INRA Multidisciplinary Scientific Assessment

Agriculture and biodiversity
Benefiting from synergies

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The international community has committed itself to slowing the loss of biodiversity between now and 2010. It is in this context that the notion of "biodiversity management" has developed over the last 10 years. This new approach goes beyond the conservation of particular species, focusing on the ecological functions of biodiversity. It addresses what functions are provided by biodiversity and its ecological, economic and cultural importance for human activities, particularly in agricultural systems and landscapes.

The long history of agriculture in France has left its stamp on the landscape by transforming natural environments and is consequently closely linked to biodiversity. Historically, the introduction of agriculture has shaped landscapes, creating new ecological conditions, which in turn generate biodiversity. Agricultural environments and landscapes constitute a reservoir of diversity in terms of the number of species and the number of functions useful for agriculture (pollination, recycling of organic matter, etc.). However, intensification of agricultural practices threatens this diversity.

Modern French agriculture makes little use of these natural ecological services, replacing them with chemical inputs (pesticides and fertilisers). Decreases in the diversity of crops, the simplification of cropping methods, and the homogenisation of landscapes (hedgerow removal for example) have negative effects on biodiversity in agricultural areas.

In the face of population growth, environmental changes and diminishing fossil fuel reserves, can agriculture re-establish its links with biodiversity? Evaluating the services supplied by biodiversity linked to agriculture, with the aim of maximising mutual benefit, is the subject of this INRA Multidisciplinary Scientific Assessment paper situated at the interface between ecology, agronomy, economics, law and sociology.

Background and methodology underlying this scientific assessment

Expert analysis of associations between biodiversity and agricultural activities was carried out, between June 2007 and June 2008, at the request of the ministries responsible for agriculture and the environment. This request is consistent with national (the national strategy for biodiversity, concerning in particular agriculture , the adaptation of agricultural and environmental measures under the new programme for rural development in mainland France, and the 9th Conference of the convention dealing with biological diversity), European (revision of the Common Agricultural Policy, the CAP, particularly as concerns the conditions relating to public subsidies for agriculture) and international (definition of objectives to halt the loss of biodiversity under the framework of the International Convention on Biological Diversity) policies. It has also found support in discussions concerning biodiversity in the framework of the *Grenelle de l'Environnement* in France.

The questions formulated by those requesting this scientific assessment concern the effects of agriculture on biodiversity, the possible roles and values of this biodiversity for agriculture, the technical opportunities to "integrate" biodiversity into agriculture and their economic and social feasibility.

This assessment mainly concerns "natural" biodiversity in agricultural production systems (agrosystems). It does not deal with genetic resources per se (i.e. generation and maintenance of diversity within domesticated species), although the possible role of such biodiversity to mitigate impacts on biodiversity and/or to better use biodiversity was within the scope of the exercise. It considers only mainland France, and excludes aquatic environments and forests per se although those environments were considered in the perspective of biodiversity dynamics at the landscape scale.

This analysis was conducted by an expert group consisting of about 25 researchers specialised in ecology, agronomy, economics, sociology and law from INRA and other French (CNRS, IRD, agricultural schools) and foreign institutions (Agroscope and the Institute of Environmental Sciences in Zurich and the University of Louvain). The work of these experts was based on the analysis of some 2000 publications, consisting mainly of scientific articles, but also international reports and technical documents. The

experts summarised and analysed these articles, identified useful elements, and assembled these to provide an authoritative aid for decision-makers.

Principles of multidisciplinary scientific assessment

The assessment responds to complex questions of public concern by assessing, the state of multidisciplinary scientific knowledge through a global literature review, outlining what is known and identifying uncertainty, gaps in knowledge and controversies. The assessment did not carry out additional studies of its own, does not provide specific advice or recommendations, nor formally attempts to analyse future trends.

The assessment is based on work by a group of researchers specialising in various different disciplines and attached to different research organisations. This resulted in the production of a report assembling the various contributions of the experts together with a shorter summary report targeted to a wider audience, and in particular, decision-makers.

Biodiversity: the concept and the issues involved

The term "biodiversity" was first coined in the 1980s and attained international political recognition at the Rio Earth Summit (1992), which led to the Biological Diversity Convention. In this convention, the concept of biodiversity is presented as covering three levels of organisation of living entities: ecological diversity (the diversity of ecosystems), specific diversity (the diversity of species) and genetic diversity (diversity within species). This definition emphasises the interdependence between the three levels of organisation and identifies biological diversity as one of the most important issues and concerns for sustainable development.

The last decade has seen a change in the concept of "biodiversity". A technical, economic and social dimension aiming to take into account the services provided by biodiversity to various human activities and actors has progressively been added to the initial, mostly patrimonial, view in which biodiversity is considered primarily as a support for evolution and the protection of important environments and species.

In this concept, biodiversity is considered to be the "natural" compartment (species, habitats) with which agriculture is actually closely associated.

Three approaches can be applied to the relationships between agriculture and this definition of biodiversity. The first favours greater specialisation of land use, with some areas dedicated to the protection of biodiversity and others dedicated to agricultural production, which may be intensive. The second aims to conserve biodiversity in agricultural environments, by promoting practices acceptable to farmers but of limited impact on biodiversity. The third involves synergistically integrating biodiversity into agricultural processes; in addition to limiting the impact of agriculture on biodiversity, it seeks to make better use of biodiversity in agricultural production.

The positive and negative effects of agriculture on biodiversity

Biodiversity and agriculture cannot be dissociated, due to the large proportion of land used for agriculture (60% in mainland France) and the historical role of agricultural activity in structuring environments and the diversity of landscapes, particularly through the creation and maintenance of open (un-forested) areas that can harbour considerable biodiversity.

Debates about the impact of agriculture on biodiversity focus on the effects of intensification during the second half of the 20th Century. This intensification of agricultural production led to an increase in the productivity of cultivated areas, associated with the use of mineral fertilisers and synthetic pesticides and with the "simplification" of agricultural landscapes resulting from a reduction in the diversity of production systems.

Studies of the effects of agricultural practices and of landscape characteristics in Europe on the diversity of a large range of living organisms have confirmed the substantial impact of agriculture on biodiversity at various spatial scales. At the scale of individual plots, fertilisation, tillage and pesticide use constitute environmental changes with an overall negative effect on biodiversity. At the landscape level, the disappearance of semi-natural environments on the edges of agricultural land, such as woodland, semi-natural grassland, hedges and the field margins typical of hedged farmland, also has a deleterious effect on biodiversity. The same is true for the spatial homogenisation of crops and the synchronisation of practices (harvesting and mowing dates, for example). Furthermore, intensive agriculture in homogeneous landscapes favours the development of crop pest populations.

By contrast, less intensive production methods have positive effects on biodiversity, in particular for beneficial animals, such as pollinators and the natural enemies of pest species. These positive effects are due to lower levels of environmental disturbance and the greater heterogeneity of less intensive agrosystems. They are particularly evident in landscapes sufficiently complex to act as biological reservoirs.

Landscape mosaics are thus a key element for the conservation of biodiversity in agricultural areas. They attenuate the negative effects associated with the intensification of practices at plot level, by increasing the percentage and composition of semi-natural elements present and, to a lesser extent, both the connections between and the quality of habitats. These compensatory effects are only observed in sufficiently heterogeneous environments, as found on about one third of the land currently used for agriculture in France. Historic and current homogenisation of the landscape may lead to decreases in biodiversity that are difficult to reverse.

Improvements in the ecological services provided by agrosystems are based on the increasing complexity of spatial structures surrounding plots or landscapes, the de-intensification of cropping systems by decreasing the use of pesticides, mineral fertilisers and tillage, and by introducing long, more diverse rotations using a larger number of cultivated species and varieties.

The services that biodiversity provides to agriculture

The services provided by biodiversity cover a large spectrum of factors contributing to the generation of agricultural income: crop yield and quality, soil fertility, pest control and pollination. Other services, such as contributions to landscape quality are not directly beneficial to the farmer, but are beneficial to the community as a whole.

The effect of biodiversity on production has been particularly well studied for grasslands. Botanical diversity and associations between species facilitate functional complementarities (particularly for leguminous plants, as the nitrogen they fix is also beneficial to neighbouring plants) and have a proven stimulatory effect on the desire to eat of herbivores, thereby increasing production. The presence of certain flowering plant species may also improve the organoleptic characteristics of cheeses. These services provided by biodiversity are already, at least partly, valued by certain forms of agriculture.

The economic and agronomic benefits associated with the services of pollination and pest control by natural enemies may be significant for certain major field crops (oilseed rape), orchards, vines and grain legumes. These services may reduce input costs and avoid management problems associated with chemical control, particularly those resulting in losses of key organisms such as pollinators, the functions of which cannot be replaced by inputs. These organisms require semi-natural areas for their survival and reproduction. The benefits described above thus depend on the conservation of a landscape appropriate for the maintenance of "source" populations. Biodiversity-dependant services may also be important for maintaining the physical stability and fertility of soils, through the action of the soil macro- and micro-fauna, although this remains controversial. Intensive fertiliser use and tillage reduce both the provision of these ecological services and their agronomic value in intensive agricultural situations. As decreases in the amount of fertiliser applied may lead to decreases in the agronomic performance of these systems, a potential beneficial synergy is the use of organic fertilisers, which favour the maintenance of abundant soil populations. For all these services linked to ecosystem functioning, it is possible to distinguish between mobile species (insects) capable of finding the elements required for their survival in the landscape and sedentary species (earthworms...), which are limited to the immediate environment and are thus more vulnerable.

The analysis of these services was based on previous work in experimental systems often far removed from real agricultural conditions. It is therefore necessary to consider when and to what extent these services can be integrated into actual agricultural practices and to identify the factors favouring their more systematic use.

Better integration of biodiversity and agriculture into production systems

Opportunities to better integrate practices believed to favour biodiversity into agricultural practice are determined by technical, economic and social factors.

Some agricultural practices already limit the negative impact of agriculture on biodiversity and capitalise on the services offered by biodiversity. Although its practices do not explicitly focus on biodiversity, organic farming (OF) appears to be a mode of production favouring biodiversity, at least in complex landscapes.

More generally, the utilisation of long, diversified rotations, an appropriate spatial distribution of crops, intercropping, catch crops, cover crops, the use of varieties with lower susceptibility to disease and the simplification of tillage are important elements for biodiversity in arable areas.

In areas of animal production, increasing connectivity between hedges and the surrounding landscape may re-establish the landscape mosaic where there has been extensive hedge removal. The degree of grassland intensification and the proportions of grassland and forage crops, particularly forage maize, are also important. Decreasing fertiliser use and the density of animals per hectare also improve biodiversity conservation, as does desynchronising hay cutting.

In fruit production areas in the south of France, decreases in pesticide use and the promotion of integrated fruit production, including the diversification of plant species by cover planting in orchards, conserves and makes better use of biodiversity.

The principal obstacle to the adoption of practices and modes of production more favourable to biodiversity are the costs of adopting changes in techniques or the total conversion of production modes. The possible decrease in yield resulting from "de-intensification" to favour both biodiversity and its services can potentially be compensated, at least partly, by cost savings in the purchase of phytosanitary products and mineral fertilisers. However, few evaluations of these savings have been published. Biodiversity can be valued through the price of the final product, through the certification of origin (French *AOC*) system for cheeses, for example, with specifications relating to the feed and pastures of the animals concerned. This approach could be used to recognise the value of pasture biodiversity through the effect of that biodiversity on the organoleptic quality of the resulting cheeses.

Physical and monetary inputs, work load and equipment remain the dominant features in agricultural decision making. Technical changes favouring biodiversity alter the consideration accorded to the different factors, increasing the weight given to knowledge, training and technical know-how. Similarly, the factors "time" and "work" change in nature, with greater priority given to tasks aimed at the management of services provided by biodiversity.

It should also be borne in mind that the various strategies for integrating biodiversity into agriculture are based on seeking compromise and synergy at the level of the landscape and of local human communities, as a function of local ecological and agricultural conditions.

Conditions and tools for public action

The chief obstacles to the adoption of public policy to address objectives fixed by international commitments are: imperfect knowledge about the relationships

between agriculture and biodiversity; and the difficulties involved in measuring biodiversity with a standard method appropriate for different scales.

There are actions specifically targeting the conservation of biodiversity, the most successful of which is Natura 2000. However, the strength of the relationship between agriculture and biodiversity is such that all measures concerning agriculture in general must be considered when studying the effects of biodiversity policies. Such studies are complicated by the diversity of the measures themselves, which may have explicit aims concerning biodiversity, a more general aim to conserve the environment or another aim altogether, but with effects on biodiversity.

The evaluation of past actions with explicit objectives concerning biodiversity or the conservation of the environment in general is informative: it shows that the ecological performance of the measures used has sometimes suffered from the dispersed and unstable nature of the implemented measures and from incompatibilities with the objectives of the CAP.

The issues of conservation and management of biodiversity implicate various levels of governance, including national and European policies and also local and regional initiatives. The temporal (duration of measures) and spatial (territory, as the socially and ecologically relevant level or organisation) dimensions are key elements determining the efficacy of measures.

Local co-operation among farmers and with other actors, allowing the collective consideration and participation in issues, objectives and implementation, contributes to the efficacy of the process. Monitoring the efficacy of policies can also contribute to their being progressively improved.

Developing a new scientific discipline

Research aiming to improve the integration of biodiversity and agriculture involves the convergence of several diverse scientific communities, including for example those working in the areas of ecology, agronomy, law, economics and sociology. These different disciplines tackle this issue with often very different viewpoints, concepts, methods and objectives.

Ecology focuses principally on the dynamics of species and communities. As such, agriculture constitutes a good study model for the mechanisms underlying the dynamics of biodiversity in human dominated ecosystems. Some ecological publications aim to experimentally demonstrate the services provided by biodiversity.

Agronomy has mainly focused on understanding the flows of matter and energy in relation to productivity, quality and pollution, but has paid little attention to biotic interactions (with the emphasis on control using phytosanitary products). Systemic approaches complementary to analytical approaches are currently being developed, so as to be able to take into account interactions occurring within agrosystems.

Finally, social sciences consider the relationship between biodiversity and agriculture from the perspective of economic, legal and social values associated with biodiversity. They seek to explain how these values can be taken into account in the behaviour of individual actors and in public policy.

This fragmentation of the scientific community and the different approaches used explain the difficulties encountered in amassing pertinent knowledge from the various domains relating to the complex question of relationships between agriculture and biodiversity across different time scales and organization levels.

However, these fields are growing closer together, as shown by surveys of recent literature with increasing numbers of published pluridisciplinary studies, and also by the consideration within each discipline of the contribution of other sciences.

For more information:

X. Le Roux, R. Barbault, J. Baudry, F. Burel, I. Doussan, E. Garnier, F. Herzog, S. Lavorel, R. Lifran, J. Roger-Estrade, J.P. Sarthou & M. Trommetter (éditeurs), 2008. Agriculture et biodiversité. Valoriser les synergies. Expertise scientifique collective, synthèse du rapport, INRA (France)

This short summary report and the assessment report are available from the INRA website: www.inra.fr
The summary will be published in French by QUAE EDITIONS and available in English from the INRA Website.