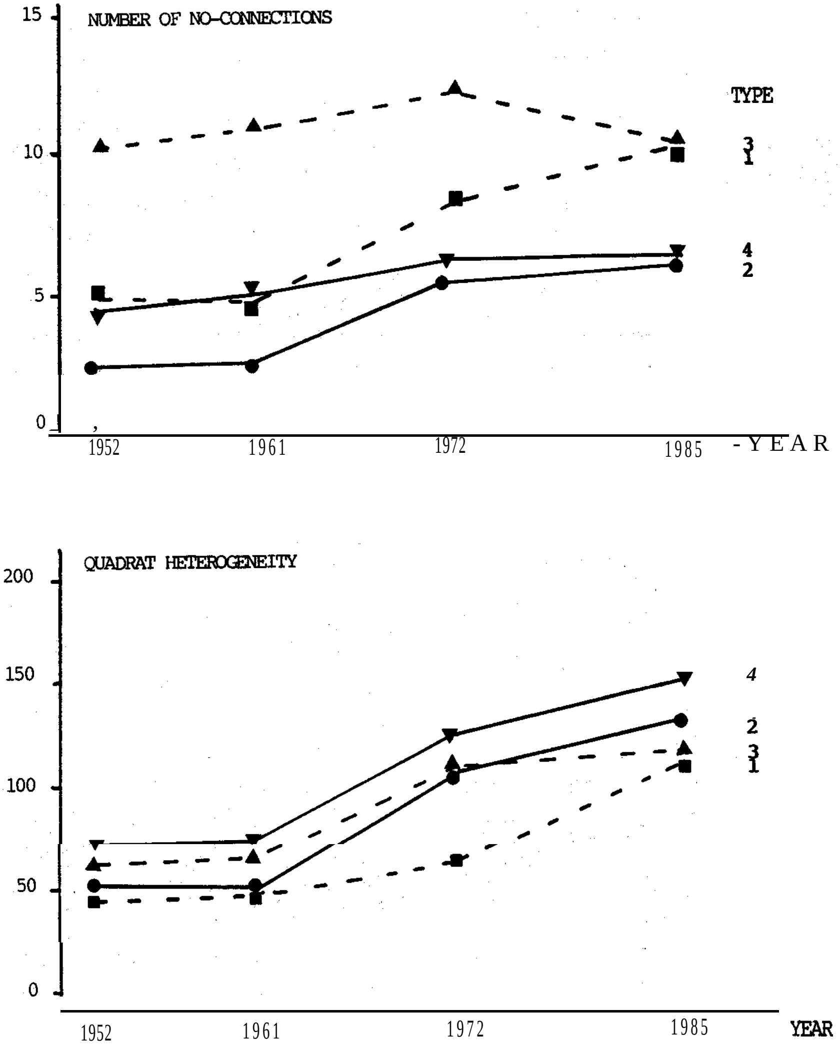
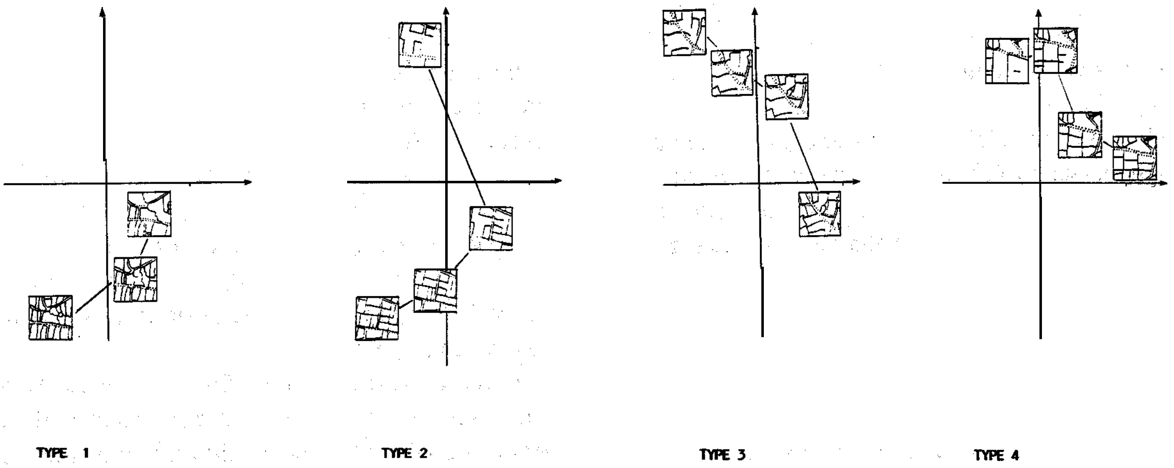


Fig. 3b.


TYPE 1

TYPE 2

TYPE 3

TYPE 4

Fig. 4. Example of trajectories of **quadrats** of the various types.

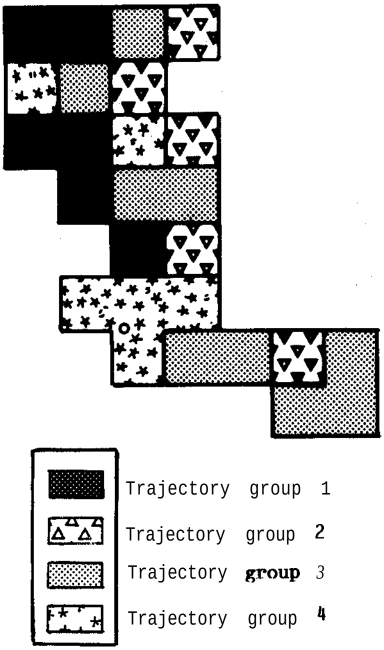


Fig. 5. Map of the various types of trajectories of changes.

a village with a few small farms and an area used by large farms. The trajectories of the quadrats of the last two groups have been identified as being very different; the geomorphological stripes encompass quadrats with various trajectories. Trajectories of these zones are illustrated on Fig. 6. The maximum rate of changes was between 1961 and 1972 (about 100 score units/annum for all groups), except for the large farm area (12 score units/annuum). This latter area seems to behave more at its own scale and not under pressure of the administration and subsidies. For example it changed a lot after 1972 (113 score unit/annuum), probably due to the introduction of silage maize.

The relative autonomy of each geographic zone can be seen on Fig. 7, which represents the distance between the center of mass of a geographic zone and the center of mass of the whole landscape on the factorial map (l-2) for each period. The village area is always different; the large farm area become similar in 1972, after every quadrat changed elsewhere, then it is different. The south and the north areas tend to become similar to the whole landscape while the center seems to behave randomly.

When we look higher in the spatial hierarchy, we see that each zone damps the changes of its individual quadrats. Overall, the whole landscape changed less than the fastest of its quadrats because it still has internal diversity. The rates of change for the three time intervals (21, 101, 18 score unit/annuum) are even lower than the averages rates of change of the individual quadrats (51, 156, 50). It also appears that at higher scales trajectories tend to follow axis 1 only (Fig. 6), as if length of hedgerow and connectedness were the only important variables. Cos^2 of the aggregates are never high with axis 2, except in the south in 1961.

Discussion

The main goal of this study was to find a method to describe and to understand changes occurring in an agricultural landscape, using spatial variables related to ecological processes. Changes were known to be important, but apart from hedgerow length, variation of descriptor values over time, as well as the rates of change, was unclear.

The structural gradient yielded by the correspondence analysis is more complex than a mere decrease of hedgerow length. Grain size heterogeneity and connectedness are also important variables. In fact, they have similar part in the variance of the first axis (20–30%). But they are not correlated; there are various possible spatial arrangements for a given length of hedgerow. So, it is necessary to use them simultaneously to describe the landscape. In the Lalleu area grain size heterogeneity was still high in 1985. If hedgerow removal continues, grain size heterogeneity should decrease with large fields becoming dominant as found by Baudry (1985) in another municipality of Brittany. The number of no-connections is a less important variable (in term of structural differentiation); it contributes only 10% of the inertia of the first axis. Unconnected hedgerows are generally ephemeral elements in a landscape, Notteghem (1986) noticed that they are the first to be removed. The ecological consequences of losing unconnected hedgerows are unknown. The consequences of other changes are more easy to envision. Loss of habitat and fewer

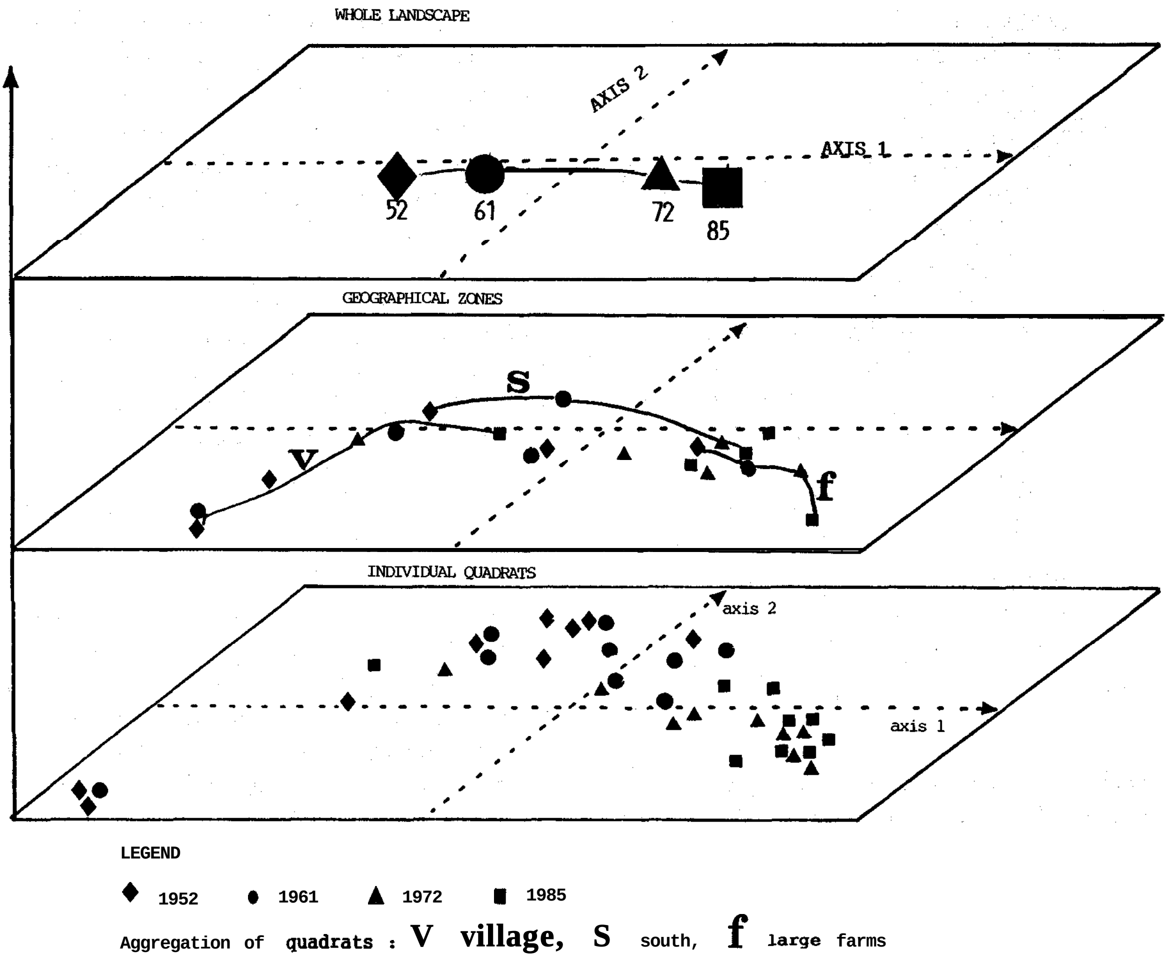


Fig. 6. Dynamic of the spatial hierarchy in the factorial plan 1-2: at the first level are individual quadrats (for the sake of clarity, only quadrats of the southern zone are represented, all quadrats are on Fig. 2); at the second level geographic zones are mapped, trajectories of the village (v), of the south (s) and the large farms area (f) are represented; at the third level is the trajectory of the whole landscape.

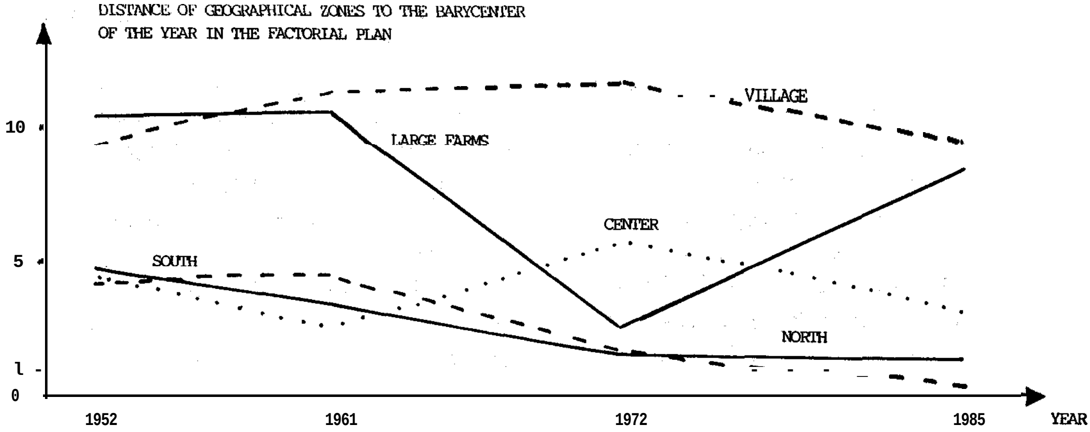


Fig. 7. Variation of the distances between the centers of mass of the geographic zones and the center of mass of the whole landscape for each year between 1952 and 1985. This distance measures the dissimilarity between the geographical units and the whole landscape.

routes for movement or colonization are the expected effects of diminishing hedgerow length and connectedness. Increasing field size and heterogeneity created new habitats for open field species. The balance in terms of species richness needs to be assessed, as well as the effects of the trajectories of changes on species living in hedgerows.

Changes occurring in the rural landscape depend on the overall change of agricultural systems, such as mechanization, and increase of farm size, and also on local conditions, such as the contrast between landscapes of large farms and those around villages. Ownership patterns are important driving forces of landscape dynamics, as evidenced by the dramatic changes occurring after reallotment programs. Reallotment programs and the effects of subsidies for hedgerow removal exemplify the impact of agricultural policies on landscapes. The lack of environmental input in such policies has been largely responsible for the deterioration of the rural environment.

Because of the many factors driving agricultural landscape dynamics, trajectories and rates of changes vary in both space and time. There is a fundamental differences between agricultural and natural landscapes: the shifting mosaic assumed in the models of the latter (Shugart 1984; Smith and Urban 1988) does not exist in the former. In the rural landscape changes are not cyclic. For this reason, we cannot expect any kind of equilibrium at the global landscape level, nor cyclic behavior of the individual quadrats. This complexity is also reflected in the lack of predictability of changes.

The hierarchical approach (Allen and Starr 1982; Urban et *al.* 1987) was useful to understand these changes. By observing change at higher spatial levels, that is, the levels at which the rural society is operating, effects of human constraints appeared. We observed results similar to Smith and Urban (1988) using simulated data on forest stands, that rates of change at higher level are slower than the average change at a fine scale, seen at the same time scale. In agricultural landscapes too, differences in rates of change at different levels, means possible differences in change of ecological processes operating at different scales.

In addition, we have shown that fewer variables discriminate landscape structures at higher levels of scale, though they are studied at the resolution scale of the finest levels. The heterogeneous dynamic of individual quadrats leads to a fragmentation of fine grain species habitat (ground insects, plants), which means isolation of population in slow changing quadrats and extinction in fast changing ones. Species operating at the global landscape level such as birds of prey may see more gradual changes, so extinction may be slower, but once it occurs, there is no local source for recolonization. These details are important for the assessment of the ecological consequences of landscape changes.

Regarding the weight of the different variables at different levels, from an ecological standpoint it is a plausible hypothesis that species using several hundred hectares are not as sensitive to connectedness (axis 2) as are species using only a few hundred meters of hedgerows.

Beyond this case study, remains the problem of modeling landscape changes. Obviously changes are only predictable when both environmental, technical and socio-economical factors are taken into account. Indeed, this requires a complex model, even at the conceptual stage (Baudry *et al.* 1988) and data collection in several landscapes to understand the past and current trends. The impact of agricultural policies is of overriding importance (Golley and Golley 1988; Mowle and Bell 1988) but is particularly difficult to assess because of the mediation of farmers operating within a given cultural, technical and environmental context. In the case of the hedgerow network landscape the awareness of the public and of farmers to their ecological and aesthetic values is an opportunity to implement environmental constraints in planning and management . This can only be done by a better understanding of unconstrained landscape dynamics. Recognition of the central role of landscape structure on environmental quality by landscape ecology helps to give advice in landscape design (Baudry and Burel 1984). Studies like the one presented here allow the measurement and comparison of overall landscape characteristics. Furthermore, they are at the scale in which planners act. The goal is then, not to maintain a dense hedgerow network everywhere, but rather to change it according to agricultural practices and ecological functioning. In this way, we might propose plans with less hedgerows, but higher connectedness to control or enhance fluxes in the landscape.

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