Agriculture, landscapes and connectivity

Jacques Baudry

Introduction

Agriculture is the activity that uses a majority of the land in Europe. It has been so for several thousand years, therefore, it had play and still plays a major role in the dynamics of plants and animal species distribution and abundance. This shows up in the emergent agri-environment policies that aim at maintaining the biodiversity in agricultural areas. It is also widely acknowledged that many species are dependant upon farming activities to thrive and that land abandonment is as a much a threat as "intensification" for the conservation of nature (Baudry and Bunce, 1991). This is especially important in the Mediterranean zone, where mature forest harbor temperate zone species, as exemplified by birds (Blondel and Farré, 1988; Suarez Seoane *et al.*, 2002). Thence, knowledge on how farming activities can participate to nature conservation is a requisite. This is done mostly at a local scale (Paoletti, 1999), with some attempts at the landscape scale (Ryszkowski, 2002), where connectivity is a key factor. Analysis of biodiversity and agriculture at a broader scale is seldom done, though it may be crucial for managing species across regions.

Understanding the role of agriculture in connectivity requires information generally needed for "connectivity analysis", as well as specific information related to agriculture. The analysis of connectivity requires a knowledge of the whole matrix, not only of "corridors" (Ricketts, 2001), specific information on agriculture concerns the mode of operation within farms.

The purpose of this paper is to contribute to the discussion by analyzing:

- Agriculture and how it relates to biodiversity,

Environmental Connectivity: Protected Areas in the Mediterranean Basin, García Mora, M.R. (Coord.)
 ISBN - 84-95785-33-1

- What are the implications for “connectivity” at different scales, and
- What are the implications in terms of monitoring agriculture for biodiversity.

The need for more attention to biodiversity conservation outside of reserves and parks, as the requirements for the development of a multifunctional agriculture creates fertile grounds for a better-integrated approach.

Agriculture and biodiversity

The topic has been largely studied from an ecological point of view, but poorly understood from an agronomic one. Therefore, studies focus on the impact of agriculture and land use changes rather than on how do land use systems contribute to biodiversity patterns. That is the land use system is not the starting point, it only contributes in form of variables relevant in the frame of the ecological analysis. This may truncate the representation of the system, especially as the decision subsystem is left apart. Farming, as all land use systems, has social, technical and ecological components and objectives. The objectives drive the choice of the technical components and can have collateral eco-damages if ecological objectives are lacking. The unwanted ecological effects may also be positive, which produced the wealth of biodiversity in agricultural landscapes. Understanding the mechanisms that lead to land use decision is a key to tease out points of actions in the system. Negotiations between farmers and biodiversity stakeholders need this as a starting point.

The central concept is that a farm is a system within which farmers base their activities on rules to achieve production objectives, but also, in most cases, the sustainability of the land potential (Fresco *et al.*, 1994). This implies a coordination of the use of the different fields, as well as the design (e.g. size, type of boundaries, fences) of these fields (Papy, 2001). This makes the farm scale cropping system.

The management of the farm territory and land use allocation are the two main factors controlling biodiversity. At an extreme point of the farming system gradient, control by technology and high energy inputs is the paradigm, at the other end, control by landscape design and allocation of crops to optimize the use of the landscape physical heterogeneity is the rule. The type of commodity that is produced (i.e. milk, meat) can be the same in either situation. In a context of agricultural policies that singles out the production of commodities for the market, as the EU during the 1970's, energy driven systems are favoured. The shift to multifunctionality should boost ecologically landscape and land use design.

Models and policies often focus either on landscape design (i.e. implementation of corridors) or land use practices (i.e. less pesticide), while sound management needs the combination of both. The main reason is that corridor quality is not independent of adjacent land use (Le Coeur *et al.*, 2002) and that changing practices is not enough to provide new landscape elements, especially perennial ones (strip of grass, hedgerows).

The analysis of farming systems permits to decipher the rules of land allocation, and to understand the organization of the landscape mosaic. The factors that organize farm land allocation are several: from soil heterogeneity, to crop succession as well as labour and machinery availability (Thenail, 1999). Type of production (milk, cash crops, meat etc.) is, of course of primary importance, though the feedback loop between farm constraints and type of production is not always clear.

Patterns of agricultural landscapes arise from this combination of within farm and between farms land use diversity (Baudry and Papy, 2001). Heterogeneities that arise from land uses can be grouped in a hierarchical manner. At the top is the differentiation between farmland and non-farmland, then farmland is divided into perennial, pluriannual and annual crops, the later are made of single or associated crops and so forth. Within a cropping season, several heterogeneities show up, from bare soil after ploughing to vegetation of different height and volume, some crops produce flowers but may be mown early etc. These different crops and states produce different habitat, food, and hiding places. The permeability of the crops (the ease by which an organism can traverse them) varies also greatly from crop to crop and for a crop during the year. The use of fields by the individuals of a species will therefore vary. Ouin *et al.* (2000) demonstrate this for small mammals. Crop management may also create differences for a crop; for instance irrigation maintains the vegetation wet, more difficult to use for partridges.

The shift from spring-sown cereals to winter cereals exemplifies the importance of within year dynamics. It had a tremendous impact on bird population in UK, because during the winter weeds (a source of food) disappeared from fields (Robinson and Sutherland, 2002).

Farms and landscapes can be differentiated by their cropping systems. Crop succession, the way crops follow one another in the same field is another important concept. It a basis for good farming practices to avoid diseases and retain nutrients in the soil. The concept of *regional cropping system*, defined as *the combination of crops due to a specific land use organization in a region* is emergent (Papy, 2001). It could be a useful mean to link ecological and land use systems. A cropping system creates specific landscape mosaics that characterize the agriculture of the region. From the crop mosaic and its changes over years, it is possible to have a picture of the spatial patterns of crop states at various time scales.

Apart from field use and management, the structure and management of field boundaries is an important environmental issue. Its is functionally related to field land use (Thenail *et al.*, 2000; Le Coeur *et al.*, 2002).

In conclusion, farmers control types of habitats, quality of those habitats, but may have little control on the spatial arrangement of those habitats, except in large farms that are “a landscape”. The situation is similar to the one of water management, as farmers do not manage water basins. Several farmers use part of the relevant ecological functional unit. This is often overlooked by policy makers and is a cause of the “scale gap” between fine scale farming practices and coarse scale regional planning. Only cooperation among farmers for concerted use of the land can bridge this gap. In the evaluation of policies, this point should be given a high priority (Papy and Torre, 2002).

The representation of agricultural and biodiversity

We propose to utilize a hierarchical view in ecology and agronomy to build some representations of the interactions between farming and ecological systems at the landscape and regional levels. In this representation (Figure 1) both proximate factors that directly control landscape dynamics and ultimate factors that exert control through farming systems or are shown.

Within the European Union, the so-called Common Agricultural Policy (CAP), has had, in fact, heterogeneous effects that have led to an increasing differentiation of production between regions (Laurent and Bowler, 1997). Some regions produce milk, other cereals. One consequence is the high contrast in land use, hence landscape patterns, from one region to the next, which probably decrease large-scale connectivity. Furthermore, the technical means implemented for a production can lead to contrasting land uses, as exemplified by milk production (Baudry *et al.*, 1997).

Connectivity

Certainly a central concept of landscape ecology, that has promoted a wealth of field and modeling studies (Burel and Baudry, 1999). Connectivity is *the degree to which the landscape facilitates or impedes movement among resource patches* (Taylor *et al.*, 1993). It has to do with the possibility of movement within and across landscapes. The movements can be walking along physical corridors, but also going from "stepping stones" to "stepping stones". The pathway is then a virtual corridor. The size of the stepping stones (fragmentation) is an important matter as they can be temporary habitats. An example is the case of coastal marshes for migratory birds. The drainage of wet meadows to convert them to crops diminishes the size of the resources. Though it is now recognized as a functional aspect of the ecology of landscapes and not merely a structural aspect, connectivity still "suffer" from a structural perspective with an overemphasis on certain landscape elements (corridors), as hedgerows. As for any process in landscapes, connectivity must be looked at in a multiscale perspective.

The movements of individuals or propagules are scaled in time and space, from daily foraging movements (for animals) to movements related to migration or colonization of vacant habitats (for both plants and animals). Species range and dispersal ability frame the relevant time/space scales.

For example, a hedgerow is a corridor for carabids, but due to the limited movements of those species, it may take several generations to move all along a corridor. A bird or a small mammal journeys the same distance in minutes or days. Slow dispersers, fine grain species perceive differently landscape changes; as long as a small piece of habitat remains, they survive, while coarse grain species (i.e. predators mammals) vanish rapidly when a small part of their habitat disappears. Thence, fine grain species distribution reflects more landscape patterns in the past than present ones (see Burel, 1993 for insects).

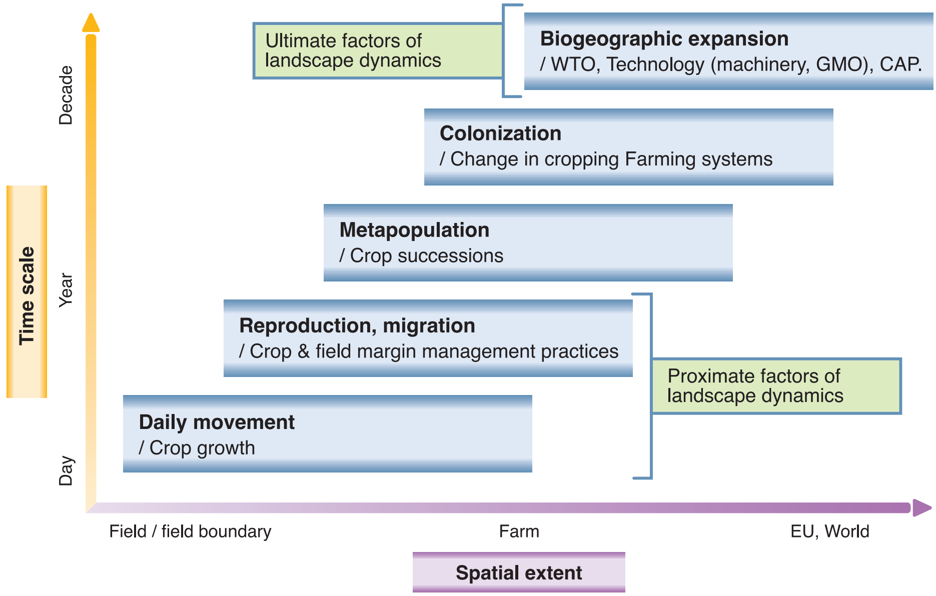

Figure 1. A hierarchical view of landscapes. Ecological processes (in italics and bolds)/ production activities.

When planning, it is important to clarify what kind of connectivity we want to promote. Do we want to have enough habitats connected to sustain populations, meta-populations, and maintain continuous exchanges all through the biogeographic range of the species, or do we mostly seek to sustain regional connectivity for distinct metapopulations?

If corridors are important, the extent and density of the networks required by the different species to survive, as populations, will be very different. The area over which farming systems sustaining the landscape have to be different as well. One may think that if a landscape is suitable for coarse scale species, it will do for fine scale ones. In fact, species that move over large areas perceive fewer gaps in corridor that slow moving species do.

Connectivity depends, in fact, of the utilization of whole regional landscapes and its dynamics. The dynamics of agricultural landscapes differs markedly from the one of natural ones. For the later, the dynamics is internal to landscape patches (growth, succession, accumulation of fuel that increases the risk of fire etc.) even if catastrophic events (floods, hurricane, light storm) come from outside. In agricultural landscapes, changes are very much stochastic, seen from a landscape patches, decisions on land use (Figure 1) do result from a socio-technical realm, outside of the ecological one. Connectivity among crops varies from year to year due to individual decisions of farmers, as do hedgerow removal or plantation. Seen from flora and fauna, randomness may be huge. This is why as annual crops increase in a landscape, plants and animals with high dispersal ability are selected. Slow moving species have difficulties to keep track of land cover/use change and to find suitable places.

Beside its relation to biodiversity, connectivity is a concept useful in considering other ecological processes, such as nutrient cycling, soil protection against erosion etc. In this case, the problem is mostly to disconnect source of nutrient or running water from downward soil or water. Networks of corridors for species movement often play this role. Concerning nutrients, buffer zones such as hedgerows, riparian forest or meadows, have a potential for denitrification, thus protecting water (Haycock *et al*., 1996). These buffers are also useful against erosion, as is a fine grain mosaic of crops that do not leave large area of soil denuded during the rainy or windy season. The interplay between geochemical fluxes and biodiversity is a growing field of research mainly seeking at understanding the role of biodiversity (Naeem, 2002). Conversely, the role of biogeochemical fluxes, especially nutrient fluxes is of major importance for the maintenance or the impairment of biodiversity. It is part of the more general functioning of food webs and the role of landscape structure in this functioning (Polis *et al*., 1997). These food webs can be much altered by farming activities from the local to the global scale, but it is possible to design landscapes that maintain the nutrients within a limited area and enhance trophic interactions (Baudry and Burel, in press).

The monitoring of agriculture

As provider of food, agriculture and its production have been monitored since the antiquity. Today, many sources of information are available: census, satellite images, to forecast production, to check set-aside schemes etc. The potential to make maps and analyze them is important, though I am not aware of their use from a biodiversity standpoint.

Combination of land cover maps and knowledge of farming system functioning can lead new representation of landscapes to be used in ecological modelling. We started for local landscapes . The basis is information on the relationships between landscape patterns and farming systems (Baudry *et al*., 2000; Thenail, 2002). Regional approaches must be feasible as well. The objective is to obtain the various landscape patterns that are relevant for different types of species (differing by habitat requirement and dispersal ability) of interest in conservation. This the purpose of LUCAS (Land Use/Cover Area Frame Statistical Survey), an initiative from EUROSTAT (www.landsis.lu/projects/). It aims at collecting information on land use/cover, with a special focus on agriculture. This include the information on hedgerows on other linear features. Such data would enrich the large scale approaches of habitats, as the one developed by Osborne *et al.* (2002) for the great bustard in Spain.

Conclusion

Agriculture and biodiversity still have a long way to go together. Their blend is an expression of both ecology and culture, and objectives of sustainability and multifunctionality requires that both be developed. The participation to nature conservation is a complement to reserves and National Parks. Because of the detrimental impact of farming practices on flora and fauna during the last decades, agriculture and nature conservation are often perceived as only a source of conflict. Interactions can take a different path if set in a new framework that combines the functioning of both agriculture and ecological systems. This will permit to decipher where the triggers are to change farming systems. These changes involved both the creation of new habitat, as hedgerows) and the use of novel practices in single farm. For landscape connectivity agricultural policies must involved regional aspects and several farms. The general control of fluxes either biotic or abiotic in landscapes should receive a special attention, as abiotic fluxes can be source of pollution and disconnection of biotic fluxes change the trophic functions.

Acknowledgements: I thank the ministry in charge of the environment for its support to my research on agriculture and biodiversity, this paper is number 2 of the DIVA coordination program. The EU project GREENVEINS (EVK2-2000-22010) contributes also to this paper.

References

Baudry, J. and Bunce, R.G.H. (Eds.), 1991. *Land abandonment and its role in conservation., Options Méditerranéennes*, A15. 148 pp.

Baudry, J.; Bunce, R.G.H. and Burel, F., 2000. Hedgerow diversity: an international perspective on their origin, function, and management. *Journal of Environmental Management* 60: 7-22.

Baudry, J.; Burel, F.; Aviron, S.; Martin, M.; Ouin, A.; Pain, G. and Thenail, C., In press . Temporal variability of connectivity in agricultural landscapes: Do farming activities help? *Landscape Ecology*.

Baudry, J.; C. Laurent and Denis, D., 1997. The technical dimension of agriculture at a regional scale: methodological considerations. C. Laurent and I. Bowler (Eds.), *CAP and the regions: Building a multidisciplinary framework for the analysis of the EU agricultural space*. Paris, INRA Editions: 161-173.

Baudry, J. and Papy, F., 2001. The role of landscape heterogeneity in the sustainability of cropping systems. In: J. Nösberger; H.H. Geiger and P.C. Struik (Eds.), *Crop Science - Progress and Prospects*. Oxon, Cabi Publishing: 243-259.

Blondel, J. and Farré, H., 1988. The convergent trajectories of bird communities along ecological successions in european forest. *Oecologia* (Berlin) 75: 83-93.

Burel, F., 1993. Time lags between spatial pattern changes and distribution changes in dynamic landscapes. *Landscape and Urban Planning* 24: 161-166.

Burel, F. and Baudry, J., 1999. *Ecologie du paysage : concepts, méthodes et applications*. Paris, Lavoisier. 359. p.

Spanish edition. 2002. *Ecología del paisaje*. Barcelona, Mundi Prensa. 353 p.

English edition. In press. *Landscape Ecology*, Oxford & IBH Publishing Co. p.

Fresco, L. O.; Stroosnijder, L.; Bouma, J. and van Keulen, H. (Eds.), 1994. *The future of the land: Mobilising and integrating knowledge for land use option*. West Sussex, Wiley & Sons. pp. 409

Laurent, C. and Bowler, I. (Eds.), 1997. *CAP and the regions: Building a multidisciplinary framework for the analysis of the EU agricultural space*. Paris, INRA Editions.

Le Coeur, D.; Baudry, J.; Burel, F. and Thenail, C., 2002. Why and how we should study field boundaries biodiversity in an agrarian landscape context. *Agriculture, Ecosystems & Environment* 89(1-2): 23-40.

Osborne, P. E.; Alonso, J.C. and Bryant, R.G., 2002. Modelling landscape-scale habitat using GIS and remote sensing: a case study with great bustards. *Journal of Applied Ecology* 38: 458-471.

Ouin, A.; Paillat, G.; Butet, A. and Burel, F., 2000. Spatial dynamics of Apodemus sylvaticus in an intensive agricultural landscape. *Agriculture, Ecosystem, Environment,* 78: 159-165.

Paoletti, M.G., 1999. Using bioindicators based on biodiversity to assess landscape sustainability. *Agriculture, Ecosystems & Environment,* 74: 1-18.

Papy, F., 2001. Interdépendance des systèmes de culture dans l'exploitation agricole. In: E. Malézieux; G. Trébuil and M. Jaeger (Eds.), *Modélisation des agro-écosystèmes et aide à la décision*. Montpellier, Editions CIRAD-INRA, collection Repères: 51-74.

Papy, F., 2001. Pour une théorie du ménage des champs: l'agronomie des territoires. *Compte Rendus de l'Académie d'Agriculture,* 87(4): 139-149.

Papy, F. and Torre, A., 2002. Quelles organisations territoriales pour concilier production agricole et gestion des ressources naturelles? *Etudes et Recherches sur les Systèmes Agraires et le Développement*, 33.

Ricketts, T.H., 2001. The matrix matters: effective isolation in fragmented landscapes. *The American Naturalist* 157: 87-99.

Robinson, R.A. and Sutherland, W.J., 2002. Post-war changes in arable farming and biodiversity in Great Britain. *Journal of Applied Ecology* 39: 157-176.

Ryszkowski, L. (Ed.), 2002. *Landscape ecology in agroecosystem management. Advances in Agroecology*. Boca Raton, CRC Press. pp. 366

Suarez Seoane, S.; Osborne. P.E. and Baudry, J., 2002. Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. *Biological Conservation* 105(3): 333-344.

Taylor, P.D.; Fahrig, L.; Henein, K. and Merriam, G., 1993. Connectivity is a vital element of landscape structure. *Oikos* 68: 571-573.

Thenail, C., 1999. The spatial organization of farms and farming activities (fields and hedgerows management) in a bocage landscape: contribution to the landscape structuring. C.H. Jacobsen; C. Thenail and K. Nilsson (Eds.), *Agrarian landscapes with linear features: an exchange of interdisciplinary research experiences between France and Denmark*. Proceedings of a French/Danish research seminar in Rennes, 2-5 May 1998. Hoersholm, Danish Forest and Landscape Research Institute. 3: 93-114.

Thenail, C., 2002. Relationships between farm characteristics and the variation of the density of hedgerows at the level of a micro-region of bocage landscape. Study case in Brittany, France. *Agricultural Systems* 71: 207-230.

Thenail, C.; Le Coeur, D. and Baudry, J., 2000. Relationships between field boundaries, farming systems and landscape: consequences on biodiversity pattern in agrarian landscapes. *4th European symposium on European Farming and Rural Systems Research and Extension: environmental, agricultural and socio-economic issues.*, Volos, Association for Farming System Research and Extension, European group.