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Biodiversity Drifts in Agricultural Landscapes

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1. Introduction

We are in the midst of the sixth global mass extinction event (McNeely & Scherr, 2002; Thomas et al., 2004). Around the globe, biological communities that took millions of years to develop—including tropical rain forests, coral reefs, old-growth forests, prairies and coastal wetlands—have been devastated as a result of human actions. Biologists predict that tens of thousands of species and millions of unique populations will go extinct in the coming decades (Brown & Laband, 2006; Millennium Ecosystem Assessment, 2005a). If the current predictions are correct, the rates of environmental changes may outpace the capacities of organisms to adapt to the changes.

There are seven major threats to biodiversity: habitat destruction; habitat fragmentation; habitat degradation (including pollution); global climate change; the overexploitation of species for human use; the invasion of exotic species; and the increased spread of disease. Most threatened species and ecosystems face at least two or more of these threats, which can interact synergistically to speed the way to extinction and hinder efforts at protecting biodiversity (Burgman et al., 2007; Millennium Ecosystem Assessment, 2005b). All seven threats are the result of an expanding human population's ever increasing use of the world's natural resources (Primack, 2008).

Agroecosystems include a large proportion of the world's biodiversity (Pimentel et al., 1992). Over the past two decades, research has demonstrated the value of agricultural biodiversity in all its forms, including crop and livestock genetic diversity, and associated species important for production, for example, pollinators, soil microorganisms, beneficial insects, and predators of pests and wild species that occur in agricultural landscapes (Uphoff et al., 2006). Some species are almost completely dependent on agricultural habitats for survival, e.g. Great Bustard *Otis tarda*, Grey Partridge *Perdix perdix* or the Black-tailed Godwit *Limosa limosa* (Kleijn et al., 2006).

Since the 1960's both industrial agriculture in developed countries and the original green revolution in developing countries have depended on improved seeds, chemical fertilizers, pesticides and irrigation. This production model involved a small number of crops, generally in monoculture (to increase efficiency in use of inputs and mechanization), increased pesticide and fertilizer use and short crop-rotations (Benton et al., 2003). Wild flora and fauna were considered direct competitors for resources or harvested products, while water was diverted from wetlands and natural habitats for irrigation (Uphoff et al., 2006), and intensification has reduced the suitability of agricultural fields for a wide range of organisms (Benton et al., 2003). The cultivation of annual crops has expanded at the cost of non-crop habitats such as extensive grasslands, fallow, hedges and field margins (Benton et al., 2003; Tilman et al., 2001b). Non-crop habitats provide dispersal corridors for wildlife and habitat islands required by many species as refuges and feeding areas (Öckinger & Smith, 2007; Stoate et al., 2001). Non-crop habitats can also act as biodiversity reservoirs for natural enemies, which can potentially improve natural pest control in agricultural landscapes (Ives et al., 2000; Wilby & Thomas, 2002), however, they can also act as reservoirs for pest species, which can colonize the crops (van Emden, 1965).

The expansion of agricultural intensification (AI) is often considered to be an important factor that has contributed to a rapid decline in biodiversity in agroecosystems (Benton et al., 2003; Mattison & Norris, 2005) and negatively affected the production of ecosystem services, e.g., maintenance of fertile soils, biotic regulation, nutrient recycling, assimilation of wastes, sequestration of carbon dioxide, and maintenance of genetic information (Benton et al., 2003; Chamberlain et al., 2000; Hooper et al., 2005; Robinson & Sutherland, 2002; Tilman et al., 2002). Wilcove et al. (1998) estimated that 38% of the endangered species in the United States are negatively affected by agricultural practices. Changes in landscape composition and intensive management practices are believed to be the main factors causing this decline. Also many species of raptor have been negatively affected by prey declines, probably associated with AI (Tucker & Heath, 1994). Furthermore, the potential of biodiversity for providing ecological resilience, i.e., the capacity to recover from disruption of functions, and the mitigation of risks caused by disturbance (Holling, 1996; Swift, 2004) is poorly documented. A better knowledge of which goods and services are provided by agroecosystems is urgently needed since we live on the brink of no return.

At the present time, 10% of the global land area is under intensive agricultural use, 17% is under extensive use associated with the use of far fewer artificial inputs, and 40% is grazed by domestic livestock (Mooney et al., 2005; Wood et al., 2000). The world's population of 6.3 billion people is projected to grow to 7.2 billion by the year 2015, 8.3 billion by 2030 and to 9.3 billion by 2050 (FAO, 2003). By 2050, food production must double to meet human needs. In order to meet this increasing demand for food and fibre, production systems are expected to become increasingly dependent on synthetic inputs of fertilizers and pesticides (Clay, 2004). Since the world's population will continue to increase, we will increase agricultural output by 30–50% over the next 30 years; thus, the need to protect biodiversity will compete directly against the need for new agricultural land (Tilman et al., 2001a).

Not only biodiversity is at risk, lately there has been an increase in public awareness of the possible effects of agro-chemicals. Many studies document increased risk of cancer among children and adults associated with exposure to an array of pesticides (Alavanja et al., 2007; Dich et al., 1997; Zahm & Ward, 1998). Sometimes the dangers are ignored by the responsible entities, for example, the fungicide vinclozolin, which is widely used in vineyards, was registered for use in 2000, despite laboratory tests indicating that it causes testicular cancer and disrupts normal androgen activity in laboratory animals (U.S. Environmental Protection Agency, 2000). Pesticide poisoning is also a daily hazard for the majority of the world's rural population (Dinham & Malik, 2003). The World Health Organization (WHO, 1990) has indicated that 20,000 women, men and children die of accidental pesticide poisoning each year, three million are poisoned, and nearly three fourths of a million new people each year will suffer from chronic effects of exposure. For all these reasons, new solutions are necessary for producing more food and fibre, protecting the resource base upon which agriculture depends and promoting social well-being (Millennium Ecosystem Assessment, 2005b).

2. Agriculture intensification and Agri-environmental schemes

In Europe, the Common Agricultural Policy (CAP), born 50 years ago, began by subsidizing production of basic foodstuffs in the interests of self-sufficiency, after the difficult period of the war. Currently, CAP, give farmers an important role in improving quality, preserving biodiversity and traditional landscapes and keeping rural economies alive. Furthermore, more informed consumers are entitled to food that is safe and of high quality; this induced the creation of regulations defining organic foods and also what can be considered an organic farm. More extensive systems, such as organic farming, aim to mitigate the negative effects of modern agriculture and enhance biodiversity (Krebs et al., 1999; Reganold et al., 2001; Tybirk et al., 2004). Agri-environmental schemes (AES) were introduced into the European Common Agricultural Policy (CAP) in the early 1990s to reduce biodiversity loss in agricultural landscapes and mitigate other harmful effects of modern agriculture. AES are considered the most important policy instruments for protecting biodiversity in agricultural landscapes (European Environment Agency report, 2004) as they provide financial incentives to farmers for adopting environmentally friendly practices mostly at the field scale (i.e., reduction in pesticide and fertiliser applications or delaying harvesting).

With the increasing number of organic farms, several studies and meta-analyses have been conducted, with the sole purpose of finding a correspondence between the decline in biodiversity and the AI in conventional versus organic farms. Nevertheless, sometimes these studies are inconclusive, contradictory and sometimes positive results are found. Recent European-wide studies have questioned the effectiveness of AES for biodiversity conservation. Over half the studies showed significant positive effects of AES on the diversity or abundance of target groups such as plants, birds or arthropods, but the remaining studies showed non-significant or even negative effects (Kleijn et al., 2006; Kleijn & Sutherland, 2003). Usually the positive effects of organic farming relative to conventional agriculture are in terms of botanic diversity (Bengtsson et al., 2005; Hald, 1999; Hyvönen et al., 2003) whereas arthropods appear to respond ambiguously to organic cropping (reviewed in Hole et al., 2005). There are also other studies on other measures of agriculture intensification, for example, grazing intensification, extensive vs. intensive farming, etc.

One, however, should not expect immediate results from the introduction of AES. For example, Ameixa & Kindlman (2008) did not find any relation between agricultural practices and the diversity and abundance of carabids in several agricultural fields, which was probably because the species that live in agricultural fields have already undergone some kind of selection and are for this reason adapted to the constant changes. For example, in many parts of Europe, agricultural landscapes are well over 2000 years old (Groppali, 1993; Williamson, 1986), so organisms must be adapted to this environment. Thus, studies that compare organic vs. conventional fields should not aim to see an immediate change in biodiversity patterns in agricultural landscapes after years of intense land use, but find other methods to access this problem.

Another expectation is that even if AES are applied and therefore agriculture becomes less intensive, diversity will increase only until a certain maximum in agricultural fields above which no more species will be found (Figure 1). This is because the number of species that can live in a particular habitat is always finite, defined by local climatic and soil conditions and this maximum number is not affected by the way people are handling this habitat: lion will never be found in arctic tundra. On the other hand, even heavily exploited habitats will still harbour some species: the carabid, *Pterostichus melanarius*, is a good example of a species well adapted to intensively managed agroecosystems and was found to be even more numerous in these, compared with more natural habitats (Ameixa & Kindlmann, 2008).

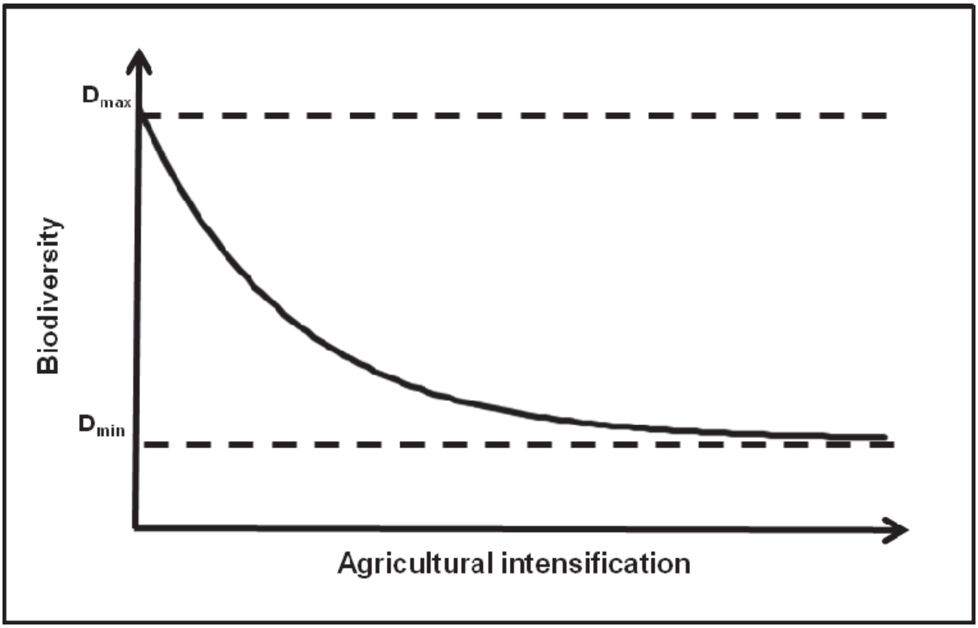

Fig. 1. Hypothetical representation of the diversity expected to be found in agricultural fields. D_{max}: Maximum diversity that can be found in agricultural lands; D_{min}: minimum diversity that can be found in agricultural lands.

3. Landscape composition

Krebs et al. (1999) suggest that biodiversity in agroecosystems depends on both farm management and landscape heterogeneity. Landscape context can modify the influence of organic farming on plants (Roschewitz et al., 2005a) or may be even more important for the diversity of bees, butterflies, carabids and spiders than the local farming system (Kremen et al., 2002; Schmidt et al., 2005; Weibull et al., 2000; Weibull et al., 2003). The contrasting results between organic and conventional fields maybe larger when these fields are isolated in homogeneous landscapes and the species pool may be too small to allow a response in terms of biodiversity to organic farming (Tscharntke et al., 2005).

The landscape context of an agricultural field may make a difference in compensating field isolation or agricultural practices that reduce diversity. Field boundaries, hedges and fallows satisfy a set of wildlife requirements (refuge, food, breeding sites, etc.) that promote species persistence in agricultural landscapes (Benton et al., 2003) facilitating both recolonization and maintenance of populations in agricultural landscapes (Duelli & Obrist, 2003). Duelli & Obrist (2003) attribute the lack of effectiveness of AES to the simplification of agricultural landscapes.

However, again we have to take in to account that diversity is expected to increase with complexity of the landscape only above a minimum threshold (Figure 2), as landscape will always harbour some species. Positive effects of landscape complexity will eventually level-off after a given level of complexity is reached, as the number of species that can live in a particular habitat is always finite, defined by local climatic and soil conditions (Concepción et al., 2008).

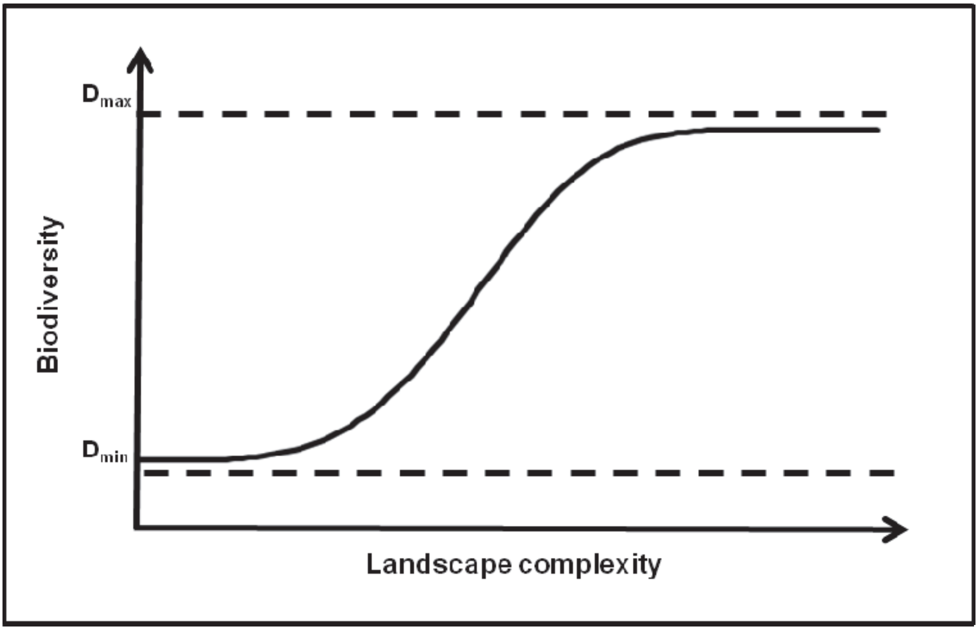

Fig. 2. Hypothetical non-linear effects of landscape complexity around cultivated fields on the biological diversity in such fields. D_{max}: saturation point of complexity, above which landscapes are so complex that no further effects of complexity are expected; D_{min}: minimum threshold of complexity below which landscapes are too simple for maintaining biodiversity (adapted from Conception 2008).

4. Meta-analysis on different taxa

The above indicates there is enough evidence that agriculture has become much more intensive during recent decades and simultaneously there has been a drastic decline in biodiversity in agroecosystems. This means that biodiversity in agroecosystems is negatively correlated with AI. However, correlation does not necessarily mean causation, and therefore – in theory – the decline in biodiversity in agroecosystems might have been caused by other factors and from a practical point of view, the effects of these should be minimized. This doubt provoked abundant case studies on how exactly AI can affect biodiversity of particular groups of organisms. The results of such studies, however, are contradictory and many are inconclusive. Because there is now a great number of these studies the results need to be summarized and patterns revealed. Although there are several such reviews, none of them analyze the situation in its entirety, which is the task of this section.

We searched the Web of Science using the following key-words: agriculture intensification; organic agriculture; agro-environmental schemes; effects of agriculture; landscape composition; land use; biodiversity. The search was restricted to studies on invertebrates, birds, plants and mammals. We then categorized them according to their conclusion regarding the relationship between AI or Landscape composition and biodiversity as having a positive, negative, none or mixed effect. We used 54 studies for determining the relationships between AI and biodiversity and 36 for those between landscape composition and biodiversity. If a study considered more than one taxon, more than one parameter (e.g. diversity and abundance) or more than one measure of comparison (e.g., AI and landscape composition) we treated them as independent studies. During this procedure, all reviews and studies containing only models or did not provide a clear statement allowing us to categorize them into one the four categories, were excluded.

When categorizing, we have always respected the conclusions formulated by the authors, even if we did not always agree with them, because introducing our personal views could have affected the outcome of our analyses. We accepted all measures of diversity used in the papers studied, which includes the number of species, diversity indexes, and even number of individuals in the group studied, even though we do not consider the latter as valid, because the number of individuals can be affected by one or a few dominant species, adapted to the particular conditions.

There was a wide variety of measures of AI in the papers. These include usage/absence of pesticides and/or artificial fertilizers, amounts of pesticides/fertilizers used, intensity of tillage, comparison of organic vs. conventional farms, grazing intensity or comparison of extensive vs. intensive cropping. Measures of landscape composition, include, more or less heterogeneity, land use, average size of fields, percentage and size of arable land and/or non-crop habitats in the landscape. In table 1 are the reference to the studies used in the meta-analysis of the relationship between AI and Biodiversity.

Relationship between AI and biodiversity	**Birds**	**Invertebrates**	**Mammals**	**Plants**
Ameixa & Kindlmann, 2008		x		
Batáry et al., 2007		x		
Bates & Harris, 2009			x	
Benton et al., 2002	x			
Blackburn & Wallace, 2001		x		
Bradbury et al., 2004	x			
Brittain et al., 2010		x		
Burel et al., 1998	x	x	x	x
Clough et al., 2007a		x		x
Clough et al., 2007b		x		
Cole et al., 2005		x		
Davey et al., 2010	x			
Davy et al., 2007			x	

Delgado & Moreira, 2010	x			
Di Giulio et al., 2001		x		
Dıaz & Telleria, 1994	x			
Doxa et al., 2010	x			
Duelli et al., 1999		x		
Feehan et al., 2005		x		x
Geiger et al., 2010	x	x		x
Genghini et al., 2006	x			
Gibson et al., 2007				x
Hald, 1999				x
Hasken & Poehling, 1995		x		
Hendrickx et al., 2007		x		
Hodgson et al., 2010		x		
Holzschuh et al., 2007		x		
Hutton & Giller, 2003		x		
Hyvönen et al., 2003				x
Kleijn & van Zuijlen, 2004	x			
Kleijn et al., 2001	x	x		x
Kleijn et al., 2004	x	x		x
Kleijn et al., 2006	x	x		x
Knop et al., 2006		x		x
Kremen et al., 2002		x		
Melnychuk et al., 2003		x		
Östman, 2002		x		
Ottvall & Smith, 2006	x			
Peach et al., 2001	x			
Pfiffner & Luka, 2003		x		
Pocock & Jennings, 2008		x	x	
Roschewitz et al., 2005a		x		
Roschewitz et al., 2005b		x		
Rundlof & Smith, 2006		x		
Rundlöf et al., 2008		x		
Schmidt et al., 2005		x		
Schmitzberger et al., 2005				x
Shah et al., 2003		x		
Thorbek & Bilde, 2004		x		
Weibull et al., 2000		x		
Weibull et al., 2003		x		x
Wickramasinghe et al., 2003			x	
Wickramasinghe et al., 2004			x	
Wilson et al., 2007	x			

Table 1. References to studies used in the meta-analysis of the relationships between AI and biodiversity for the four groups of organisms studied.

Figure 3 shows the frequencies of papers listed in Table 1, claiming different effects (positive, negative, no effect or mixed) of AI on biodiversity. There is no clear pattern in the results.

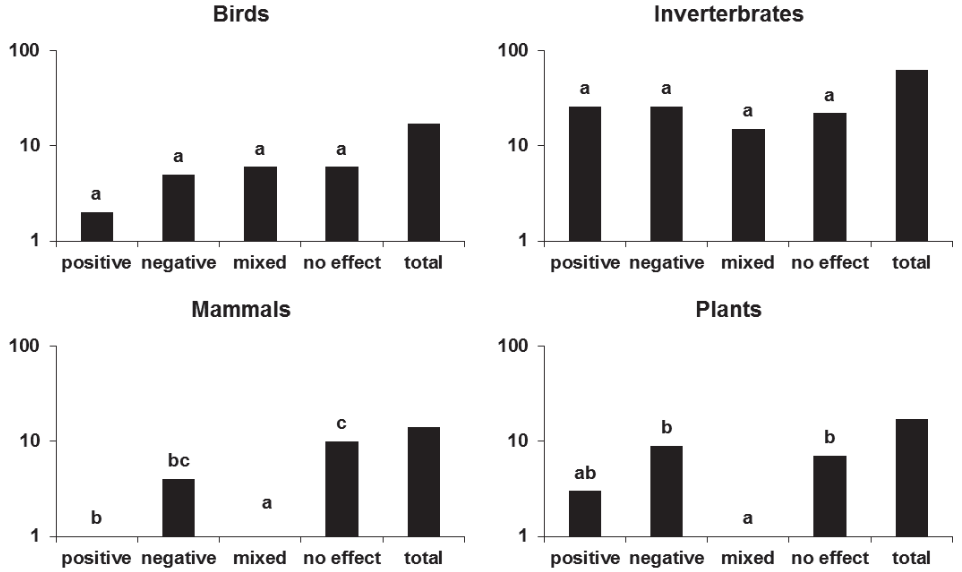

Fig. 3. Frequencies of papers claiming various types of effect of AI on biodiversity for the four taxa studied. G-test, significance 5%

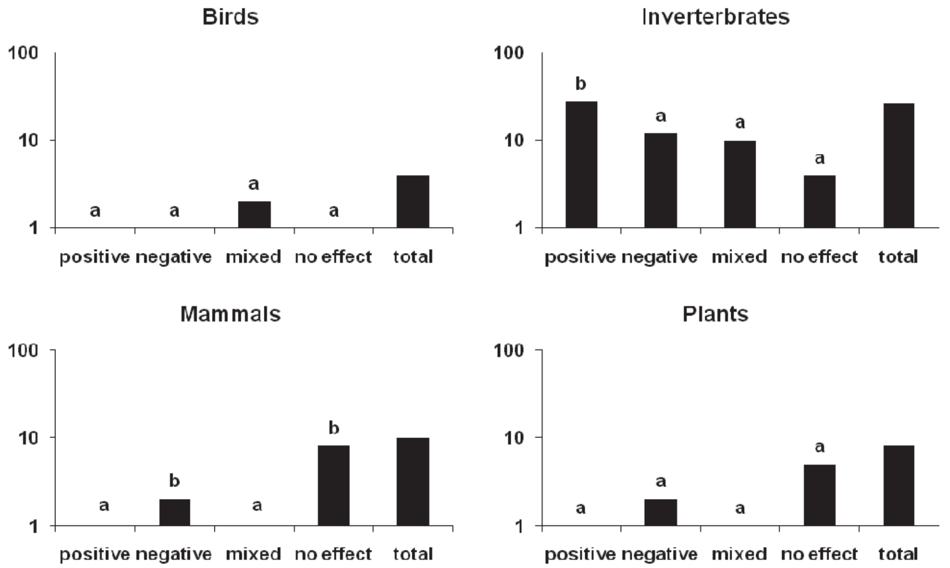

Fig. 4. Frequencies of papers claiming various types of effect of landscape structure on biodiversity for the four taxa studied. G-test, significance 5%

Figure 4 shows the frequencies of papers listed in Table 2, claiming different effects (positive, negative, no effect or mixed) of landscape structure on biodiversity. Similarly, there is no clear pattern in the results, except for the significantly larger number of papers claiming a positive effect of landscape structure on biodiversity of invertebrates, compared with the other groups of organisms studied.

Landscape structure and biodiversity	**Birds**	**Invertebrates**	**Mammals**	**Plants**
Asteraki et al., 1995		x		
Aviron et al., 2005		x		
Banks & Stark, 2004		x		
Batáry et al., 2007		x		
Bates & Harris, 2009			x	
Bradbury et al., 2004	x			
Brittain et al., 2010		x		
Burel et al., 1998	x	x	x	x
Burel et al., 2004		x	x	
Clough et al., 2007b		x		
Cole et al., 2005		x		
Dıaz & Telleria, 1994	x			
Doxa et al., 2010	x			
Duelli & Obrist, 2003		x		
Genghini et al., 2006	x			
Gibson et al., 2007				x
Hendrickx et al., 2007		x		
Holzschuh et al., 2007		x		
Kitahara & Sei, 2001		x		
Kleijn et al., 2004	x	x		x
Kremen et al., 2002		x		
Kremen et al., 2004		x		
Öckinger & Smith, 2007		x		
Peach et al., 2001	x			
Petit & Burel, 1998		x		
Pocock & Jennings, 2008		x	x	
Roschewitz et al., 2005b		x		
Rundlöf et al., 2008		x		
Schmidt et al., 2005		x		
Schmitzberger et al., 2005				x
Thies & Tscharntke, 1999		x		
Thorbek & Bilde, 2004		x		
Vollhardt et al., 2008		x		
Weibull et al., 2000		x		
Weibull et al., 2003		x		x
Wickramasinghe et al., 2003			x	

Table 2. References to studies used in the meta-analysis dealing with the relationship between landscape structure and biodiversity of the four groups of organisms studied.

5. Final remarks

The studies on the relationship between biodiversity and AI conducted so far do not always indicate a negative relationship between AI and biodiversity. Despite this, the number of studies showing this relationship is worrying. In addition, toxicological studies should be undertaken as they are unlikely to support the idea that AI should be promoted.

There is an inevitable conflict between the increasing need for higher agricultural production and the need to preserve biodiversity. Even though agroecosystems are increasingly subjected to human disturbance, they are still able to sustain some diversity and undoubtedly important for some aspects of life of certain species, like, farmland birds or predators of pests. For example, *Otis tarda* usually lives in areas traditionally cultivated using a cereal - fallow rotation.

Without any doubt, current production models seem to fail in the maintenance of biodiversity, and the more sustainable traditional systems are not so appealing, because they are less productive. However, these comparisons are mostly based only on yield and ignore the cost of agrochemicals or fuel. Producers should change their ways of thinking and realize the importance of their role in preserving diversity for future generations as a source of revenue. This change is especially important in developing countries, which are starting their "green revolution" and should learn from the mistakes of others.

Small steps are being undertaken to change intensive production models into more sustainable ones. One should not expect an immediate response of biodiversity to environmentally-friendly changes in agricultural practices, which by intensive land use over many years have systematically selected plant and animal species, even if the environmentally-friendly changes might lead eventually to an increase in biodiversity. Landscape composition also plays an important role. For example, the existence of sources of plants and animals close to agricultural fields like, boundaries, hedges and fallows, (heterogeneous landscape) are extremely important refuges, food sources and/or overwintering places. Heterogeneous landscape can also help some species to cope with the disturbances common in agricultural fields.

The enormous variation among taxa suggests that some species are more sensitive to disturbance than others. It is not surprising that insects that are *R* – selected species, with a short maturation time, breeding at a young age, short lifespan, producing many small offspring quickly, high mortality rates of young and no parental care, can more easily adapt to agroecosystem disturbances than birds and bats that are considered to be *K* – selected species, with a long maturation time, breeding relatively late in life, a long lifespan, producing relatively few large offspring, low mortality rates of young and extensive parental care. Large species tend to have long life-cycles and consequently require a degree of stability of resources over time (Blake et al., 1994).

Agroecosystems will always be linked with human activities, and in this way the future of biodiversity in these systems will always be dependent on human actions. Mankind should realize, however, that not only biodiversity suffers from the consequences of agriculture intensification but so does public health.

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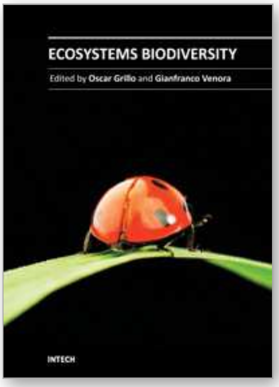

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Ecosystems can be considered as dynamic and interactive clusters made up of plants, animals and micro-organism communities. Inevitably, mankind is an integral part of each ecosystem and as such enjoys all its provided benefits. Driven by the increasing necessity to preserve the ecosystem productivity, several ecological studies have been conducted in the last few years, highlighting the current state in which our planet is, and focusing on future perspectives. This book contains comprehensive overviews and original studies focused on hazard analysis and evaluation of ecological variables affecting species diversity, richness and distribution, in order to identify the best management strategies to face and solve the conservation problems.

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