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Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union

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Abstract

The objective of this study is to assess land-use intensity and the related biodiversity in agricultural landscapes of the EU25 for the current situation (2000), and explore future trends, based on the four EURURALIS scenarios up to 2030.

Data from the Farm Accountancy Data Network (FADN) were used to classify farm types in 100 regions of the EU15, according to agricultural intensity. For the ten New Member States (EU10), which are not yet considered by the FADN, country level data were used to obtain similar farm types. Three processes were considered for the assessment of future trends in agricultural land-use intensity: (1) land-use change, (2) conversion into organic farming, and (3) changes in productivity of crop and grassland production.

An ecosystem quality value was attributed to each farm type according to dose-effect relationships between pressure factors and biodiversity compared to the value for an undisturbed situation. The biodiversity in agricultural landscapes was then calculated as the average ecosystem quality multiplied by the relative area size of each farm type within a region. A similar method of attributing ecosystem quality values to other land-use types allowed comparison between different land-use types.

Referring to the current situation, results indicate the lowest ecosystem quality values to be found in intensively used agricultural areas in lowlands (e.g. The Netherlands and northern France) and irrigation systems (e.g. Greece), whereas relatively high values are found in Spain and the New EU Member States. Scenario results show that for the A1 scenario (Global economy), the highest loss in ecosystem quality will take place in all regions in croplands and grasslands. The B2 scenario (Regional communities) provides the best opportunities to improve ecosystem quality of agricultural landscapes. In most scenarios, agricultural land is decreasing, while the remaining agricultural areas tend to be used more intensively. The negative impact of intensification on biodiversity is partly set off by (active or spontaneous) nature development on abandoned agricultural areas, but the overall trend seems to be generally negative.

The strength of this methodology is that it provides a quick overview of land-use intensity change and biodiversity trends. Through the use of this farm-type level of analysis we have provided a good picture of the differences in land-use intensity and the related biodiversity between the EU regions and the scenarios.

Keywords: Biodiversity; Agricultural landscapes; Land-use intensity; European Union

1. Introduction

Land-use change is an important form of global pressure affecting biodiversity (e.g. Sala et al., 2000; UNEP, 2002; UNEP-RIVM, 2003; Zebisch et al., 2004). The most important type of land use in Europe is agriculture, with 34% of the European terrestrial area used for crop production and 14% for grassland (Verburg et al., 2006). Higher-scale studies on the effects of land-use change on biodiversity have focused mainly on ‘major land-use types’ with little attention paid to the intensity of land use (e.g. Sala et al., 2000). Agricultural landscapes are considered to be homogenous matrices. In practice, there is a large

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heterogeneity in farming systems and management practices. Low-intensity farming systems are critical to nature conservation and protection of the rural environment (Bignal and McCracken, 1996), while large-scale input-intensive systems can cause major environmental problems in agricultural and surrounding non-agricultural ecosystems (Donald et al., 2001; Benton et al., 2002).

The biodiversity in agricultural landscapes depends largely on the intensity of land use, so an assessment of changes in agricultural biodiversity at the European scale needs spatially explicit information on land-use intensity. We can distinguish between input intensity, which is measured by input variables, e.g., chemical fertilizer, pesticides, and output intensity, measured as production per unit land area and time (Turner and Doolittle, 1978). Farming systems differ regionally in intensity and have, in the past, shown large changes. Post-war agricultural policies in the EU focused mainly on increasing agricultural productivity by promoting technical innovations and by ensuring the rational development of agricultural production (as laid down in article 33 of the EC Treaty). These policies can be considered successful in as far as they have resulted in increased yields and enhanced capacity for self-sufficiency. However, increased agricultural intensity has also resulted in an increasing pressure on biodiversity, and this is likely to continue (Tilman et al., 2001). Petit et al. (2001) indicated that agricultural intensification would be the most important form of pressure on biodiversity in the coming decades.

In response to biodiversity loss, environmental objectives and landscape preservation in recent years have become prominent issues in the EU Common Agricultural Policy (CAP) and related environmental policies. The EU has committed itself to halt biodiversity loss by 2010 (EU, 2002).

This study reported on here is incorporated into the EURURALIS project (Klijn et al., 2005), a scenario study aiming to stimulate discussion on the future of Europe's rural areas (Westhoek et al., 2006). In this paper we aim to: (1) assess the land-use intensity and relating biodiversity in agricultural landscapes in the EU25, for the current situation (2000) and to (2) analyze the impact of (agricultural) land-use change on biodiversity for the four EURURALIS scenarios for 2010, 2020 and 2030.

The database of the EU Farm Accountancy Data Network (FADN) and other farming statistics were used to classify farm types according to land-use intensity. Attribution of ecosystem quality values to farm types was based on a literature review carried out for the GLOBIO3 modelling development.[2] Ecosystem quality values for other land-use types, using the same methodology, were attributed, so that biodiversity tradeoffs between agricultural intensification and expansion of extensively managed agricultural land can be analyzed. The EURURALIS scenario storylines and outcomes of the GTAP (Global Trade Analysis Project) model (Hertel, 1997; Van Meijl et al., this issue), IMAGE (Integrated Model to Assess the Global Environment) (IMAGE Team, 2001; Eickhout et al., 2006) and CLUE (Conversion of Land Use and its Effects) (Veldkamp and Fresco, 1996; Verburg et al., 2006) models used in EURURALIS were used to model future changes in land-use intensity and biodiversity.

Section 2 elaborates on the methodological building blocks, in other words, the data sources and the modelling framework, while Section 3 describes how these were used to produce the results on ecosystem quality presented in Section 4. Section 5 discusses results and supporting methods, with Section 6 presenting our concluding remarks.

2. Data sources and modelling framework

2.1. FADN database and other sources of farm statistics

The Farm Accountancy Data Network (FADN-CCE-DG Agri and LEI) contains data on the level of the individual farm enabling farms to be grouped on the basis of a range of variables. A broad set of data is available to link the sample farms with a land-use intensity gradient to differentiate between farm types. Data have been collected since 1989. The database for the year 2000 includes data on more than 50,000 sample farms across the EU15. The Dutch Agricultural Economics Research Institute (LEI) has created a division in 100 (sub)national regions, the so-called HARM regions, in order to allow comparisons of different regional divisions of the EU15 used by Eurostat (NUTS2) and FADN. The distribution of certain farm types within a HARM region can be assessed by multiplying all sample farms within a region by their Utilized Agricultural Area (UAA) and the number of farms they represent.

FADN considers the following land-bound production types: specialist field crops, specialist permanent crops, specialist grazing livestock, mixed cropping and mixed crops/livestock. The activity that is the largest in terms of economic size, determines the production type. For example, a farm that obtains more than 66% of its total standard gross margin from the sale of field crop products belongs to the 'specialist field crops' production type, irrespective of the surface area dedicated to it.

FADN provides data on a number of variables that are related to the land-use intensity in terms of input intensity: irrigated area, type of grassland, number of livestock units per hectare, conventional or organic farming, expenditures on inputs (fertilizer and soil improvers, crop protection products, feeding stuffs for grazing livestock) and expenditures on major land improvements. FADN also provides data on output intensity, e.g., crop yields (in tonnes/ha) and crop and livestock output (in €).

[2] http://www.globio.info.

Because of the lack of farm accounting data at the sub-national level in the New Member States of the EU (EU10), statistics at country level were taken to distinguish farm types in the New Member States. The farming systems of the Food and Agriculture Organization of the United Nations (FAO) as described by Dixon et al. (2001) provide a useful framework to link the socio-economic conditions of farms with the agro-ecological condition of the environment (Tekelenburg et al., 2003). Complementary, statistics on agricultural land use at country level from FAO (FAO, 2002), European Environment Agency (EEA) (Petersen and Hoogeveen, 2004), Eurostat and International Federation of Organic Agriculture Movements (IFOAM) (Yussefi and Willer, 2003) were used. Data on Cyprus were not available.

2.2. Attributing ecosystem quality values to farm types

2.2.1. Introduction

In order to measure biodiversity loss we adopted the indicator "*trends in abundance and distribution of selected species*" appearing on the list endorsed by the Malahide EU-Stakeholder Conference.[3] Biodiversity is expressed as the mean abundance of species originally present in natural ecosystems relative to their abundance in undisturbed situations, which we call the ecosystem quality. The maximum value is 100% and indicates an undisturbed natural situation, while 0% represents a completely transformed/destroyed ecosystem without any wild species left. This indicator is close to the natural capital index (NCI) concept (Ten Brink, 2000).

Alkemade et al. (in preparation)[4] assessed the impact of different land uses on the relative species abundance, the ecosystem quality, for the GLOBIO3 modelling development. Agro-ecosystem quality is the result of combined effects of several pressures on the landscape scale of analysis. We focus on the impact of land-use intensity, which includes the combined effects of ploughing frequency, fertilizer and pesticide applications, and specialization of production, monoculture, and crop or grass productivity. Tilman et al. (2001), Zechmaister and Moser (2001), Gaston (2000) and Wilson et al. (2003) showed a strong correlation between land-use intensity and biodiversity loss.

A literature review was carried out on the following to determine the dose-effect relationship of the intensity of agricultural land use on biodiversity:

- land-use–biodiversity loss gradients (comparison between land-use systems and the pristine, or low human impact, situation);
- pair-wise comparison of biodiversity impact between different farm types (separate for cropping and grassland systems);
- pair-wise comparison of impact on biodiversity for conversion from conventional farming into organic farming.

Here, we adapt these results for the European situation. As in Europe the primary vegetation is largely unknown we assumed that most of land-use change processes now occurring in the tropics, are not fundamentally different from what occurred in Europe (Lambin et al., 2001). A table was drawn up on the basis of the literature review, and complemented by the authors on the basis of their knowledge and experience, to indicate the ecosystem quality for farm types on the basis of land use and production intensity in the European context (Table 1).

2.2.2. Conventional farming on cropland

Comparison of several land-use–biodiversity loss gradients showed that ecosystem quality decreases as agricultural practices intensify. Alkemade et al. (in preparation) (see footnote 1) classified the many production systems described into three broad classes: agroforestry systems (Wood et al., 1982; Fujisaka et al., 1998; Jones et al., 2003) with an average ecosystem quality of 50%, extensive agriculture (Beck et al., 2002; Vallan, 2002; Davies et al., 2003; Wilson et al., 2003) with an ecosystem quality of 25% and intensive agriculture (Wood et al., 1982; Fabricius et al., 2003; Jones et al., 2003) with an ecosystem quality of 10%. The differences between ecosystem quality values could be confirmed by other authors, who had not compared remaining species richness or abundance compared to the pristine situation. Perfecto et al. (1997) and Erwin and Scott (1980) showed that high levels of fertilizers and pesticide applications depress ecosystem quality to a large extent. Siebert (2002) found that in intensive non-shaded cacao production less than 5% of the original plant species are observed. We could conclude a remaining ecosystem quality in intensive agriculture of 10%. Extrapolation of this relationship for highly intensive production systems on the basis of additional long-term water and soil investments such as irrigation, drainage and soil levelling practices would result in half the ecosystem quality (5%). The specialization of agricultural production at landscape level (a historical process going back to the 1950s in Europe by which arable farms are concentrated in one region and livestock production in another) also depresses ecosystem quality to the same extent. Robinson and Sutherland (2002) calculated an average decrease of 26% for birds, Bradbury et al. (2000) recorded a Yellow Hammer decline of 10% per year and Aebisher (1991) recorded a 4.1% decline annually, halving the abundance in 20 years.

2.2.3. Conventional farming on grassland

Intensification of extensively used grasslands and abandonment without replacement of natural grazers may both lead to decreased species richness and/or a decreased average abundance of species (Tasser and Tappeiner, 2002).

[3] http://www.eu2004.ie/templates/document_file.asp?id=17810.
[4] Contact the corresponding author for more details.

Table 1
Summary of ecosystem quality per farm type

Ecosystem quality[a] (%)	Farm types	Production systems
100	No production	Primary vegetation
40	Extensive grassland management	Medium to high cattle density on natural grassland
35	Extensive organic farming	Low-External-Input and Sustainable Agriculture (LEISA), permaculture
25	Extensive farming	Traditional farming; extensive farming; Low-External-Input Agriculture (LEIA)
20	Intensive organic farming	Rainfed organic farming
20	Intensive grassland management	Grassland production based on ploughing, reseeding and fertilization
15	Highly intensive organic farming	Organic farming in developed countries (where conventional agriculture is based on long-term soil and water investments)
10	Intensive production systems	Intensive agriculture; integrated agriculture; High-External-Input Agriculture (HEIA); conventional agriculture
5	Highly intensive production systems	Irrigation based agriculture; integrated agriculture; drainage based agriculture; additional soil levelling practices; regional specialization; specialization of production at the farm and landscape level

[a] Expressed as percentage of the original pristine situation (see text for further explanation).

No consistent optimal grassland productivity for maximum biodiversity could be found in grassland ecosystems, but maximum species richness was always found at light grazing regimes. In the Mediterranean, maximum biodiversity on grassland is reached at 25% productivity. For pristine natural grassland ecosystems, where grazing by wild herbivores is part of the natural situation, as well as long-term highly valued semi-natural grasslands, where domesticated animal grazing takes place, the expected ecosystem quality ranges from 80–100% under light grazing for 0.2–0.4 livestock units per hectare (LU/ha) and 40–50% under heavy grazing for more than 0.7 LU/ha (Stuarthill, 1992; Gibson et al., 1993; Roques et al., 2001; Cagnolo et al., 2002; Alados et al., 2003). Abandoned grassland suffers a loss in ecosystem quality of some 25% with reference to optimal grazing density, i.e. 75% ecosystem quality would remain (Smith and Rushton, 1994; Tucker and Heath., 1994; Poschlod et al., 1997; Sternberg et al., 2000; Cagnolo et al., 2002).

Management intensity (fertilization and reseeding) has been found to be a good predictor ($R^2 = 0.73$) of grassland vegetation type in mainland Scotland (Wilson et al., 2003). Each grassland vegetation type consists of a typical composition of plant and animal species as well as a typical grazing and/or grassland management regime. Management intensity is negatively correlated with vegetation types of high species richness. In the case of fertilization of permanent grassland, the ecosystem quality decreases to 20% on average; in other words, it drops to half the expected ecosystem quality of extensively managed grassland with heavy grazing regimes (Bullock et al., 2001; Di Giulio et al., 2001; Ujazdowski, 2002; Wilson et al., 2003). The ecosystem quality of intensively managed grassland corresponds then to the situation between extensive (25%) and intensive (10%) cropland management.

2.2.4. Organic farming

Pair-wise comparison between conventional and organic farming showed on average a 2.7 times increase in the species abundance of five species groups: 2.1 times for birds (e.g. Brae et al., 1988; Tew et al., 1992; Bradbury et al., 2000); 2.9 times for plants (e.g. Hald and Reddersen, 1990; Tew et al., 1992; Frieben and Köpke, 1995); 3.2 times for insects (e.g. Dritschilo and Wanner, 1980; Hokkanen and Holopainen, 1986; Hald and Reddersen, 1990; Kromp, 1990; Feber et al., 1997); 2.4 times for mammals (e.g. Tew et al., 1992); and 1.8 times for earthworms (e.g. Blakemore, 2000). Bengtsson et al. (2005) estimated an increase in mean species abundance by 50%, based on an in depth meta-analysis. Very intensive conventional farming was taken as the benchmark in all studies. The conversion of more extensive land-use types into organic farming will result logically in a decreasing gain (Frieben, 1997; Soil Association, 2000; Stolton, 2002). We translated this into an average absolute gain of 10% for conversion of any type of conventional cropland or grassland farming into organic farming. This implies a tripling for very intensive systems (i.e. from 5% to 15%), a doubling for intensive agriculture (from 10% to 20%) and a 1.4 times gain for extensive agriculture into Low-External-Input and Sustainable Agriculture (from 25% to 35%).

2.3. EURURALIS scenario storylines and core models

2.3.1. Scenario storylines

Scenarios are alternative images of how the future might unfold; these function as appropriate tools for analyzing how driving forces can influence biodiversity and other ecosystem services (Alcamo, 2001). The EURURALIS scenarios (Westhoek et al., 2006) used in this study, as inspired by the IPCC-SRES scenario families (Nakícenovíc et al., 2000) and subsequent studies, is structured along two dimensions: lean government (A) versus ambitious government regulation (B); globalization (1) versus regionalization (2). This results in four scenarios: Global economy (A1), Continental markets (A2), Global co-operation (B1) and Regional communities (B2).

Environmental legislation and socio-economic pressures to intensify or extensify agricultural production differ among the scenarios (Westhoek et al., 2006). Technological developments (e.g. to enhance yields) are assumed to increase in the order B2 ≈ A2 < B1 < A1, whereas environmental legislation tends to become more restrictive, in the order A1 ≈ A2 < B1 < B2. Organic farming is particularly promoted in the B scenarios. Demographic pressure, which for the EU increases in the order B2 < A2 < B1 < A1, also plays a role in land-use change processes, as it co-determines the demand for residential and industrial/business areas as well as for agricultural products.

The storylines presented by Westhoek et al. (2006) do not specifically describe changes in land-use intensity and related farm types. One could argue that, for example, in the B1 scenario, agricultural land-use intensity may present convergence into more similar farm types. Technology development, decrease in land prices and restrictive environmental legislation might induce some extensification of the highly intensive classes; whereas the decrease in government support envisaged for this scenario might cause movement towards bigger and more uniform parcels to benefit from the economies of scale, which would particularly affect the more extensive land-use classes.

2.3.2. EURURALIS core models

Core models used in EURURALIS are GTAP, IMAGE and CLUE. A modified version of the global general equilibrium Global Trade Analysis Project (GTAP) model (Hertel, 1997; Van Meijl et al., 2006) was used in iteration with the integrated assessment model IMAGE (IMAGE Team, 2001; Eickhout et al., in press) to quantify changes in agricultural area at national level. GTAP models the economic consequences of the scenarios, whereas IMAGE takes account of technological and environmental developments. The land-use changes are allocated spatially by CLUE at a resolution of 1 km × 1 km (Veldkamp and Fresco, 1996; Verburg et al., 2006).

3. Methodology

Fig. 1 presents a schematic outline of the methodology used in this study to determine ecosystem quality for the current (2000) and the future situation.

3.1. Assessment of agricultural intensity in 2000

3.1.1. EU15 farm typology

The distribution of different farm types throughout the EU15 was analyzed with data from the Farm Accountancy Data Network (FADN-CCE-DG Agri and LEI) for the year 2000. Additionally, data from 1990 and 1995 were used to look at recent changes and to check the consistency of the data. As mentioned in Section 2.1, FADN production types are distinguished on the basis of economic size of production. Therefore, all individual farms were reclassified in four land-use types based on the extent of land use: cropping systems, permanent cropping systems, grassland and arable grazing livestock. In the final biodiversity assessment, cropping systems and permanent cropping systems were aggregated to cropland and grassland systems and arable grazing livestock systems to grassland. The results of this reclassification and the ecosystem quality attributed to each class are given in Table 2 (cropland) and Table 3 (grassland).

All (FADN's) specialist field crops were allocated to cropping systems because 92% of all farms have more than 66% of their land in cropland. The remaining area is mainly temporary grassland, which can differ per year. Specialist permanent crops were all allocated to permanent cropping systems. Although many specialist permanent crops also grow field crops and/or have grassland, growing permanent crops is the main activity.

Specialist livestock types often have a large area of cropland; for this reason this production type was divided into two land-use types: grassland systems (>66% grassland) and arable grazing livestock systems (<66% grassland). The mixed production types were divided into the classes with similar criteria as for the other production types. Farms with more than 66% grassland area allocated to grassland systems, 33–66% to arable grazing livestock, and less than 33% to cropping systems or permanent cropping systems, depending on the dominant land use.

Within each land-use type, farm types were distinguished on the basis of land-use intensity. For croplands, input costs on fertilizers and soil improvers and crop protection products have been used as the main indicators to distinguish between extensive and intensive systems. Furthermore,

Table 2
Classification of (annual and permanent) cropping systems

	Criterium organic	Criterium irrigation	Criterium intensity[a] (€/ha)	Class[b]	Ecosystem quality (%)
Irrigated	Non-organic	Irrigation		17 (37)	5
Highly intensive	Non-organic	No irrigation	>250	16 (36)	5
Intensive	Non-organic	No irrigation	80–250	15 (35)	10
Extensive	Non-organic	No irrigation	<80	11 (31)	25
Highly intensive organic	Organic	Irrigation OR	>250	14 (34)	15
Intensive organic	Organic	No irrigation	80–250	13 (33)	20
Extensive organic	Organic	No irrigation	<80	12 (32)	35

[a] Intensity = costs of: fertilizer and soil improvers, crop protection products and feeding stuffs for grazing livestock.
[b] Classes without parentheses are for cropping systems, with parentheses for permanent cropping systems; in Figs. 2 and 3 farm types are indicated with these class numbers.

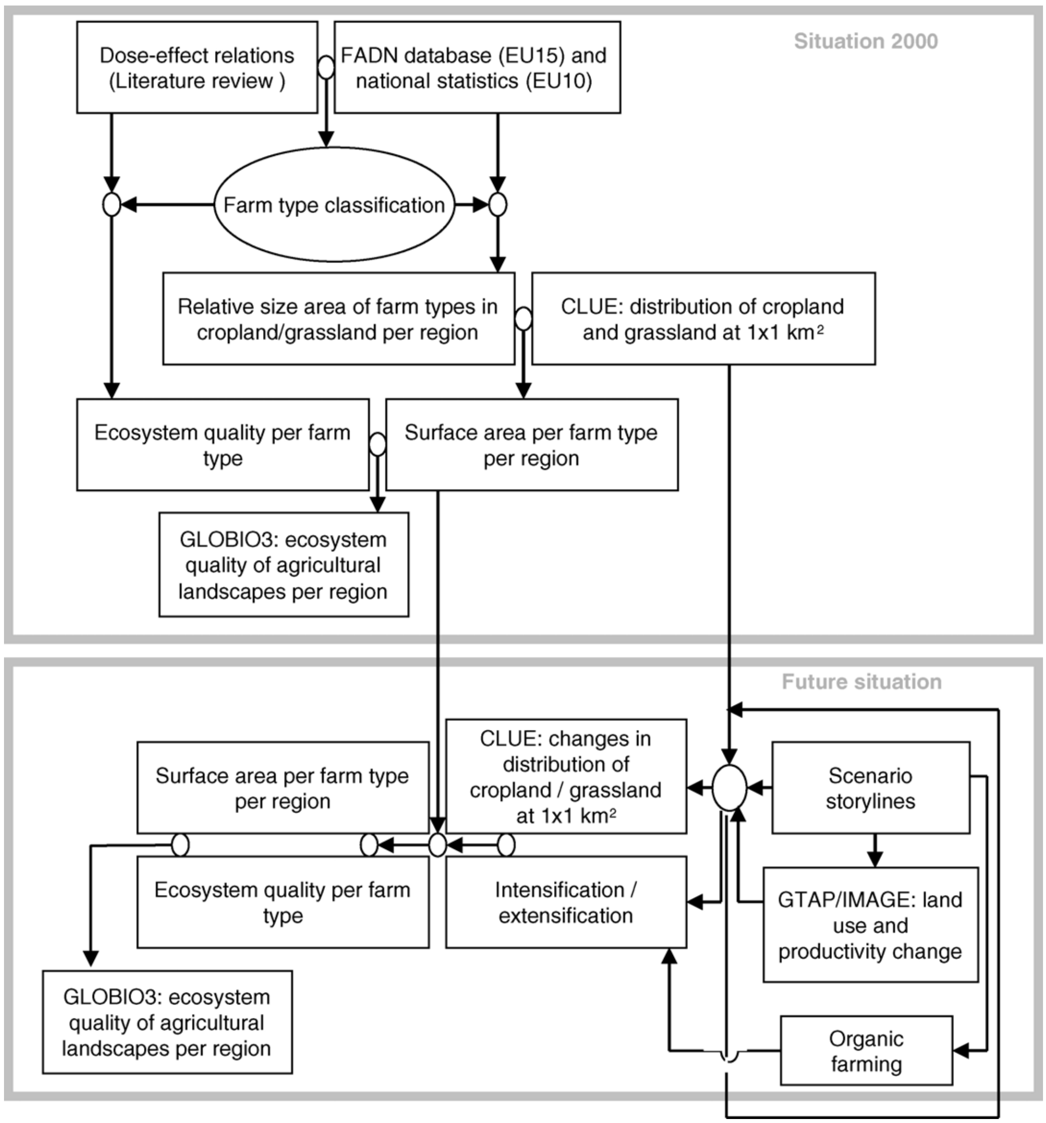

Fig. 1. Schematic outline of methodology used in this study to determine ecosystem quality. The scenario storylines were developed by Westhoek et al. (2006). GTAP, a global economy model and IMAGE, an integrated assessment model were used iteratively to quantify area changes in agricultural land use and land productivity at the country level (Van Meijl et al., 2006; Eickhout et al., in press). The CLUE model (Verburg et al., 2006) allocated (changes in) land use to a 1 km × 1 km grid level.

Table 3
Classification of livestock systems (grassland and arable grazing livestock)

	Criterium grassland	Criterium intensity	Class[a]	Ecosystem quality
Natural grassland	Rough grassland in UAA[b] > 66%	< 0.3 LU/ha[c]	41	100%
Extensive pasture	Permanent + rough grassland in UAA > 66%	< 1.0 LU/ha; input costs[d] < 80 €/ha	42	40%
Intensive pasture	Grassland in UAA > 66%	< 2.0 LU/ha; input costs < 250 €/ha	44	20%
Highly intensive pasture	Grassland in UAA > 66%	> 2.0 LU/ha OR input costs > 250 €/ha	45	20%
Extensive arable grazing livestock	Grassland in UAA < 66%	< 1.0 LU/ha; input costs < 80 €/ha	43	32.5% = (40 + 25)/2
Intensive arable grazing livestock	Grassland in UAA < 66%	Input costs 80–250 €/ha	46	15% = (20 + 10)/2
Highly intensive arable grazing livestock	Grassland in UAA < 66%	Input costs > 250 €/ha	47	15% = (20 + 10)/2

[a] In Figs. 2 and 3 farm types are indicated with these class numbers.
[b] UAA = Utilized Agricultural Area.
[c] LU/ha = livestock units/hectare.
[d] Input costs = costs of: fertilizer and soil improvers, crop protection products and feeding stuffs for grazing livestock.

indicators are formed based on whether irrigation takes place on the farm and whether farming is organic to give information on the land-use intensity. The type of grassland in combination with livestock density (expressed as livestock units per ha) is the best generally applicable indicator for grassland.

If any irrigation takes place on the farm, we assume that soil and water improvements have been made to improve the productivity of the land. Based on the notion that in cases where land improvement investments are high, annual input costs are also high, both irrigated and high input farms were allocated to the highest land-use intensity class.

Thresholds for input costs were based on statistical analysis and previous work in the ELPEN project[5] and IRENA project[6] (Andersen et al., 2004a). Various thresholds have been used in previous classifications. For extensive systems, 40, 80 and 150 €/ha have been applied as a maximum level for input costs. Choices for thresholds depend on the land-use type, the application and whether regional differences have been taken into account. Although in different regions differences in farming systems and in the environment could require different indicators and thresholds, a common typology is more appropriate for our needs because it allows for direct cross-sectional comparisons.

We decided to apply a maximum of 80 €/ha spent on inputs for extensive systems and a minimum of 250 €/ha for highly intensive systems, with intensive systems in between. Analysis of variance and post hoc multiple comparisons showed these groups to be significantly different in other indicators of production intensity, such as crop output per hectare and the yield of maize and wheat. Variation within groups is lowest when these thresholds are applied.

Organic farming systems were divided in three intensity classes. Based on the literature findings (see Section 2.2.4) conventional production systems converted into organic farms were assumed to increase ecosystem quality in their fields by an average of 10%. The relative gain for intensive systems is higher, but the resulting ecosystem quality is lower in absolute terms than for extensive organic farming. In the FADN database, data on organic farming were missing for some regions (Italy, France). Eurostat data on organic farming per land-use type were used to make up for missing data and for regions where percentages were very low, and probably less reliable (Greece, Belgium). For livestock systems, organic farming was not explicitly included in the farm type classification. Where available, FADN data were used to represent organic farming in these regions. Eurostat data was used if no other data were available. For regions where FADN lacks data whereas Eurostat shows that organic farming is present, complementing the database with Eurostat data was assumed to give the best estimates.

Thresholds for livestock systems are based on the literature review and previous projects mentioned earlier. The literature consulted offered no clues to distinguish intensive and highly intensive grassland systems in terms of ecosystem quality. Nevertheless, to improve insights in differences between regions and years, we do identify these types as different classes. The ecosystem quality on arable grazing livestock systems was taken as the average of the related intensity class of cropland and grassland.

3.1.2. EU10 (New Member States) farm typology

The available statistics for the New Member States do not differentiate between production systems so much as by the FADN database, but a general overview can be obtained by assigning area of land to the farm type classes of cropland and grassland production systems.

For cropland, the area of 'irrigated' agriculture was taken from FAO data (FAO, 2002). IFOAM country statistics (Yussefi and Willer, 2003) were used to indicate the fraction of organic farming per country. The percentages of the extensive farm types and the intensive farm types were estimated on the basis of the farm structure share of family farms (FAO, 2002) and the description of farming systems by Dixon et al. (2001). The FAO data were not available for the Baltic States and Cyprus and Malta. For these countries, we assumed that after subtraction of irrigated and organic areas, 50% of the agricultural area is occupied by extensive and 50% by intensive production systems.

EEA statistics (Petersen and Hoogeveen, 2004) provide information on the area of different types of grassland. Mountain grassland was considered as 'natural grassland' with 100% ecosystem quality. Extensive grazing in semi-natural area is 'extensive pasture' with a low livestock density. Permanent grassland (without further differentiation) is similar to 'intensive pasture' with reseeding and fertilization.

3.1.3. Calculation of ecosystem quality

The ecosystem quality EQ_{il} of agricultural landscapes, as conditioned by land use, is calculated for each HARM region (EU15) or country (EU10) i, for cropland ($l = c$) and grassland ($l = g$) separately as

$$\mathrm{EQ}_{il} = \sum_{k=1,n} \mathrm{RS}_{ki}\,\mathrm{EQ}_{ki} \tag{1}$$

where RS_{ki} is the relative area size of the farm types k with ecosystem quality EQ_{ki} in HARM region or country i.

The ecosystem quality on organic farms is assumed to be 10% higher than on conventional farms. Hence, the added value of organic farming O_{il} is calculated for each HARM region or country i as

$$O_{il} = 0.1\,\mathrm{RS}_{\mathrm{organic},il} \tag{2}$$

where $\mathrm{RS}_{\mathrm{organic},il}$ is the relative area size of organic farming of cropland or grassland in a HARM region or country i. O_{il} is added to EQ_{il}.

[5] http://www.macaulay.ac.uk/elpen.
[6] http://www.webpubs.eea.eu.int/content/irena/index.htm.

Table 4
Estimated impact of land-use changes on ecosystem quality

Land use	Scenario	Ecosystem quality of other land-use type converted into agriculture (%)	Ecosystem quality of area converted from agriculture into any other land-use type
Cropland	A1	5	Average + 5%
Cropland	A2	5	Average + 5%
Cropland	B1	10	Average
Cropland	B2	20	Average
Grassland	A1	20	Average + 10%
Grassland	A2	20	Average + 10%
Grassland	B1	30	Average
Grassland	B2	40	Average

3.2. *Modelling future changes in agricultural intensity*

3.2.1. *Scenarios*

Based on the scenario storylines, assumptions could be made on how the distribution of farm types will change. To be consistent with the land-use change models used in EURURALIS, changes in farm types are not modelled explicitly, but are based on the scenario assumptions and results of the other models. Hence the change in farm types is linked to land-use changes calculated by CLUE (Verburg et al., 2006) and the productivity changes assessed by GTAP-IMAGE (Eickhout et al., in press; Van Meijl et al., 2006) as schematically indicated in Fig. 1.

Three processes were considered for the assessment of future trends in agricultural ecosystem quality: (1) land-use change (e.g. from cropland to grassland or nature), (2) conversion into organic farming, and (3) changes in productivity of crop and grassland production.

3.2.2. *Land-use change analysis*

Firstly, an overlay was made of the CLUE_2010 map of each scenario (Verburg et al., 2006) with the CLUE_2000 map, and the difference map with all changes was calculated. Secondly, the database of the land-use types in the year 2000 was compared with the difference map. Thirdly, for each grid-cell represented in the land-use types database and the corresponding area of the CLUE_2010-2000 map, assumptions were made on where transitions take place and, as a consequence, what the impact on ecosystem quality would be (Table 4).

It is assumed that in the A scenarios, agricultural areas taken out of production are mainly the extensive production systems. The 'most extensive farm types present in the region' is translated into the 'average ecosystem quality + 5%/10%' for cropland/grassland. The economic orientation in these scenarios implies that farmers aim at high economic efficiency with less concern for the environment. Results from GTAP/IMAGE show that crop yields are increasing fast especially in the A1 scenario. Intensive farm types are generally more efficient in terms of crop yields and income than extensively managed systems. The ecosystem quality is therefore assumed to be 5% on new cropland and 20% on new grassland. In the B scenarios, there will be more environmental restrictions. New land taken into production is subject to this, so the assumption is that this land is more extensive than the average.

The result of these steps is the database for 2010, containing the fractions of surface area occupied by each land-use type and the corresponding land-use conditioned ecosystem qualities. The ecosystem quality EQ_{il} of agricultural landscapes as conditioned by land use is calculated as in Eq. (1). These steps are repeated for 2020 and 2030.

3.2.3. *Conversion into organic farming*

According to the storylines, organic farming is expected to expand, particularly in the B scenarios. In A1, there are few, if any, government incentives for organic farming. Besides, organic products become relatively more expensive due to the liberalization of agricultural markets. On the other hand, incomes are relatively high and some consumers are prepared to pay in order to satisfy their preference for organic products which many associate with 'healthy' rather than 'environment friendly' consumption. Some of these products are imported from third countries. In B1, there are moderate government incentives for organic farming. Little change is expected in the relative price of organic products as compared to conventional food because, apart from subsidies, the effects of liberalization are roughly compensated by developments of specific technologies and plant varieties in addition to the higher standards required for conventional products. Incomes are slightly lower than in A1, but even so, more consumers are prepared to pay the extra costs. Consumer preferences for organic products are even stronger in B2. Besides, due to market protection and strong government support, the price gap between organic and conventional is the smallest of all the scenarios. For A2, consumer preference for organic food is similar to A1, but consumption of organic products from EU farmers is assumed to be higher due to import barriers and the smaller price gap with respect to conventional products, even though incomes are somewhat lower than in A1. These deliberations resulted in assumptions on the increase of agricultural area used for organic farming ($RS_{organic,il}$) in relation to 2000; these are presented in Table 5.

Table 5
Conversion of conventional into organic farming in absolute percentages in relation to 2000

	2010 (%)	2020 (%)	2030 (%)
A1	5	5	5
B1	5	10	15
A2	5	8	10
B2	5	10	20

The effects on biodiversity of the changes in the area of organic farming are taken into account by recalculating O_{il} according to Eq. (2).

3.2.4. Changes in productivity of crop and grassland production

General effects of intensification or extensification per scenario in a 30-year period are estimated by the productivity increase for crops and grassland. For the baseline, only the input intensity was taken into account. Farm types were deliberately based on input intensity, as input level defines effects on the ecosystem quality in the first place. However, changes in input intensity are not explicitly modelled, while GTAP and IMAGE do provide model results on changes in productivity on the country level. These estimates were applied to the underlying HARM regions. As there is a clear relation between input intensity and productivity within regions, productivity changes can be used as a proxy for changes in agricultural intensity. The relative increase in productivity is translated into a relative change in average ecosystem quality. For the A scenarios, the applied dose-effect relationship from productivity increase to biodiversity loss is: 1% productivity increase corresponding to a relative ecosystem quality loss of 1%. This corresponds to the trend of the past 150 years. The average increase in production intensity from the pre-industrial 1850 to the current 2000 production systems of 15% per 10 years has lowered ecosystem quality from 20–25% to 5–10% in absolute terms. In the A scenarios there are few incentives to decrease the environmental pressure in agriculture or to maintain and improve biodiversity.

In the B scenarios, the awareness that environmental pressure of agriculture should be decreased is high, and maintaining or improving wild biodiversity in the agricultural landscape (multifunctionality of the land) is an important issue. The impact on biodiversity is expected to be lower in the B scenarios because productivity increase is expected with (partly) environmental-friendly technology development. The dose-effect relationship from productivity increase to biodiversity loss is therefore 1% productivity increase, corresponding to 0.5% relative ecosystem quality loss.

Intensification will cause higher biodiversity loss in absolute terms in more extensive land uses. A 10% loss of ecosystem quality from extensive agriculture of 25% results in 2.5% loss in the A scenarios, while in intensive agriculture, with 5% ecosystem quality, the loss is only 0.5%.

3.3. Agricultural ecosystem quality in context

The impact on overall biodiversity in a region (in terms of NCI) is not only a function of the average ecosystem quality in the agricultural landscapes, but also of the relative size of nature area and the average ecosystem quality of natural ecosystems. Whether a decreasing agricultural area is positive or negative for overall biodiversity depends on whether abandoned agricultural land is replaced by nature areas or urban areas. The CLUE model (Verburg et al., 2006) provides information on changes in the relative area size of cropland, grassland and nature. Verboom et al. (in press) have performed a biodiversity assessment of nature areas. The impact of change in agricultural land use on overall biodiversity in the EU25 was analyzed by comparing the Natural Capital Index (NCI) between different years and scenarios. The NCI is calculated as

$$\mathrm{NCI}_i = \sum_{l=c,g,n} \mathrm{EQ}_{il}\,\mathrm{RS}_{il} \qquad (3)$$

where EQ_{il} is the ecosystem quality of a land-use type l (cropland, grassland and nature) in a region i and RS_{il} is the relative area size.

4. Results

4.1. Distribution of farm types in the European Union

The occurrence of farm types differs per HARM region. In Fig. 2 we present the occurrence of farm types in the EU15 per country. Fig. 3 presents the farm type distribution in the New Member States (EU10), where similar farm types have been identified, but put into fewer classes.

It is clear that in the Mediterranean regions, the percentage of irrigated farming as well as extensive farming is higher than in other regions in the EU15. In Scandinavia, farming is also relatively extensive and there are high levels of organic farming. It should be noted that the livestock systems in Sweden and Finland seem to be relatively intensive, but organic farming is very common. Farming is, in general, the most intensive in North-west Europe. Farming in the New Member States is much more extensive than in most countries in the EU15.

The relative size area of different land-use types also varies. In general, there is less grassland in more southern regions. Permanent cropping systems do occupy a large part of the area here. We also see that the arable grazing livestock systems (classes 43, 46 and 47) occupy almost as much of the area in the EU15 as the grassland systems (classes 41, 42, 44, 45). In the New Member States, cropland occupies a much larger part of the area than grassland.

When farm type distributions of 1990, 1995 and 2000 are compared (results not shown) we see that the average input intensity has not changed much in this period. Intensive as

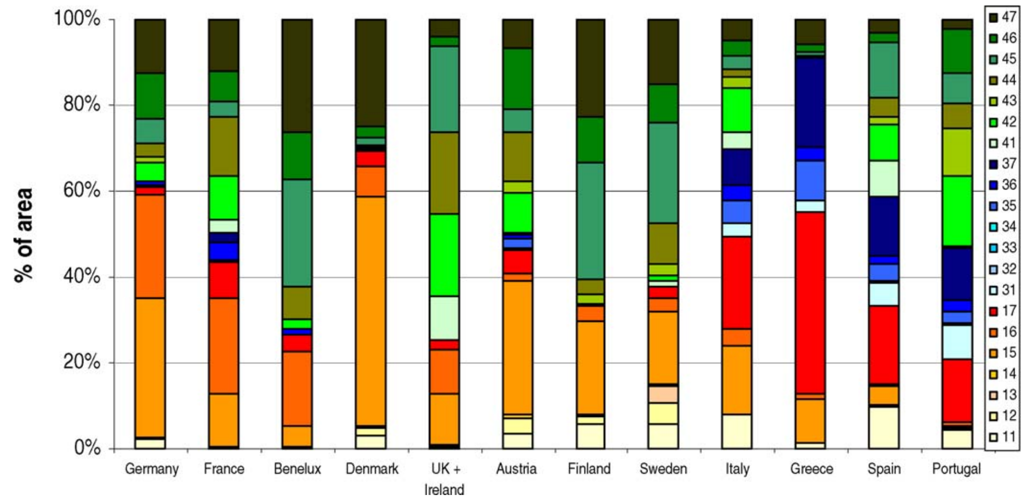

Fig. 2. The distribution of farm types in different countries in the EU15. Farm type classes are labeled in Tables 2 and 3.

well as extensive farms have decreased in area a little in favour of medium intensive farm types. Irrigated farming has increased a little. The average input intensity is relatively stable, but inputs are used more efficiently, as productivity increases in most regions. Apparently, the large intensification of agricultural production has mainly taken place before 1990 and currently there is some stabilization.

4.2. Ecosystem quality in 2000

Ecosystem quality is on average 10% of its original pristine value in cropping and permanent cropping systems in the EU25, with a range of 6–24% among regions. The ecosystem quality in grazing systems is much higher: 26% on average with a range from 15% to 82% (respectively regions with mainly intensively fertilized and/or re-seeded permanent grassland and extensive (semi) natural grazing). The lowest ecosystem qualities are found in intensively used agricultural areas in lowlands (e.g. The Netherlands and northern France) and in irrigation systems (e.g. Greece). Ecosystem qualities for cropland are relatively high in the New Member States (e.g. 22.3% and 24% for cropland in respectively Slovenia and Poland), the Iberian Peninsula, southern Italy and Scandinavia. These regions also have a high ecosystem quality for grassland. The highest values for grassland are found in Scotland, southern Spain and the Alps. This is mainly due to the high abundance of rough grassland in these areas. The influence of organic farming is low in most regions as its percentage is below 4% in these regions. In Italy, Austria, Finland and Sweden organic farming takes place on around 10% of the area. With an extra ecosystem quality of 10%, this increases the average ecosystem quality in these regions with 1%. Fig. 4 presents the ecosystem quality in cropland in 2000 at the top. Fig. 5 shows the ecosystem quality in grassland in 2000.

Ecosystem quality as well as the relative area size is indicated. In some regions (e.g. Greece), ecosystem quality in cropland is very low, but agriculture is only a minor land-

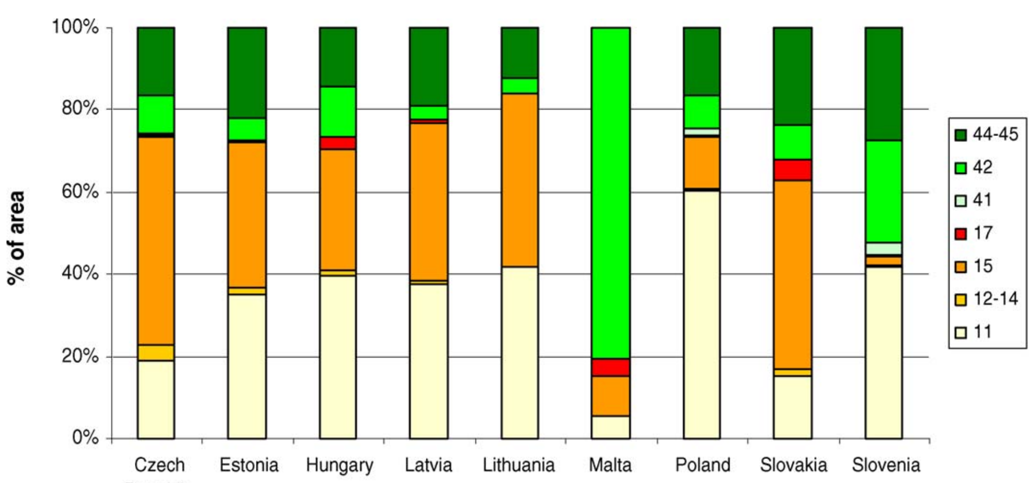

Fig. 3. The distribution of farm types in different countries in the New Member States. Farm types are not distinguished as much as in the EU15, but they are assumed to be similar to farm types labeled in Tables 2 and 3.

use type in the region. The impact on overall biodiversity in such regions is therefore relatively low.

4.3. Scenario results

Scenario results on trends in ecosystem quality are also presented in Figs. 4 and 5. In the scenario 'Global economy' (A1), the highest loss of ecosystem quality takes place in all regions in croplands as well as in grasslands, as a result of intensification. Productivity increases a lot in this scenario and this will have a large influence on the ecosystem quality, especially in croplands. In the scenario 'Continental markets' (A2), there is a small decrease in ecosystem quality in croplands, and a small increase in grasslands due to changes in land-use intensity. The 'Global co-operation' (B1) scenario shows a small increase in ecosystem quality of

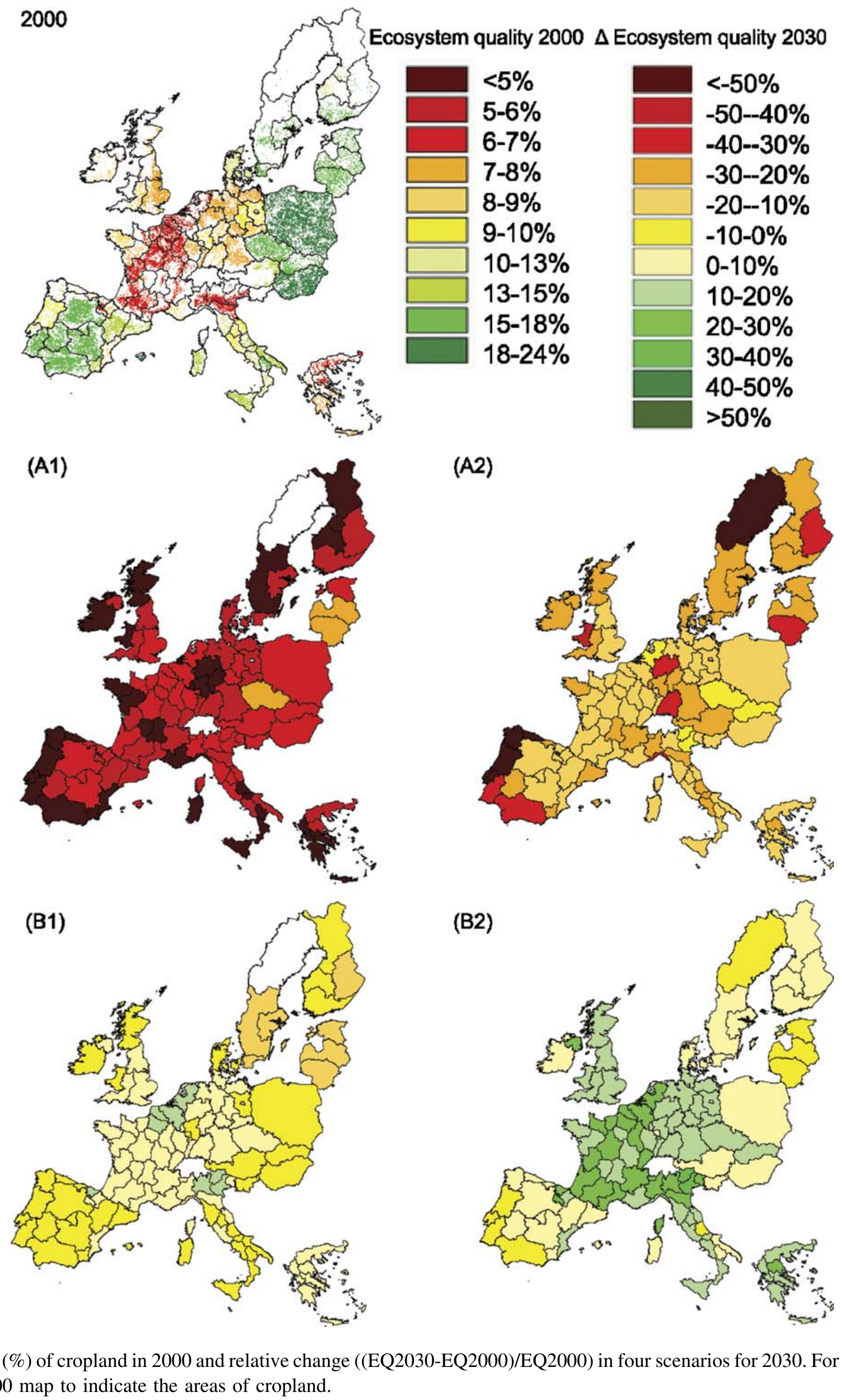

Fig. 4. Ecosystem quality (%) of cropland in 2000 and relative change ((EQ2030-EQ2000)/EQ2000) in four scenarios for 2030. For the year 2000 an overlay is made with the CLUE 2000 map to indicate the areas of cropland.

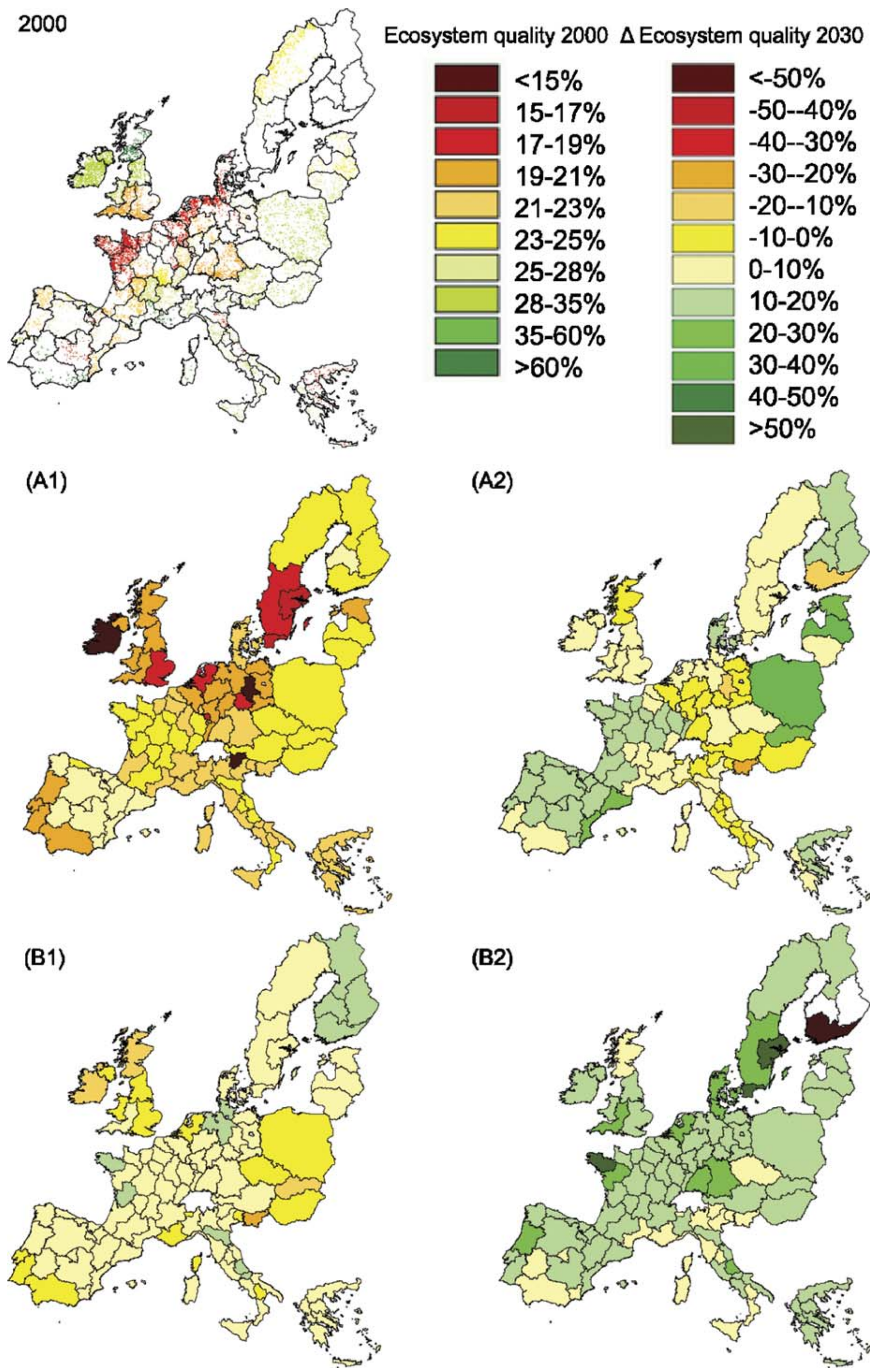

Fig. 5. Ecosystem quality (%) of grassland in 2000 and relative changes ((EQ2030-EQ2000)/EQ2000) in four scenarios for 2030. For the year 2000 an overlay is made with the CLUE 2000 map to indicate the areas of grassland. Note the colours have a different meaning than in Fig. 4.

cropland in the centre of the EU15, while there is a small decrease in the New Member States, and many southern and northern regions. Productivity increases considerably in the B1 scenario, but is partly obtained with environment friendly measures. In most EU15 regions, these environment friendly production techniques can stop biodiversity loss. In the 10 New Member States, productivity is currently very low and productivity increases will cause ecosystem quality loss. Finally, the ‘Regional communities’ (B2) scenario shows an increase in ecosystem quality in almost all regions.

The divergence in changes in ecosystem quality is the result of macroeconomic and environmental storylines of the scenarios. Land-use change has a larger influence in the A1 scenario (average change due to land-use change in EQ for Europe in absolute terms is −1.2%) than, for example, in the B2 scenario (+0.07%). The impact of conversions into organic farming on ecosystem quality ranges from 0.5%

Table 6
Change in average biodiversity in Europe, calculated by the NCI

	Cropland		Grassland		Nature		Total area[c]	NCI[a]
	EQ[a]	RS[a]	EQ	RS	EQ[b]	RS		
2000	12.48	33.32	26.29	14.73	46.29	46.15	94.20	29.39
2030 A1	7.51	27.86	22.11	14.05	46.50	47.84	89.75	27.44
2030 A2	10.29	31.58	28.60	15.27	46.98	45.03	91.88	28.77
2030 B1	12.43	27.60	26.20	14.77	46.67	49.67	92.04	30.48
2030 B2	13.60	28.27	30.06	14.78	48.42	48.92	91.97	31.97

[a] EQ = ecosystem quality; RS = relative size area (*source*: Verburg et al., 2006); NCI = Natural Capital Index = $\sum(EQ \times RS)$.
[b] Results on ecosystem quality of nature are taken from Verboom et al. (in press).
[c] The total area captured in the biodiversity assessment is not 100%. Remaining area is mainly urban/residential area, for which we assume 0% ecosystem quality.

(A1) to 2% (B2) in absolute terms. Technology indicators such as agricultural productivity change from the IMAGE model (output production intensity) showed average country increases between 2% (B2 in Czech Republic) and 53% (A1 in Portugal) for crop productivity and between −23% (productivity decrease for B2 in Hungary) and 50% (A1 in Ireland) for grassland productivity.

4.4. Agricultural ecosystem quality in context

In most scenarios, agricultural land area is decreasing, cropland area faster than grassland area (Verburg et al., 2006). As the ecosystem quality of grassland is much higher than cropland, this positively influences the average ecosystem quality in agricultural landscapes. In the B scenarios, nature development will take place on many agricultural lands that are abandoned. In the A scenarios, the extent of urban development on former agricultural land is also large. The impact of changes in ecosystem quality and relative area size of agricultural landscapes on the average NCI in Europe are presented in Table 6.

In the A1 scenario, the decrease in agricultural ecosystem quality is so large that decreases in agricultural area do not seem to be able to compensate for the increasing intensity. Although there will be a small increase in nature area, a large part of the former agricultural land becomes urban area. This results in a negative impact on the NCI. In the A2 scenario, ecosystem quality as well as agricultural area is relatively stable in relation to the other scenarios, and impacts are, in general, not that large. The relatively stable agricultural ecosystem quality in combination with an increasing area of nature in the B1 scenario seems to be positive for the NCI. In the B2 scenario the relatively high increase in agricultural ecosystem quality is accompanied by a decrease in agriculture area and increase in nature patches, which results in a positive influence on the NCI.

5. Discussion

5.1. Biodiversity

The farm-type level of analysis provides a good indication of the differences in ecosystem quality between EU regions and scenarios. Results become especially interesting when those for different land-use types are integrated. The ecosystem quality in 2000 in cropland is lowest in the Benelux, France, northern Italy and northern Greece. These represent either the highly productive regions where farming is very intensive, and/or where irrigation takes place on most of the farms. For grassland, the distribution is slightly different. The ecosystem quality is very high in the Alps of southern France and northern Italy. In these regions, cropland management is relatively intensive, while grassland management is very extensive.

In regions where grassland occupies a major part of the agricultural area (e.g. The Netherlands) the average ecosystem quality in agricultural landscapes (cropland and grassland together) can be relatively high, even when crop production is very intensive. The ecosystem quality of intensively managed grasslands is still 20%, compared to 25% of extensively managed croplands. Regions with a high percentage of cropland in their agricultural area have the lowest average agricultural ecosystem quality. These are northern France, Germany, northern Italy and Greece. The northern United Kingdom has much more grassland in its agricultural area and thus shows a high average ecosystem quality in agricultural landscapes.

In cropland, the ecosystem quality decreases faster than in grassland, as production intensity increases faster. Increasing productivity also means that less land is needed for production. In some areas, this causes a large decrease in cropland, while grasslands do not decrease; they even expand in some regions. In Bretagne, Pays-de-la-Loire, Galicia, south-west France, southern Italy, northern Scandinavia and Scotland, we see that a very large part of the cropland area is abandoned or replaced by nature areas or grassland, especially in the A1 scenario (Verburg et al., 2006). As a result – in contrast to the general decline in ecosystem quality in the A1 scenario – these specific regions present an overall improvement.

In A2, changes in cropland and grassland balance each other out. Decreases in ecosystem quality of cropland and grassland together are highest in Spain, New Member States and Scandinavia. The impact on the average NCI in Europe is small. In the B1 scenario crop productivity increases most in Spain, Ireland and the New Member States. In Spain this is accompanied by a high decline in cropland area and so a lower influence on the NCI. In the New Member States cropland area does not decrease much and the impact on the NCI is negative. The B2 scenario is positive for all regions, but mostly for The Netherlands, Bretagne and Italy.

Regions that seem to be the most vulnerable to biodiversity loss due to agricultural practices are the New Member States, Scandinavia, Ireland and Spain. These are the regions with the highest losses or lowest gains in all scenarios.

5.2. Quality of data sources

The FADN database is very extensive and provides detailed information on individual farms. A particular strength of using the FADN data for a typology of farming systems is that it directly relates to the management practices of the farms. There is no other source that contains data on the level of individual farms that gives so much insight into farm management practices. There are also some limitations though.

In total FADN represents 52% of the farms and 86% of the Utilized Agricultural Area in the EU15, when compared to the data in the Farm Structural Surveys (Andersen et al., 2004a). Economically small and 'non-professional' farms are excluded from the database. Especially in mountainous areas and on other marginal land, these farms may occupy a large proportion of the area. It is possible that exclusion of these farms will underestimate the ecosystem quality in agricultural landscapes.

Another weakness of FADN is that its major unit of data collection is the Utilized Agricultural Area (UAA), not the area actually occupied by the agricultural business. The use of common land, the grazing of fallows and seasonal lets are excluded from consideration. As many variables have been used on a per hectare basis, this may influence results. The data indicates, for example, that grasslands are used very intensively in Greece, while grazing on common land may in practice decrease the pressure on the land.

Production costs are used as proxy indicators for agricultural input intensity, as FADN does not provide data on absolute amounts of inputs. The amount of money spent on inputs is not necessarily directly related to the absolute amounts used on the farm. Prices of fertilizers and crop protection products are very similar throughout the EU15 though, and can, therefore, serve as a good proxy. Andersen et al. (2004b) show input costs to be clearly related with nitrogen surplus.

FADN will collect data in the future for the New Member States as well. Currently, data are not yet available. We could not explicitly identify farm types in these regions, but with country level data on agricultural land use we were able to link different types of land-use intensity to the production intensity gradient related to farm types. Although the approaches are based on different data sources, we are confident that reliable comparisons can be made between regions and scenarios.

The farm type distribution is linked to the CLUE land-use maps. CLUE does not distinguish between cropping and permanent cropping land, so all these kinds of farm types were allocated to cropland. It is assumed that arable grazing livestock systems in the field are identified as grassland in land-use maps. A comparison of the Utilized Agricultural Area from FADN with the extent of cropland and grassland in the CLUE maps showed that in most regions the extent of these land-use types where very similar. FADN represents 80% of all land identified as agricultural land in the CLUE maps. The largest deviation occurs in regions with a large extent of rough grassland. In FADN this land is included as agricultural land whereas CLUE identified most of these areas as nature rather than pastures. In Scotland for example, the average ecosystem quality of grassland is very high, but with the overlay of the CLUE map not all grassland area considered is presented.

A major source of uncertainty is the assignment of ecosystem quality values to the different farm types. As the natural situation or primary vegetation in Europe is largely unknown, the comparison between a land-use type and its corresponding primary vegetation is not directly possible. Therefore we used figures from other parts of the world, especially the tropics and assumed that basically the same processes would have happened in Europe. Some European studies confirm the global figures (e.g. Wilson et al., 2003). Another difficulty is that in many situations the species richness of extensively used cropland and grassland is higher than in European forests. We must however not confuse these secondary and heavily used plantation forests with primary forests. More additional studies are needed to uncover some of these issues.

5.3. Uncertainty in future changes

To be consistent with the other models used in the EURURALIS project, we based the methodology for assessing future changes in biodiversity on the output of these models. Changes in farm types can be modelled explicitly, but the direction in which the distribution will develop can only be based on scenario assumptions. By using the output from other models, changes in farm types are modelled implicitly, but the scientific basis is more coherent.

Whether the land-use changes from agriculture to other land-use types and vice versa will have the impact as estimated in the land-use change analysis cannot be said with certainty. For example, intensive agricultural land can also be taken out of production in the A1 scenario. Based on the storylines, we can assume though, that it will be mainly marginal production land that will be taken out of production. In a globalized economic world, agricultural production will become more efficient.

Projected productivity increases have a large influence on changes in ecosystem quality. GTAP and IMAGE project changes in productivity per country. For this assessment we applied the national values to the underlying HARM regions. In practice, there might be more divergence. In Italy, for example, productivity differs a lot between northern and southern regions. Ewert et al. (2005) showed that when historical changes are compared, there is a convergence in relative changes between currently more and less productive regions.

In the baseline, no ecosystem quality values below 5% were assigned to farm types. Based on current findings in the field, the average value for very intensive farms is 5%. We assume that, in the future, productivity changes on intensive farms can further reduce ecosystem quality. The uncertainty in the impacts of productivity changes is reflected in the different assumptions made in different scenarios.

5.4. Influence of agricultural landscapes on overall biodiversity

Here, we have presented the methodology to assess the ecosystem quality in agricultural landscapes as determined by land-use intensity. The influence on overall biodiversity expressed as NCI in the EU25 has been calculated. The aggregated impact on the NCI should also take other pressures into account: climate change, air pollution and fragmentation influence ecosystem quality in nature as well as in agricultural areas. These pressures have been taken into account for nature areas (Verboom et al., in press) but for agricultural landscapes we focussed on the influence of land-use intensity only.

The ecosystem quality of different land-use types is estimated separately; effects of one land use on another are only partly taken into account. The effects of agriculture on biodiversity in nature areas are assessed by the extent of fragmentation and N-deposition (Verboom et al., in press). We did not use the land-use allocation models to analyze the influence of nature areas on agriculture. Patches of nature in agricultural landscapes may increase assemblage of some species in the fields (Jeanneret et al., 2003). The influence of these nature areas is already implicitly included in the farm type classification. In the B2 scenario for example, the extensive farm types are more abundant, and in the land-use maps we see more nature patches in agricultural landscapes. The resolution of 1 km^2 is very high for analyzing land-use change in Europe (Verburg et al., 2006), but is still too low to assess interactions between these land-use types. Although an influence can be assumed, experimental studies do not provide information on which we could base dose-effect relationships for the distance to nature areas and the abundance of nature areas in agricultural landscapes on this scale.

5.5. Farm type classification

The classification of farm types in this study has not specifically been developed for this biodiversity assessment. The farm type classification can also be used for other modelling purposes, for example, to increase insights in land-use change processes or to analyze adaptation behaviour of farmers. Farm types can be extended with other dimensions, which reflect the socio-economic situation of the farm. We may then be able to model changes in farm types explicitly. Increasing spatial explicitness through combining the data with other data sources (e.g. potential yields, N-deposition) may also contribute to land-use change modelling. FADN can provide data on the altitude class of a farm and whether the farm is located in a less favoured area; these data can give more information on the specific location of a farm. Based on ‘‘helicopter-view data’’ such as climate, soil type and distance to markets, land-use change models may identify certain regions as marginal, but farm management data could show that farms are still managing fairly well in terms of economic and agricultural productivity. The farm type approach thus not only provides a good basis for biodiversity assessments but also for other purposes.

6. Concluding remarks

The strength of our methodology is that it provides a quick overview of differences in land-use intensity and biodiversity in agricultural landscapes between regions and scenarios. Results of research at the field and farm level were combined to establish dose-effect relationships for different farm types. Although agricultural intensity is the sum of many agricultural practices, dose-effect relationships cannot be assessed separately. We can compare regions and scenarios and the results for agricultural landscapes with nature areas. Grassland with a high ecosystem quality value can be mainly found in the Mediterranean (except Greece), the Alps and northern UK. Croplands with a high ecosystem quality value are mainly found in Mediterranean and Scandinavian countries and Austria. Here are farm types that are worth protecting to preserve agricultural biodiversity. In the scenario results we see that the ecosystem quality in most of these regions stays higher than in the regions with currently a low ecosystem quality. It does drop quickly though in especially the A1 scenario. In the B2 scenario the opportunities for increasing biodiversity in agricultural landscapes are the best. Low productivity increases and more environment friendly production techniques are positive for the biodiversity in the farmers’ fields. Although more intensive agriculture leaves more land for nature, the impact on overall biodiversity seems to be generally negative. It appears that the EU objective to stop biodiversity loss caused by agricultural intensification can only be reached if policies are aimed at more environment-friendly production as described in the B scenarios.

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