

Interdisciplinary Analysis of Hedgerow Network Landscapes' Sustainability

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ABSTRACT Hedgerows with pollarded trees are still emblematically shaping many agricultural landscapes in Western Europe; they are part of our heritage but their future is uncertain due to the enlargement of fields and loss of firewood use. As a consequence the sustainability of these agricultural landscapes is questioned. We studied changes in hedgerow management in a long-term ecological site in Brittany, France with an interdisciplinary approach. Importance, spatial distribution and relationship with the agricultural system have been assessed over 11 years in three contrasted hedgerow network landscapes, while management practices and farmers' perception were studied from an anthropological point of view. Two apparently opposed trends were found: first, an apparent decrease in the interest of farmers for hedgerows witnessed by the diminishing of the rate of pruning; second, changing attitudes of farmers not necessarily toward hedgerow abandonment but rather toward the production of novel shapes for pruned trees.

KEY WORDS: Pollard trees, management practices, hedgerow, wood production, LTER, farmers

Introduction

Hedgerow network landscapes (cultural bocage landscapes) are common features in Western Europe. As with most agricultural landscapes they have changed greatly over the last few decades (Agger & Brandt, 1988; Burel & Baudry, 1990). Many hedgerows have been removed to facilitate cultivation. The remaining wide and tall hedgerows are mostly located along pastures, whereas arable plots are usually bordered by narrow hedges, if any (Barr, 1993; Hegarthy *et al.*, 1994).

Hedgerows fulfil functions such as wood production, protection from wind and soil erosion, food production and delimitation of property boundaries (INRA *et al.*, 1976; Forman & Baudry, 1984; Burel, 1996; Austad, 1990). In Europe, pollarded trees in hedges remain common features in some Mediterranean, Balkan and Scandinavian countries and in the UK (Petit & Watkins, 2003; Rackham, 1986). Hedge trees are pruned in different ways depending on tree species and use, for example as fodder (pollarded ash), timber (oak and beech) or firewood and fenceposts (chestnuts) (Pollard *et al.*, 1974; Rackham, 1986; Baudry & Jouin, 2003).

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The periodicity of pruning has decreased significantly during the last century. In France, firewood production is still important: the yearly production of firewood from hedgerows is 4.4 million cubic meters. It accounts for 11% of total firewood used by families (SOLAGRO, 1997) and is the main direct economic value of hedgerows.

Concern for the ecological and social sustainability of hedgerows is expressed in many public policies in Europe. For instance, the United Kingdom (McCollin, 2000) and France have a legislation protecting 'important' hedgerows. Denmark (Gravholt Busck, 2003) and France (Breizh-bocage, 2008) have incentives to plant hedgerows. In this paper, we ask if there is a future for hedgerow networks in cultural landscapes. We use firewood production and tree pruning practices as indicators of hedgerow value to farmers. The study site was on the Pleine-Fougères long-term ecological research site. Three contrasting landscape units differing by hedgerow density were examined to test for current management of trees in hedgerows. Traditional tree management on the site (and in the Rennes basin where the site is located) is the pollarding of trees along the trunk; this results in a characteristic shape (shredded trees) (see Figure 3).

In this paper we study how pruning periodicity changed over a period of 11 years and we look at changes in pruning practices. These data are linked to farming systems to assess the sustainability of the agroecosystems. We used two complementary, integrated ecological and social sciences approaches. The first approach was based on measuring the length of hedgerows pruned annually over a period of 11 years to assess current use. The second was an anthropological study to evaluate the perception of hedgerows by farmers and how this might influence hedgerow management. A secondary objective of our research was to provide a sound scientific basis on which to develop sustainable management practices.

The Study Area

Brittany is a region with little forest covering, only 8% of the land surface. It is an agricultural area characterized by the presence of hedgerows as shown in Figure 1.



Figure 1. Aerial photograph of the study area.

The study area is in northern Brittany, France (48° 36' N, 1° 32' W). It is designated as a Long Term Socio-Ecological Research (LTER) site (www.caren.univ-rennes1.fr/pleine-fougeres) with research ongoing there since 1994. Three contrasting landscape units were delimited, differing in hedgerow network density and agricultural characteristics, to test for the effects of landscape structure on the distribution of flora and fauna (Baudry *et al.*, 2000b; Burel *et al.*, 2000; Thenail, 2002). On site A the hedgerow network has the highest density, site B has an intermediate density, and site C has a more open landscape (Table 1).

On these sites permanent grasslands are often bordered by hedgerows (61% of the boundaries between two permanent grasslands, 59% between grassland and leys, and 53% between grassland and crops). Hedgerows are less frequent along ploughed fields and roads (Figure 2).

The dominant trees in the hedgerows are primarily oak and secondarily chestnut. To produce firewood, oak trees are pollarded following traditional practice; the local name for such trees is 'ragosses' (Figure 3) (Baudry & Jouin, 2003). The height of the trees can reach from 4 to 12 m; the higher the trunks are, the more branches farmers can use. Branches are visually assessed by farmers to decide whether they are large enough to be used in open fire chimneys or central heating, or not at all. In the latter case, they were traditionally put into bundles of sticks and used for bakers' ovens. Nowadays, the branches are not used and are mostly burned in the field. Chestnut trees may also be coppiced with the branches used traditionally for barrels or tools. Nowadays they are used as fenceposts and for firewood. Hedgerow management is

Table 1. Hedgerow characteristics of the study sites

Site	Total area of the sites (ha)	Length (km)	Density (m/ha)
Site A	659	69.	106
Site B	924	77.1	83
Site C	1816	89.1	49
Sites A,B,C	3399	236	70

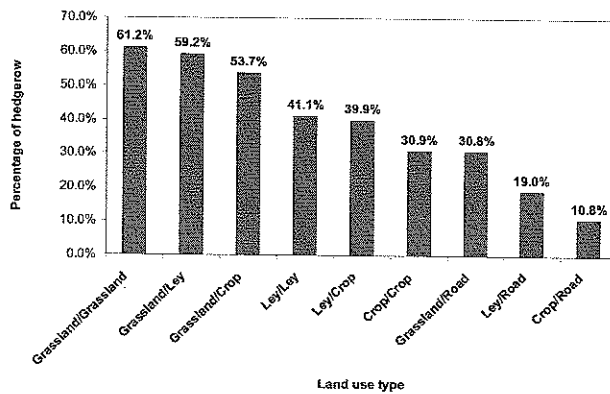


Figure 2. Percentage hedgerows bordering field, in relation to adjacent land use type in the study area.



Figure 3. 'Ragosses' trees, shapes varying with time since last pruning.

defined by the lease agreement established between owner and farmer with rules recorded in local booklets called *Usages locaux à caractère agricole* (local agricultural customs), which are updated periodically by the Chamber of Agriculture (Chambre d'Agriculture d'Ille-et-Vilaine, 1970). The rules define the use of wood and trees, and the periodicity of pruning that can vary from six to nine years depending on lease duration and tree species. The booklets do not give any details of the way trees should be pruned or the shape to be achieved but the details are defined by habits and custom (Bardel *et al.*, 2008). There is no differentiation of management regime according to the use of adjacent fields.

A dendrochronological analysis, carried out on the site on oak (*Quercus robur*) and chestnut (*Castanea sativa*) showed that pruning periodicity until 1970 varied from seven to ten years for oak and from five to seven years for chestnut (Guibal & Bernard, 2002). From 1970 on, the time between two consecutive prunings could be as much as 20 years. This trend was observed by Marguerie *et al.* (2003) in Brittany and by Martin and Rovéra (1998) in the Alps. The average firewood consumption per farm has been recorded as 15 cubic meters per year (Baudry *et al.*, 2000a).

Methods

Spatial Analysis of Hedgerow Management and Farming Systems

Aerial photographs of the LTER site were taken yearly at the scale of 1:10 000 from 1996 to 2006. The trees pruned each year were identified by comparing aerial photos in two consecutive years. This was possible because the pruning practice reduces the canopy width from 5 – 8 m to 0 m. Field validation of photo-interpretation was

carried out in 2006, confirming that the desk analysis of the hedgerows identified as being pruned in 2005 was correct.

All the hedgerows at the three study sites were mapped each year to record if they had been completely pruned during winter or not. Data were stored in a GIS, which allowed an analysis of the spatio-temporal distribution of pruning according to site, adjacent land cover, and measurement of hedgerow removal.

We used the farming system types defined by Thenail (2002) and mapped in 1994. Of the 69 farms surveyed by Thenail (2002), only 29 had their whole territory within the study sites and for those we tested to see if farm characteristics could be related to pruning periodicity or intensity. Six main farming systems were identified, as follows: Meat Cattle Farms, Cash Crop Farms, Farm after dairy production cessation, Medium Production Specialized Dairy Farm, Large Production Diversified Dairy Farm, Small Production Diversified Dairy Farms. Thenail (2002) found that the dense hedgerow network of site A was associated with smaller farms. These had the least machinery and lowest level of milk production per cow and per hectare. Productive, well-equipped farms were found at site C, and site B was intermediate in terms of land use intensity.

Data were statistically analysed with analyses of variance to test for similarity of pruning among the different farming systems, χ^2 to compare actual spatial distribution of pruning to a distribution proportional to adjacent land use. Multiple comparisons followed: student's *t*-tests were used to assess the relationship between the density of hedgerows on a farm, use of firewood to heat the farm and the rate of pruning. This test was used because the data are normally distributed but the sample sizes are small enough that the statistic on which inference is based is not normally distributed because it relies on an uncertain estimate of standard deviation rather than on a precisely known value. All tests have been performed using Minitab software (Ryan & Joiner, 1994).

Anthropological Assessment

The anthropological methods of Bernard (2006), Creswell and Godelier (1976) were used to understand the perceptions and concerns of farmers about pruned trees on the study sites. One of the researchers lived for a year in the community under study, to record the values and habits of the group (Javelle, 2007). The sources of the information collected were informal talks, open question interviews, and participation in pruning activities held during winter. The approach is a case-study analysis rather than formal statistical analysis. Thirty farmers aged from 30 to 55 years were each contacted several times. More than 65% of the farmers were over 40 years old. Interviews lasted from half an hour to two and a half hours. In addition, informal talks took place in the field, whenever the opportunity arose including 10 participations in pruning activities, and information gathered on six other occasions. This was done by observing practices, helping farmers during pruning activities and asking questions on technical aspects of the work. Participation was aimed at reducing any bias brought by the interviewer, who was perceived by the community as an external element. This was possible because the researcher showed his ability to remain open to farmers' points of view with no value judgement, allowing farmers to express themselves freely.

Results

Hedgerow Metrics

The study found that a total of 38% of the length of the hedgerows had been pruned from 1996 to 2006 in the three sites. This rate was higher (48%) in site A than on the other sites and the density of pruned hedgerows decreased from 52 m/ha (site A) to 14 m/ha in site C (Table 2). Only a few hedgerows (3%) were pruned twice during the study period.

Correlation with Time

The general trend from 1996 to 2006 was a decrease in the length of hedgerows pruned each winter, from 14.9 km in 1996 to 2.8 km in 2006 (Figure 4). Variability was low for site C where the total amount changed from 3.5 km to 2 km from 1996 to 2005. There was a significant negative correlation between hedge length and time in sites A ($R^2 = 0.63$, $p = 0.0034$) and B ($R^2 = 0.83$, $p = 0.0000$), with a linear decrease of 4% per year over the studied period. However, this was not significant for site C.

Association between Hedgerow Pruning and Land Use Type

Only in site A was the occurrence of pruning significantly higher along hedges adjacent to crops than predicted if it was randomly done ($\chi^2 = 18,79$, $p < 0.05$)

Table 2. Measures of the hedgerows pruned at each site between 1996 and 2006

Site	Length (km)	Percentage of the total length of hedgerow which has been pruned
Site A	34	48%
Site B	35	42%
Site C	25	27%
Sites A,B,C	94	38%

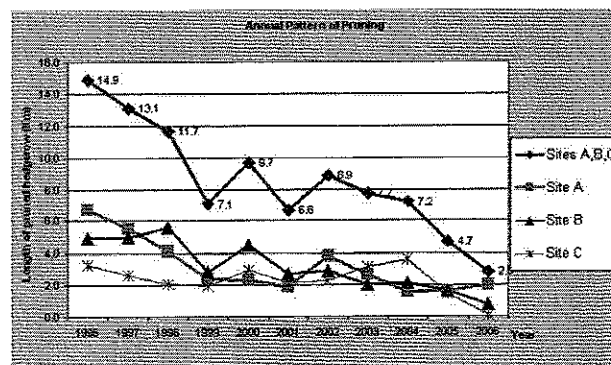


Figure 4. Annual pattern of pruned hedgerows in study area.

(Figure 5). For sites B and C the proportion of hedgerows pruned was the same for all types of land use.

Relationship with Farm System

The results of analysis of variance showed a significant relationship between the type of farming systems and the rate of pruning ($F=3.27, p=0.028$). Farms after dairy production cessation pruned more than 28 m/ha/annum, while Cash Crop Farms pruned less than 2 m/h/y (Figure 6). It seems that there was no significant relationship between the type of farming systems and the density of hedgerows.

The use of firewood to heat the house was significantly related to the density of hedgerows on the farm territory ($t = -2.67, p=0.013$) and the rate of management and pruning of the hedgerows ($t = -4.88, p=0.001$). As might be expected, it appears that the more the farmers use firewood, the more they prune their hedgerows.

Anthropological Assessment

The interviews of farmers and participation in pruning activities allowed the collection of data on past uses and customs, and on the evolution of agricultural practices. Until 20 years ago, pruning used to follow very strict local customs.

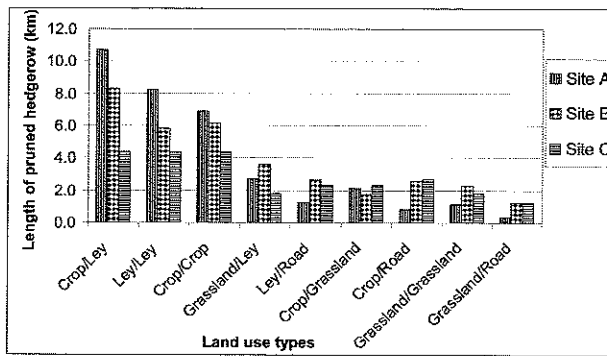


Figure 5. The length of pruned hedgerows according to adjacent land use.

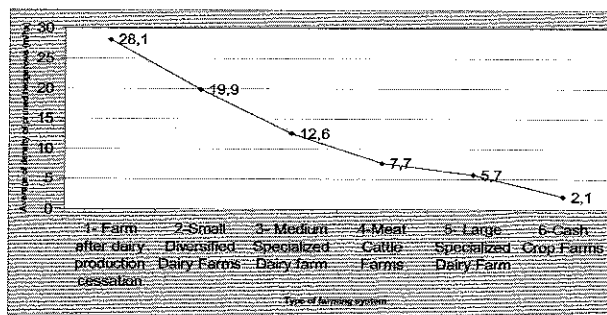


Figure 6. Average density of pruned hedgerows according to type of farming system.

The time frame for pruning varied between six and nine years and was specified in land leases. If this was not respected, it was grounds enough to expel the farmer from the farm. Trees were pruned to provide the maximum amount of useful materials. The total length of hedgerow on the farm was divided by the pruning time frame to determine the annual length to be pruned. The farmer chose which hedgerows to prune in any given year, and thus created a rotation cycle of six to nine years, that covered all the trees. Traditional aesthetic criteria had to be respected when pruning: the branches had to be cut close to the trunk with a hatchet but not so close as to damage the tree. No branch could remain. A 'badly done' job was cause for teasing. Pruning was a social event: it used to bring together men and women of all ages. Each of them was responsible for a particular task: men climbed up trees with ladders to prune, while women sorted out and 'aligned' branches in order to make bundles of wood. Young men showed off their skills, in an attempt to impress a potential future wife.

Since agricultural modernization, farmers have been reluctant to pay attention to trees that are synonymous with an outdated system which they want to get rid of. The farmers' interest and investment has turned towards crops and the pruning activities reflect these changes. In cultivated lands, the branches are seen as obstacles for crop growth and the passage of agricultural machines indicating the importance to the farmers of light for the crops and in having a clear plot. Pruning is done when grassland is turned into a crop and this occurs every five years or so. Since a five-year pruning yields only small branches, the pruning then occurs only during the next crop turn, that is, after ten years or even 15 or 20 years. The idea of regular tree pruning rotation remains, but it is now tacitly linked to crop rotation. Trees are now dependent on an organizational system of which they are no longer the centrepiece. As the pruning cycle evolved, so did the shape of the trees. Tree care is not as respected as it used to be, neither are the traditional aesthetic criteria. Pruning shapes evolved due to several criteria, such as the amount of time available for the farmer who increasingly works alone on the farm, the relationships with the farmers on the adjoining parcels, the farmer's tastes, the tools available, etc. Thus the branches are not systematically pruned. This move away from community working in relation to the trees corresponds to more individual agricultural labouring. Since there is less need for wood, farmers cut only the amount of branches necessary to minimize the inconvenience they perceive is created by the trees to their field work.

Thus, the freedom in the evolution of this practice has given the opportunity to farmers to keep hedgerows that fit their constraints in terms of work load or use of machinery. Hedgerows have a new meaning in the landscape, but it may not be sufficient for their long-term maintenance. Still, this custom does not guarantee the survival of the trees; in the past, farmers took care of regenerating trees, but nowadays, saplings cannot grow due to the use of mowing machines and herbicides. The aging trees thus are not replaced, and in any case the farmers now appear to be averse to hedgerows along cultivated fields.

Discussion

The current rate of pruning indicates that the average periodicity between pruning dates is currently more than 20 years in site A and 28 years in the other two sites.

This is very different to the traditional periodicity, where all hedgerows should have been pruned during the 11-year period of this study. This change is consistent with what is found elsewhere in Europe in such landscapes characterized by pollard and shredded trees. In Spain, the time frame for oak (*Quercus robur*) pruning shifted from six to nine years before 1849, to 10 to 12 years in the period between 1850 and 1909, and 76 years in the twentieth century (Rozas, 2004). In Norway, it has been reported to range from 15 to 60 years for deciduous trees, especially for ash (Moe & Botnen, 1997; Austad, 1988). Petit and Watkins (2003) report that in certain parts of England the pruning of hedgerow trees was abandoned in the middle of the nineteenth century.

This increase of time between pruning operations varies with the structure of the landscape. In site A, where the density of hedgerows is highest, pruning is more frequent than in the other sites. This difference can be explained by the small size of crop fields surrounded by hedgerows and thus the necessity to cut branches more often in order to obtain maximum light for crops. During the 11 years of the studied period there has been a constant decrease in the rate of pruned hedgerows for the whole area. It is significant for the dense (A) and intermediate (B) sites, but in the open landscape (C) the rate of pruning has been low (with an average duration of 37 years between two pruning dates) and constant over the period.

These results indicate that management of hedgerows depends on farmers' attitudes to the current state of the landscape. In landscapes with few remaining hedgerows, tree management is scarce and is carried out proportionally to the type of adjacent land use; as if hedgerows scattered over the landscape were no longer in competition with crops, and farmers did not feel concerned anymore.

All over the study sites, pruning increases significantly along leys compared to the other land use types. This finding from the site survey is consistent with the anthropological results, which show that farmers tend to prune their trees when leys are converted into an annual crop during the crop succession. Land use type of adjacent parcels is an important factor in decision-making for hedgerow pruning. Branches can remain on trees bordering permanent meadows since they can protect the cattle from rain, sun or wind. Trees are kept along permanent meadows since they are perceived as less of an inconvenience than those trees adjacent to croplands. The afforestation and pruning gradients match the need for light on the crops or the tolerance for shadow on the meadows. This reflects European Agricultural Policy which hardly tolerates hedgerows on agricultural plots; subsidies may be reduced if shadow impedes crop development. Temporary grassland illustrates an intermediate situation, where trees are pruned when the field is used for an annual crop but not when grass is present.

A significant relationship was found between wood consumption for heating the house and the rate of pruned hedgerows. The high rate of pruned hedgerows by the farmers who used wood-energy reveals that hedgerow pruning is related to the farmer's lifestyle. Using the wood for heating one's house is a motive for farmers using traditional methods in site A for tree management, in addition to the other reasons already explained.

Our hypotheses relating to the types of farming systems with hedgerow management were validated. This is a crucial point for the sustainability of the

landscape. As small farmers retire their farms are taken over by more productive farmers who will change the design of their field and remove hedgerows. Data from sites B and C shows that when hedgerow density decreases hedgerows are managed less. Therefore, the relationship between management, farm type and landscape is not linear; below a given density, hedgerows are barely managed, even if they border cropland. This may be explained by changes in management to fit labor availability. These changes are a clue that farmers may wish to maintain hedgerows, or at least not remove them rapidly. This can be seen as a form of adaptive management, especially if it constitutes a new social norm. In their investigation on the meaning of English hedgerows, Oreszczyn and Lane (2000) insist on the necessity of the acceptance of novel types of hedgerow management by all stakeholders. In our case study, farmers are now the only ones to make decisions on management; neither the general public, nor even the land owners are involved. This may lead to misunderstanding among different social groups.

In summary this study shows that pruning depends on farmers' attitudes to the structure of the landscape, the adjacent land use, the need for firewood by farmers and the required field size according to changing cultivation techniques.

These factors all converge to create a landscape with hedgerows concentrated around permanent grasslands with trees pruned very rarely and a few hedgerows around crops, with trees still managed but more to limit negative effects on crops than to produce firewood. It can also be seen that the recent demand for food and consequent loss of set-aside may cause an increased pressure on remaining hedgerows in cropland areas.

Conclusion

Our investigation shows two apparently opposing trends: first, a decrease in the interest of farmers for hedgerows as they pruned them less and less; second, changing attitudes of farmers not necessarily toward hedgerow abandonment but rather toward the production of novel shapes for pruned trees. The changes in social practices may permit the maintenance of hedgerows but contrary to what one would expect this is done at the expense of a good management for wood production. These traditional landscapes are still dynamic enough to transform and adapt to current agricultural needs, but the main threat is the disappearance of old trees which are not replaced. The value now given to field margins and particularly to hedgerows as resilience tools in agricultural landscapes (Kromp, 1999; Marshall *et al.*, 1997) could bring new insights to the management of cultivated parts of these landscapes where traditional hedgerows are the most threatened by current agricultural systems. If farmers regain their understanding of the benefits of such hedgerows, we foresee two trends in future hedgerow network landscapes: the first is the maintenance of traditional hedgerows along permanent grasslands, as long as the trees live, and the second is, in cropped areas, new hedgerows for such various functions as wood production, beautification, pest management and so forth, co-existing with ancient ones with new management regimes and shapes. Therefore, it can be concluded that hedgerows may still have a future role in transformed agricultural landscapes.

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