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Hedgerow diversity: An international perspective on their origin, function and management

J. Baudry†*[1], R. G. H. Bunce‡ and F. Burel§

A framework for the ecological study of hedgerows is given, before a short review of problems relating to their definition. Hedgerows have developed in response to the inherent physical and biological character of the region concerned, in conjunction with cultural factors. Traditionally, hedgerows were an important source of wood as well as other products, although such functions are in decline in many regions. They still have an important role in the landscape for soil protection and act as barriers and boundaries between management units. Although the closed landscapes of the Atlantic fringe, termed 'bocage' are often considered as the core of hedgerow distribution, there are many other regions, not only in Europe, but also elsewhere in the world with equally dense networks. It is concluded that a review of their distribution would be of great interest for the design of appropriate policies for landscape management and conservation of hedgerows. Such regions show marked differences in hedgerow character, species composition and the type of management and there is a degree of convergence between them. The diversity of hedgerows stems from their multiple origins and includes their role in the landscape, as well as their contribution to biodiversity and function. It is emphasised that hedgerows have often changed roles in history and current regulations for their protection must be based on sound science and a precise definition of their role and contribution to social objectives.
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Introduction

Hedgerows, or related structures such as rows of trees or shrubs, are conspicuous landscape elements in many parts of the World. They are human-made features and have contrasting roles recognised by different people, from those who plant or let them grow, to casual visitors and ecologists. Today, hedgerows are highly regarded primarily for their ecological and cultural values, for example as recognised by the Hedgerow Regulation 1997 legislation in the UK. In the past other functions were dominant e.g. boundaries, shelter, sources of products and even as snow breaks by railways in Poland. The change and subsequent loss of past functions are the main reasons for the threat and loss of hedgerows. This paper explores the geographical distribution of hedgerows and provides a classification according to their function in the landscape. It therefore could provide a stimulus for the definition of regulations for protection and management.

Agriculturists have praised hedgerows for their utility for centuries, (see Rozier, 1784). Geographers and ecologists have studied hedgerows for almost a century (Alexander, 1932; Bates, 1937). Geographers, ecologists, and conservationists showed increased interest in hedgerows and bocage landscapes in the 1950s and 1960s, when much removal occurred. In Great Britain Pollard *et al*. (1974) and France INRA *et al*. (1976) described important research programmes that had been carried out. Although the presence of hedgerows has long been recognised in many parts of Europe, for example in

[1] Email address of corresponding author: jbaudry@roazhon.inra.fr

∗ *Corresponding author*

† *Institute National de la Recherche Agronomique, SAD-Armorique research unit, 65, rue de Saint-Brieuc, 35042 Rennes Cedex, France*

‡ *Institute of Terrestrial Ecology, Merlewood Research Station, Grange-over-Sands, Cumbria, LA11 6JU, UK*

§ *Centre National de la Recherche Scientifique, Université de Rennes 1, UMR ECOBIO, Campus de Beaulieu, 35042 Rennes Cedex, France*

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Germany and Switzerland, the majority of research in the last two or three decades concerns the Atlantic zone of western France and Britain. Despite this narrow perception, hedgerows are actually important landmarks of human settlements and agricultural landscapes throughout the world. However, the description and distribution of hedgerows has not yet been widely carried out, although Rackham (1988) has already pointed out that hedgerows do have a much wider distribution than many people realised. Shelterbelts in prairie landscapes and fences in the tropics are well known linear features sharing many characteristics with temperate zone hedgerows, and are composed of trees and shrubs. They are adjacent to agricultural fields and form networks in a similar structure to that seen in Europe, although they are of different origin.

The continued and expanding interest in hedgerows stems from their ecological and cultural value and because they act as refuges for species unable to exist elsewhere in farmland. They are also artefacts of vanishing rural cultures. From a scientific point of view, the development of landscape ecology provides new concepts, methods and theories to gain insight on hedgerow function and their ecological status (Forman and Baudry, 1984; Burel, 1996). Studies of cultural landscapes (Rackham, 1986) stress the diversity of tree management, related to technical, and social factors of hedgerows, as well as other functions e.g. protection from erosion.

What is a hedgerow?

Definition

Few studies attempt to give a formal definition of what constitutes a 'hedgerow' beyond the statement that it is a row of shrubs and/or trees managed in various ways (although Pollard *et al*. (1974) do devote a chapter to hedgerow description). We propose that although any row of woody vegetation can be a corridor or a barrier for ecological processes, it may not be a 'hedgerow' if it is not managed. A hedgerow, whether planted or spontaneous, always has a human component and is more or less managed to provide control and to prevent its expansion into adjacent fields. Most of the time a hedgerow is a field boundary and its management forms part of farming activities. As we shall see, this human component is essential in shaping hedgerows. So, we define a hedgerow as a linear feature composed or shrubs and/or trees that forms part of a management unit. Different definitions may be used over the minimum length considered to be a hedgerow depending upon the objectives of study e.g. the minor differences between Barr *et al*. (1993) and Cooper and McCann (1997). 'Hedgerow' is a generic term scientists use, but it also exists as in a variety of local names that are the product of the cultural, technical and social values of the region concerned. This subject has been analysed and debated in several social groups, including scientists and others who are interested in the perception and language used to describe hedgerows (Oreszczyn and Lane, 1999).

The landscape elements we define as 'hedgerow' are, most of the time interconnected into networks. When it comes to analyse hedgerows, or to make decisions on individual hedgerows, the question that arises is 'where are the limits?'. For surveys, evaluation and mapping for defining the resource in a given area, one needs to define the 'hedgerow unit'. Hedgerow intersections are identifiable and provide tangible points (a hedgerow unit is defined as the segment of hedgerows between two intersections), but other measurements are possible. For example, Baudry and Thenail (1999) have used the limits of land-use units, i.e. there must be a single type of land use on one side of a hedgerow. This definition enabled them to make links between land use, land managers and hedgerow characteristics. In contrast, the Institute of Terrestrial Ecology (ITE) use 'homogeneous' units for the countryside survey with a hedge being described as a boundary, or part of a boundary which comprises a row of bushes or low trees growing close together, and which have been managed through cutting to maintain a more-or-less dense linear barrier (Barr *et al*., 1993). A minimum length of 20 m is used together with description in terms of code combinations to define the character of the hedge for example, height and proportion of gaps. The length of each boundary segment is determined by the constancy of a combination of codes along the length; where any

one description differs, then a new length is demarcated, and a new combination of codes applied. Other definitions have been used e.g. Cooper and McCann (1997) but work in ITE has shown that a precise definition of the delimitation of hedgerows can enable comparisons to be made between independent studies.

Origin and distribution

French geographers use the word '*bocage*' to mean a landscape where hedgerows are characteristic features. Bocage has been used some time in English in the past, and here we use it because the expression 'hedgerow network landscape' is inelegant. We approach the distribution of bocage, rather than hedgerows, which are of minor importance if few, are present in a landscape.

European rural geographers of the Atlantic fringe have worked for decades on bocage, as opposed to open landscapes. In France work by Bloch (1931), Meynier (1970), and Flatrès (1979) described regional differentiation. In Britain, Pollard *et al*. (1974) produced the definitive work on British hedges describing their history, status and ecological role in the British landscape. Rackham (1986) provided further details on the historical background to hedges, even dating them back to Roman times, with two chapters on hedges and hedgerow trees. Less detailed studies describe the bocage landscapes of Galicia (northwest Spain) (Bouhier, 1979) and Jutland (western Denmark) (Bazin, 1994). We can also find such landscapes in northern Spain, Italy, Switzerland, Belgium, and Germany. Shelterbelts are present in some parts of Poland and Ukraine. In their history of the Cretan landscape, Rackham and Moody (1996) describes a variety of hedges, some being 'almost English in character'. Hoskins (1955) describes how in medieval times the ancient enclosures were often taken out of woodland. He mentions that hawthorn (*Crataegus monogyna*) is the oldest species used for hedgerows and points out that it even gets its name from the old word 'haga', a hedge or enclosure. At the beginning of the eighteenth century in Britain the landscapes were still dominated by the medieval open-field system but the parliamentary Enclosure acts gradually replaced these by a chequer-board of small fields enclosed by hedges of hawthorn. These hedges were planted, usually with ditch along side in the midlands, but often on a low bank in the north and west of England. Trees were also often planted in the new hedges. Rackham (1986) gives further details of how the enclosures affected the landscape, and also points out that in north and west Britain the process of enclosure is not as well documented as the midlands and the south. In northwest England hedges by old roads often have many woody species, whilst those across fields are virtually pure hawthorn, suggesting that these are the planted Enclosure hedges (pers. Observation RGHB). Therefore, the view that Britain has one of the most dense ancient hedge networks in Europe is not strictly true—rather the majority of hedges are relatively recent.

The distribution of hedgerow types is dependent upon a combination of the inherent environmental and cultural factors. There is therefore convergence between the characteristics of the hedgerow in similar combinations of circumstances e.g. gorse (*Ulex europaeus*) occurs on hedge banks in the celtic regions of western Ireland, west Cumbria, west Wales, Brittany and Galicia, all of which have poor soils and are exposed to Atlantic gales. Elsewhere, whilst some regions as mentioned above, have well defined networks, other areas are less well known but have equally dense networks, for example, the northern slopes of the central Pyrénées. Another distinctive feature of hedgerows in Europe is in the development of the local use of planted exotic species that has led to the creation of locally distinctive hedgerows that have become well known—for example, the Fuschia (*Fuschia magellanica*) hedges of Ireland and the beech (*Fagus sylvatica*) hedges of south-west England. An independent assessment of hedgerows not only in Europe but also elsewhere is therefore long overdue.

Outside Europe, studies are scarce. Despois provides the first description of tropical bocages in Africa (Lauga-Sallenave, 1997), where villages are surrounded by hedgerows to protect gardens. Such situations are also found in Northern Ireland where there is no discontinuity between rural hedgerows

and those surrounding the gardens of houses set in the countryside. Hedgerows are also extensive in Ecuador and in Bolivia where they separate paddocks, or gardens. In China, hedgerows are also found mostly around villages, for example, Zhenrong *et al*. (1999) describe field boundaries in two subtropical Chinese villages. Twenty-three percent of field boundaries were hedgerows. Most of the time a single species of tree is planted e.g. dawn redwood (*Metasequoia glyptostroboides*) or poplar (*Populus* spp.).

In North America, hedgerows and shelterbelts were planted by early European settlers who wanted to recreate their homeland landscapes (Hewes, 1981; Sutton, 1985), and also as a means to manage and protect soils (Nabhan and Sheridan, 1977). Baltensperger (1987) describes considerable changes in hedgerow distribution in the Midwest since World War Two and the development of irrigation systems and roads. Osage Orange (*Maclura pomifera*) was the principal tree used for planting. In eastern North America and Canada, colonisation of field boundaries by bird dispersed species is widespread (Forman and Baudry, 1984; Wegner and Merriam, 1990). Such fencerows can form dense networks, but are now often under threat from mechanised farming and have often been removed.

Management is an integral feature of hedgerows, as opposed to lines of shrubs, developing spontaneously along terrace walls in the Mediterranean region, and there are many styles, which have developed during the evolution of cultural landscapes. Virtually all hedges are cut back in some way, whether using traditional implements as described by Rackham (1986) or by modern machines. These long-term methods of management also show convergence e.g. coppicing (Britain and France) and interweaving (Britain and Spain). Various forms of layering are present in many areas but the details of the practice are invariably unique to particular regions e.g. the distinctive management of hedgerow trees in Normandy and the construction of hedgerows of dead material in north-west Spain. This short review shows that hedgerows are diverse in structure, origin and arrangement within landscapes. Below, we analyse the reasons for such diversity.

Factors contributing to hedgerow diversity

We propose an analysis based upon an empirical approach resulting from long experience of field observation of hedgerows and study of their ecological characteristics in different countries. This analysis should be helpful to propose management and conservation policies to both sustain their cultural and ecological heritage, and to fulfill new roles in response to changing functions. The fact that trees live about twice as long as the average farm business emphasises their importance as indicators of historical change as emphasised by Rackham (1986) who describes such features as landscape ghosts.

Primary functions

Hedgerows are limits, boundaries, and borders. The boundary function can be both physical and symbolic, as a row of shrubs around a garden with an open gate or a fence or as stock-proof fences originating from the enclosure acts. Many historians and geographers e.g. Rackham (1986) have emphasised the function of hedgerows as physical property limits back too as far as Roman times. Fences can be enclosures to prevent cattle mixing with their neighbour's herds: the reason for the establishment of Enclosure hedgerows in Britain. In this case, planting hedgerows meant that new farming systems were coming into being. Fences are generally made of non-palatable species such as hawthorn (*Crataegus monogyna*) in Europe or spurges (*Euphorbia* spp) in Ecuador, or shrubs e.g. willow (*Salix* spp) and hazel (*Corylus avellana*) that are managed by laying. The establishment of this type of hedgerows historically has been when there is a change from collective to individual use of the land. Examples of such conversions are found in Brittany, France, during the eighteenth and nineteenth centuries; in Schleswig-Holstein (Northern Germany), land-consolidation programmes led to the edification of hedgerows (Lühning, 1984). Conversely, when this role is reversed, as during re-allotment programs, hedgerows tend to be removed or are under threat. The amenity role of hedgerows is often due to

this shelter/limit effect, the sense of feeling 'at home' (Oreszczin, 2000) and explains why European settlers planted hedgerows when they arrived in the Midwest.

Products

Hedgerows are a source of products. Wood is the most important; many forms of wood can be produced in hedgerows e.g. firewood, timber, fenceposts. The different usages of the wood lead to contrastingly different forms of trees (Figure 1). For timber, branches must be removed as much as possible from the trunk to produce logs and boards. A good physiological balance is where 30% of the lower trunk is without branches and the top 70% retains its foliage. This creates the typical shape of a tree, with a much larger crown than in forest. For firewood, it is necessary to enhance the production of branches. The typical shape is a trunk from which branches are cut every few years. A great variety of shapes are derived from pollarded trees (a short trunk and a crown of branches), shredded trees (a tall trunk with branches along the whole length) and coppice (a basal stump with several growing stems). The latter is used for sweet chestnut (*Castanea sativa*) to produce fenceposts. In Europe, each region had only one dominant type of tree management, often strictly enforced by local regulations. This contributes to the cultural character of each region e.g. the pollarded willows (*Salix* spp) of Somerset in south-west England and the candelabra ashes (*Fraxinus excelsior*) in northwest Spain. In traditional rural societies wood was the only source of energy for cooking and heating and peasants therefore needed to have access to such a resource. Often farm hedgerows were the only available source of wood to them, as woodlands were often owned by large landowners. The use of wood is still important in some areas. In northeastern Brittany (France), Thenail interviewed 65 farmers regarding wood consumption (Baudry and Jouin, 2000). She found that almost all of them utilise wood from their hedgerows and annual consumption as firewood varies from 1–30 m^3, with a median around 15 m^3. Half of the farmers use wood as the main source of energy for heating their house, half have a fireplace as an extra source of heat. The same farmers produce an average of 135 fenceposts per annum. This example demonstrates that hedgerows still have an economic value, though difficult to evaluate. Fodder production from elm (usually *Ulmus glabra*) and ash was important in several regions and especially in mountains where ash leaves were kept as winter forage e.g. In Norway, in the Picos de Europa in north-west Spain, and in the French Alpes (Martin, 1999). This function led to the planting of many trees of these two species. These species can be mixed with each other but are more abundant near farmsteads. Other products may be fruits e.g. blackberry (*Rubus fruticosus*), medicinal plants e.g. nettles (*Urtica dioica*), material for tools e.g. ash, baskets e.g. willow (*Salix* spp.) and even vegetables e.g. black bryony (*Tamus communis*) in central Spain.

Functions in a landscape

At the landscape level, hedgerows have a major role in controlling physical, chemical and biological fluxes, as well as being cultural indicators. Hedgerows and associated elements (ditches and earth banks) have been made to control physical fluxes, such as water, for drainage or irrigation, soil particles, to diminish erosion or wind. This latter function gave rise to the name 'windbreak', which are widely used in steppe areas of Europe and northern America. In this case efficiency requires that hedgerows be set up as networks through the landscape. To control water, they must be along major soil boundaries. This role is still important to diminish the speed of water runoff and prevent uneven stream flow through the year (Mérot, 1999). In regions where subsurface flow is important, control of water has been a major impetus in landscape design, using both ditches and hedgerows. In Brittany, many hedgerows are used for water flow control and are apparent in the landscape, as well as on cadastral maps. On moorland cleared one century ago, such patterns do not exist. It seems that the evolutionary process of landscape design took a long time to adapt the ditch networks to soil and topographic conditions. Strong patterns can therefore be seen in older landscapes. As ditches continue to collect water, even after they have been filled with earth, because clay particles

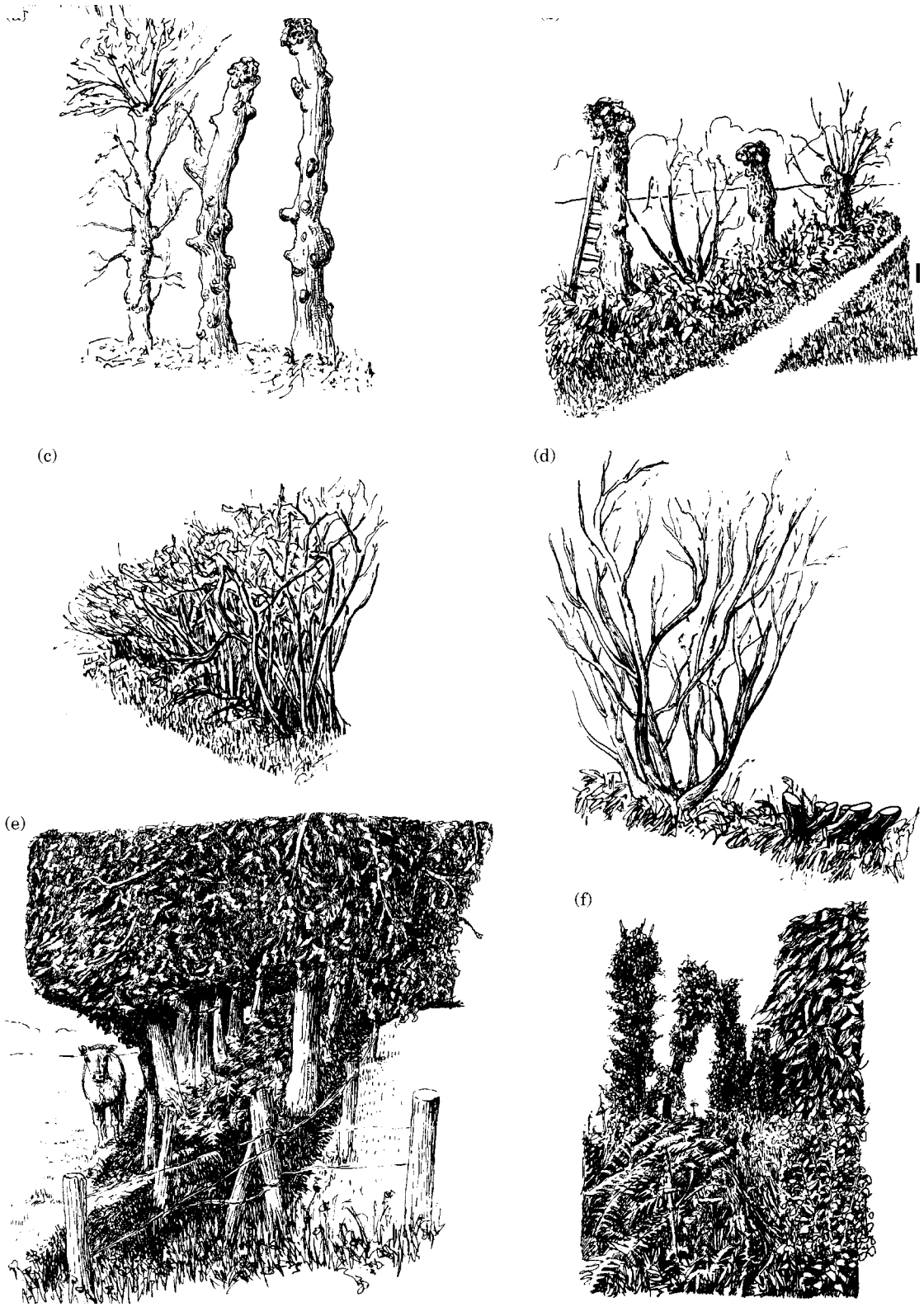

Figure 1. Six examples of the diversity of hedgerow structures. (a) typical pruned (shredded) oaks in Brittany, France (height: 5–7 m); (b) pollarded oaks (height: 1·5–2 m); (c) a dense hedgerow of shrubs originating from coppiced stools; (d) a coppiced hedgerow before and after wood harvesting; (e) a double hedgerow on a bank, Normandy, France with each row of trees belonging to the adjacent field; (f) a hedgerow of shredded oaks with associated ground flora.

accumulate on the sides and bottom, even in open landscapes former functioning is visible. Research on the role of hedgerows as a buffer against nitrates and for water protection is growing, along the lines of hydrology (Caubel-Forget and Grimaldi, 1999).

Hedgerows control biodiversity being habitats, refuges, corridors or barriers. These functions are critical for many plants and animals that otherwise could not exist in agricultural landscapes (Burel, 1996). Predators in hedgerows can also buffer cyclic-pest outbreaks, such as the ones of voles (Delattre *et al*., 1999).

The cultural and ecological values of hedgerows stem from the uniqueness of the integration between woody species, local rules, techniques and cultural history of a given region, in conjunction with its inherent ecological character. The diversity or the uniformity of roles as seen by a single owner or the local society produced the diversity of hedgerow. This historic legacy constitutes the landscapes that must now be managed.

Table 1 gives a summary of hedgerow functions and associated hedgerow features and place in the landscape. Figure 2 provides a visual assessment of a bocage landscape. Hedgerows are assessed for their own properties and for their place in the landscape. Figure 3 gives two examples of the role of hedgerows in contrasting British landscapes. In Figure 3(a), hedgerows have almost lost their original function because of the dominance of crop production the landscape. In Figure 3(b), hedgerows are still important for shelter for stock and as boundaries but are threatened by lack of management.

Table 1. Hedgerow functions at site and landscape level, and associated hedgerow features and place in the landscape

	Physical functions	Biological functions *Habitat, corridor, refuge, barrier*	Cultural and amenity functions
Hedgerow level	*Water fluxes*: consolidated ditch bordering hedgerow	According to species biological traits and ecological requirements	*Age and structure*: +earthen or stone bank ditch
	Soil conservation: importance of deep rooted trees and shrubs	• Density of vegetation cover	Management techniques of 'heritage' species e.g. *Taxus baccata* on religious sites
	Wind: dense and high tree layer providing a semi-permeable barrier to winds	• Complexity of hedgerow structure	
		• Diversity of plant species • Presence of dead trees and rocks • Management techniques and regimes	
Landscape level	*Water fluxes and soil conservation*: location of the hedgerow on the slope, key points are major limits of soil, mainly at the border of small valleys, and perpendicular to the steep slopes	• Relationship with adjacent land use	• Historical links e.g. monastic and regionally distinct sites
	Water, soil and wind: connectivity of the hedgerow network ensures continuity and control of fluxes	• Isolation of habitat patches and linear features	• Adjacency to footpaths and countryside access
		• Connectivity of the networks • Grain size of the landscape	• Grain size of the landscape

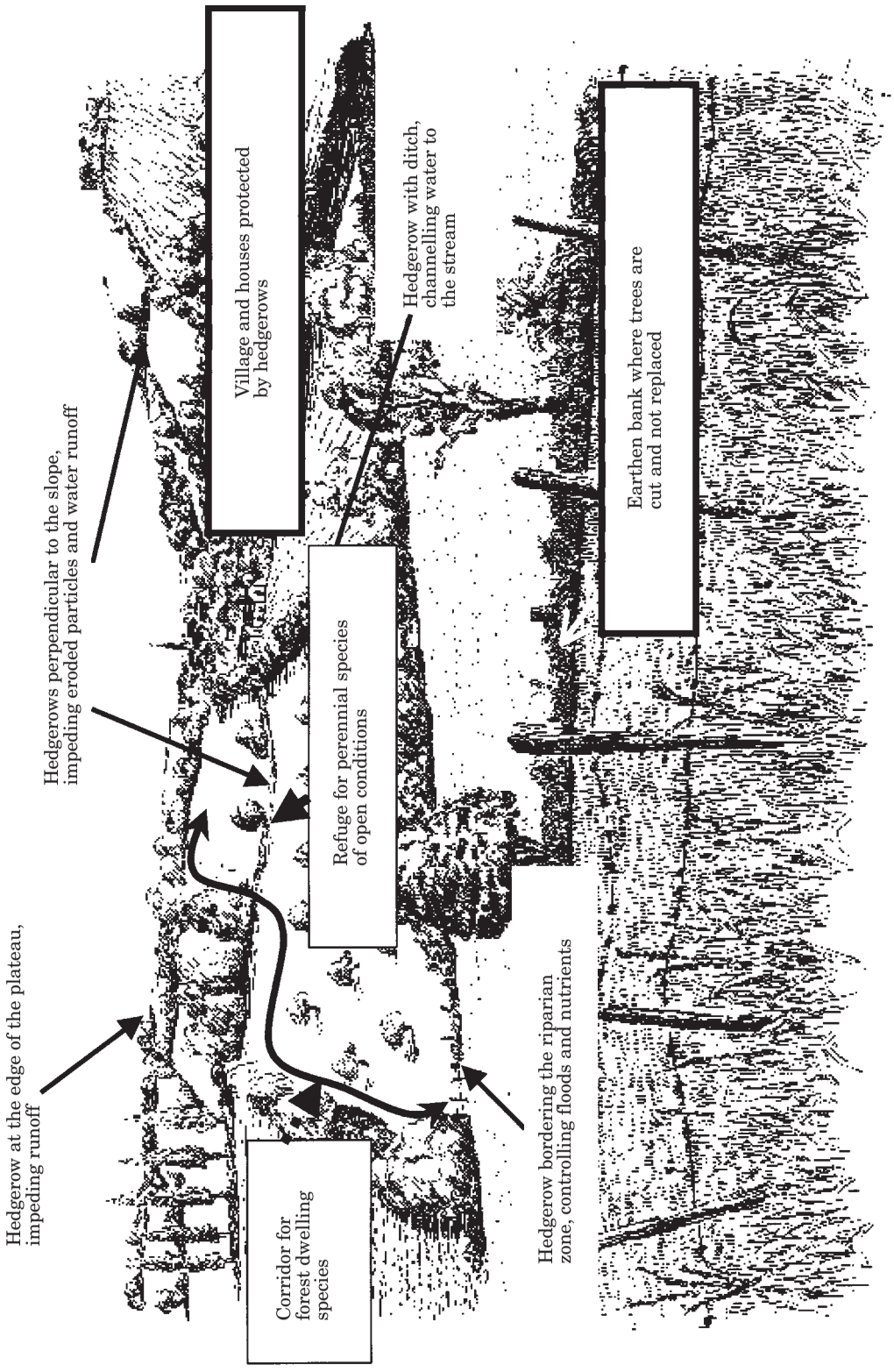

Figure 2. A visual assessment of some different functions of hedgerows in a model landscape.

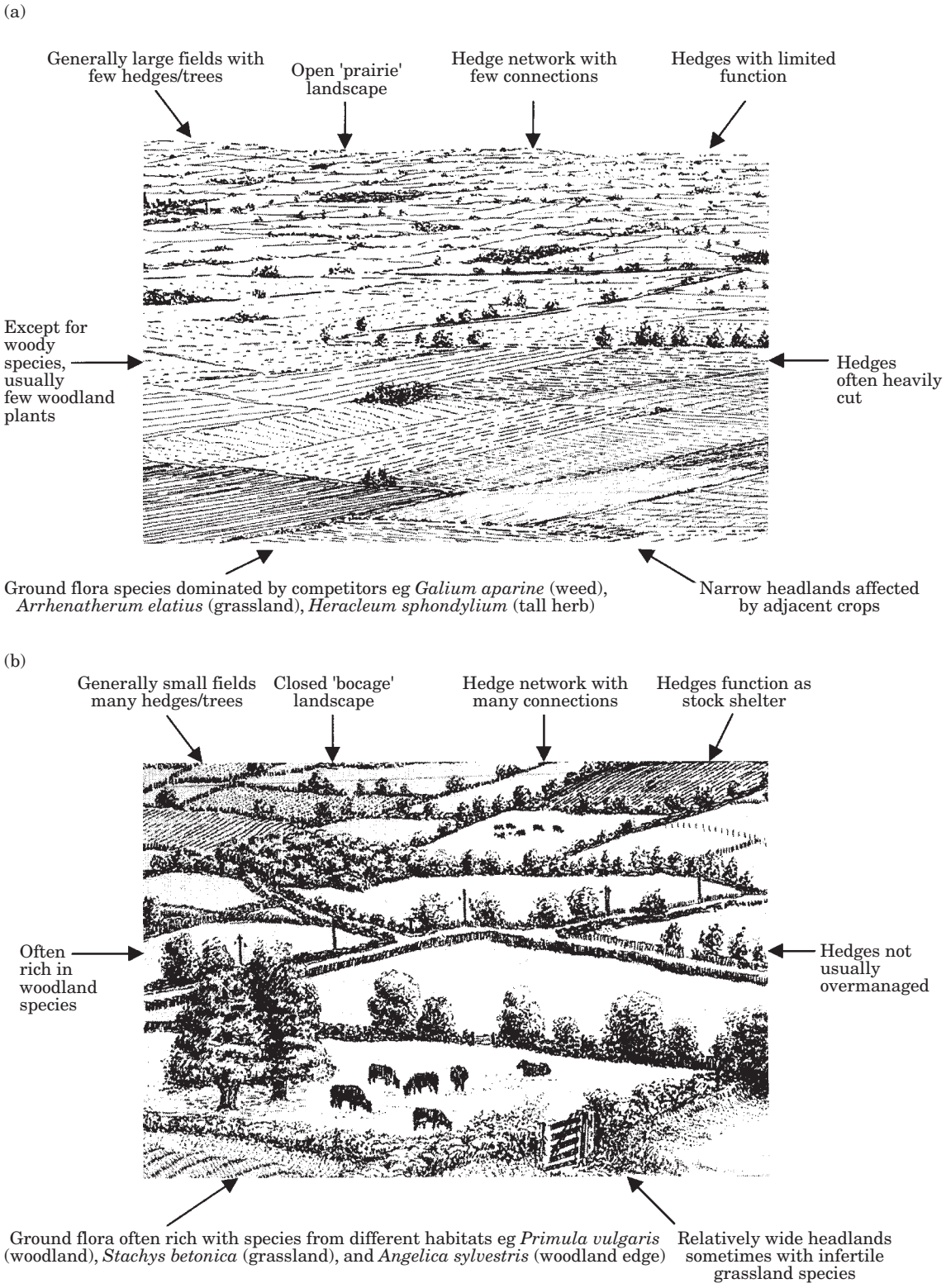

Figure 3. Two examples of model hedgerow landscapes in Britain. (a) An open landscape in east Anglia, England; (b) a bocage landscape in the west country, England.

Shifting functions and protection

Nowadays, the number of conservation groups with an interest in the management of hedgerows continues to expand. Regulations no longer come from local stakeholders and managers, with governments making laws for controlling the removal of hedgerows e.g. the Hedgerow Regulation 1997 legislation in the UK. The maintenance, restoration and planting of hedgerows has been supported in agri–environment programs such as the Environmentally Sensitive Area and Countryside Stewardship schemes in Britain. The main consequence is that those who manage hedgerows may no longer have the full control of the decisions on them. As their function as boundaries or the source of products declines, so novel functions increase e.g. as reservoirs of biodiversity or as amenity features. Formerly there were local rules to manage and plant or remove hedgerows. In many places hedgerows are now protected, as they have been in historical times. The gap between former and novel uses, as well as the lag between recognition of new functions and the implementation of those functions in law, is a source of concern since there has been much removal.

Several issues must be addressed in this context. Stakeholders and managers are different persons. Potential conflicts therefore exist between environmental goals e.g. the definition of target species for conservation and the maintenance of landscape diversity, where rules for notification need to be developed. For example, the hedgerow legislation in Britain states that priority will be given to lengths of hedgerow that have over five woody species in a 30-m length, which is considered by many to over-simplify a more complex situation e.g. the historical status of a hedgerow might be ignored.

Conservation of biodiversity

It is worth examining the 'biodiversity' function in the context of hedgerow structural diversity and multifunctions. Even if landscape scale studies are now frequent, the single hedgerow approach is still common. The hedgerow approach seeks to define the best vegetation structure for various groups of species, biodiversity being measured as simple number of species in particular taxonomic groups. These approaches have several shortcomings, even for the biodiversity function.

First, no single hedgerow can harbour all the local species pool of a given group e.g. plants, birds or insects. This is exemplified in Figure 4 which shows the cumulative number of species recorded in the herb layer of 860 hedgerow sides in Brittany (France). Species are grouped in frequency in relevés. It is worth noting that 50% of the species are only present in 5% of hedgerows. The structural diversity of hedgerows plays an important role in these patterns, as shady and sunny conditions as opposed to wet and dry situations may be present. The single hedgerow approach also does not generally include the cyclic management of hedgerows, which is partly responsible for the diversity

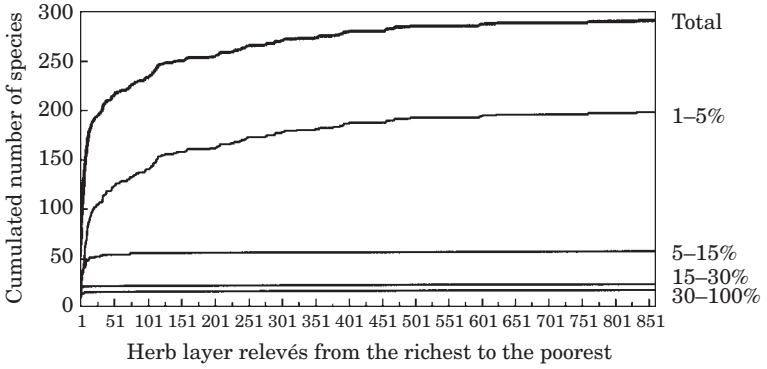

Figure 4. The cumulative number of species (CUM) recorded in the herb layer of 860 hedgerow sides in Brittany, France. Species are grouped in % presence in relevés (D. Le Cœur, unpublished data). CUM 1: species present in 1–5% of hedgerows, CUM 2 species in 5–15% hedgerows, CUM 3 species in 15–30% and CUM 4, species in 30–100% hedgerows.

of conditions. The implementation of an ideal management scheme would certain decrease the number of species present. Although tree cover may decrease from time to time due to pollarding most authors (e.g. Petit and Burel, 1998) assume that dense hedgerows, at a given time, are efficient corridors for forest species movement. Furthermore, hedgerows may remain in the landscape but still lose species, as described by Barr *et al*. (1993), and even the number of woody species can decline (Garbutt and Sparks, 1999).

Biodiversity must be assessed at the landscape scale not only because of the diversity of hedgerows, but also because of landscape scale processes. The corridor function of networks of hedgerows has been demonstrated in various conditions: for plants by Baudry (1988) and Marshall and Arnold (1995); for insects by Burel (1989) and Duelli *et al*. (1990); for birds by Dmowski and Koziakiewicz (1990) and Clergeau and Burel (1997). The effect of grain size (the average size of a field surrounded by hedgerows) has been less well studied. Burel *et al*. (1998) compared four adjacent landscapes differing mainly in their hedgerow density. They found that species number decreased from dense to open landscapes for only some groups of species e.g. diptera (Dolichopodidae, Empididea, Chiropodidae). For carabids the number of species did not vary significantly, but although species composition was different, the average body size of the species decreased from dense to open landscapes.

Garbutt and Sparks (1999) pointed out that regionally widespread species can also invade when landscapes often do not support rarer species any more because of the expansion of common plants. Therefore, the 'number of species' may be a misleading objective in terms of nature conservation because some types of hedgerow e.g. those dominated by beech (*Fagus sylvatica*) may be inherently poor in species but nevertheless, of considerable ecological interest.

Directions for future research for landscape and hedgerow management

Over 15 years ago, Forman and Baudry (1984) set up a research agenda for hedgerows based upon the emerging principles of landscape ecology. Concepts such as corridors, connectivity and barriers have proved to be useful in designing landscapes and the planting of hedgerows. Research has focused on the ecological functioning of hedgerows and hedgerow networks. Landscape planning and management could still be improved by further research. Landscape ecology, landscape planning, public policies, and farming system research are the main areas of research that need to be followed in future.

Landscape ecology represents a move upscale from individual hedgerows to a few km^2; a regional approach (several km^2) should be the next move up. Bocage landscapes are diverse and this diversity is not recognised in planning. Does this diversity mean that different management objectives should be defined for each landscape? Some landscapes need planning against soil erosion (wind or water erosion), others are of high cultural and historical value, and others harbour many rare species. Different objectives must therefore be set for each landscape, in order to conserve regional diversity. The use of a single criterion to define 'important' hedgerows (or any landscape feature) will be detrimental in the long run, as hedgerows with 'secondary' functions may be removed, though these functions may appear important later, or in a different context.

The sustainable use of agricultural landscapes requires that these landscapes should be multifunctional, not only devoted to food/fibre production, but also to hydrology, amenity and biodiversity. Formerly, land consolidation programmes were aimed specifically at regrouping the parcels from different farms in order to facilitate the use of machines and save time, leading to hedgerow removal and landscape change (Braekevelt, 1988). The policy, in itself, was not the cause, rather the use of land solely for production. Anyhow hedgerows have been removed outside planning operations (Burel and Baudry, 1990). Land-consolidation programmes can however, also be used to restore landscapes (Pointereau and Bazile, 1995). The implementation of new policies necessitate the definition of new planning principles, so new knowledge on the ecological functioning of landscapes is necessary. Among the

remaining questions, the following need to be considered:

(1) What should be the spatial components of a bocage (size of the landscape, connectivity, grain) to sustain various types of species? Few studies on hedgerows and biodiversity make reference to metapopulation theory (but see Petit and Burel, 1998), although this concept can be useful to define the geometry of a landscape, in conjunction with species life history traits.
(2) Is it better to have a bocage with a homogeneous grain (as most studies assume), compared with a landscape where fine grain and coarse grain areas are both present? For example, Burel *et al*. (1998) showed that a diversity of adjacent landscapes (a few thousand hectares) increased the total number of species present. Such complexity makes it difficult to provide insight for landscape planning which needs to take account of the scale of landscapes and their arrangement in space.
(3) Do hedgerow and landscape structure requirements for a given group of species (i.e. passerine birds) complement or conflict with those of other groups (i.e. butterflies)?

Hedgerows are usually on farms, but studies on how hedgerow types or landscape structure relate to farming system types are scarce. The conflict between large-scale cash crop farms and small scale mixed farms in term of landscape is not very useful for policy-makers or planners; it would be more useful to know, within a type of farming systems, how much and why hedgerows are retained or removed. The common assumption is that larger fields are easier to farm, so field enlargement diminishes the cost of farming. This leads to the cause and effects relationships depicted on Figure 5.

Findings from a recent study in France by a national association of farmers (Fédération Nationale des Coopératives d'Utilisation de Matériel Agricole) challenge this assumption. Measures in fields and simulation demonstrate that above six/eight hectares, the gain of increasing field size is very low. In contrast, travel from farm to fields is very expensive (Francart *et al*., 1998). Figure 6 gives the example of silage maize harvest. This kind of investigation helps to design landscapes.

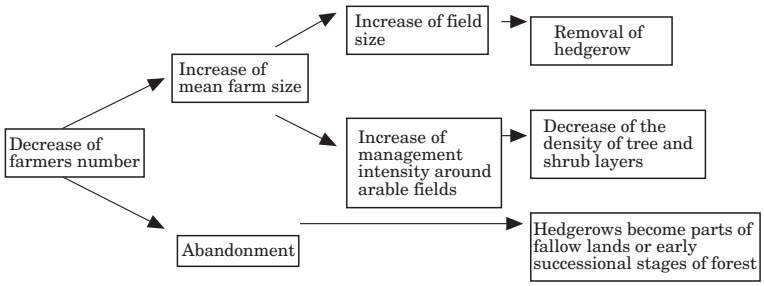

Figure 5. Threats to hedgerows likely to be caused by diminishing farming communities.

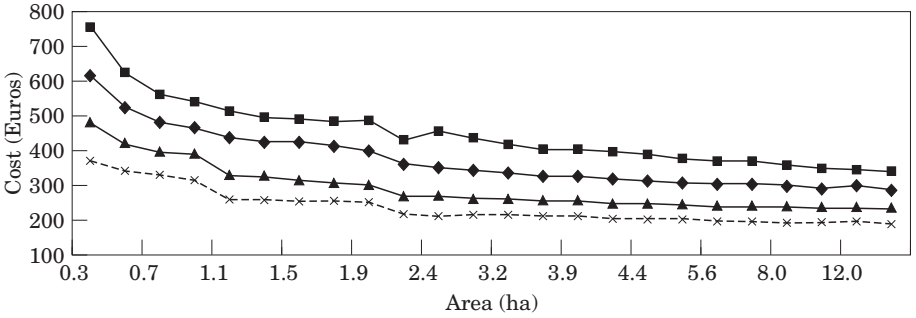

Figure 6. Cost (in Euros) of a maize silage operation as a function of field size and the distance of the field from the farm (after Francart *et al*., 1998). 60 mn round trip (–■–); 40 mn round trip (–◆–); 20 mn round trip (–▲–); 4 mn round trip (–×–).

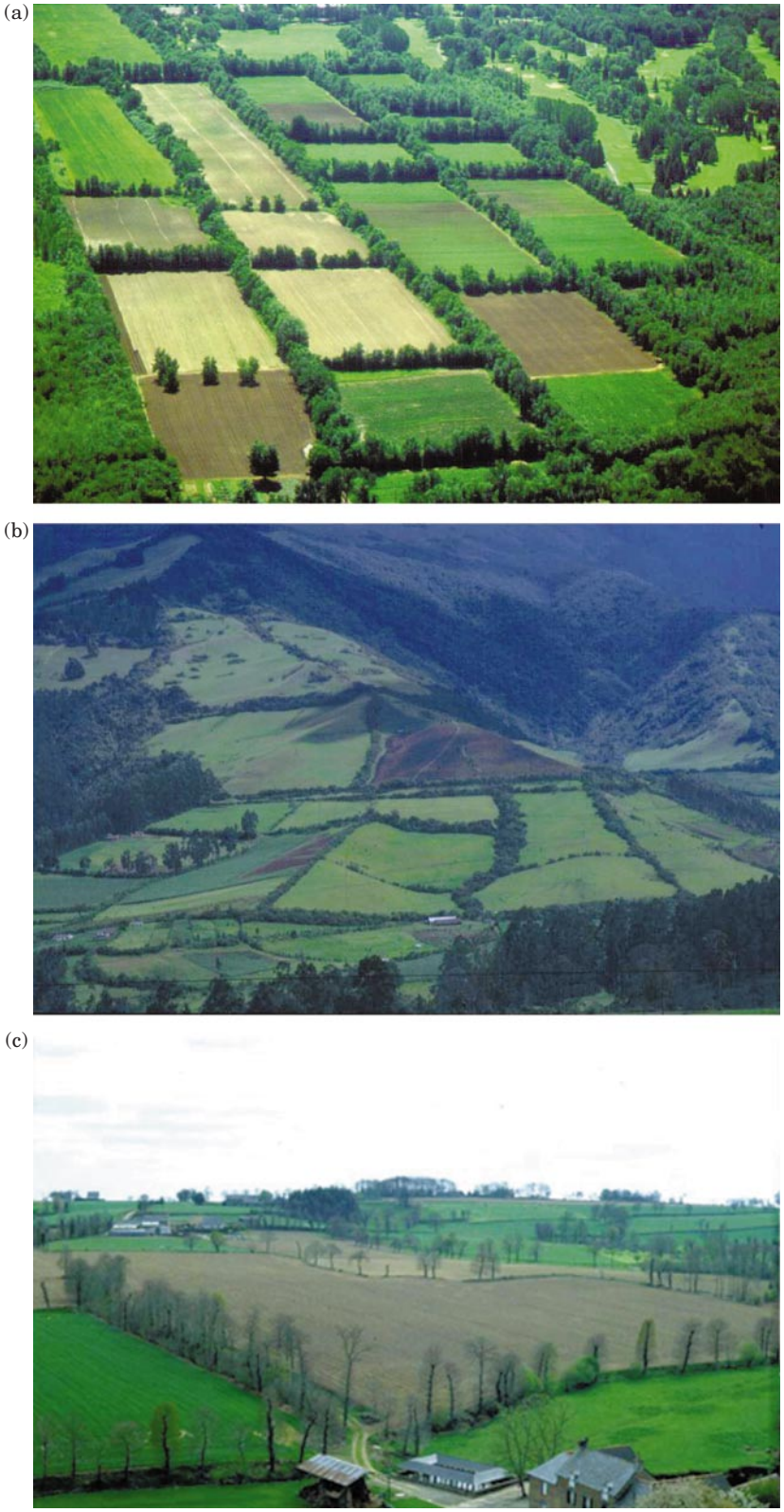

Figure 7. Three examples of hedgerow landscapes. (a) an aerial view of a bocage landscape in Quebec, Canada; with spontaneous hedgerows (photo S. De Blois); (b) a distant view of a hedgerow landscape in the Andes, Equador (photo J. Baudry); (c) a view of a Brittany, France landscape (photo J. Baudry).

Decisions on hedgerow management are generally made by farmers. They may do the work themselves or hire workers. The hedgerow management regime in a given place depends on its function. Whilst firewood is harvested in cycles of several years (6 to 12), some hedgerows are trimmed each year (e.g. hawthorn hedgerows). In the former case not all hedgerows of the farm, or the landscape, are managed in any given year. How therefore does the spatial distribution of management regimes from year to year affect the visual appearance of landscapes or the population dynamics of species?

The general public has a positive view of hedgerows and of their role in conserving biodiversity. Farmers have mixed feeling, as hedgerows may harbour both pests and beneficial organisms (Lemaire, 1980; Thresh, 1981). Although the importance of hedgerows, and field margins in general, for biological control has been claimed and assessed for decades (Altieri, 1999), it is not yet known how beneficial the presence of pest predators in hedgerows is for crop protection.

Policy-makers argue that agricultural policies are becoming more environmentally friendly. In fact, market forces are still very strong and can overwhelm policy objectives (Winter, 2000). In the field of social sciences the policy approach must be combined with studies at the level of individual farmers and the reason for their behaviour toward hedgerows. It is important that farmers accept hedgerows and maintain them. As for other environmental schemes, knowledge of the restrictions for hedgerow acceptance are probably a mix of perception and within farm constraints (Battershill and Gilg, 1997; Beedel and Rehman, 2000).

Conclusion

Hedgerows are important elements of many landscapes around the word. They have fulfilled many functions in the past and still have a major role in the ecological health of the countryside. Therefore, regulations regarding hedgerows must now not only consider the various social, historical, ecological and production functions, but also their diversity of structure and species composition. However, these issues are seldom addressed in most of the regulations protecting hedgerows. The range of variation of hedgerow characteristics and functions still need to be fully described at European and inter-continental levels, which should then act as a stimulus for conservation measures by identifying rare and threatened landscapes. This is a major challenge for scientists, policy-makers and planners. Bocage landscapes are complex with a diversity of functions, which have developed and changed over centuries, but nowadays they should be regarded as sustainable landscapes and should be managed as such.

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