PROJECT N. 037033

EXIOPOL

A NEW ENVIRONMENTAL ACCOUNTING FRAMEWORK USING EXTERNALITY DATA AND INPUT-OUTPUT TOOLS FOR POLICY ANALYSIS

IDENTIFICATION AND CLASSIFICATION OF THE MAIN AGRICULTURAL BIODIVERSITY VALUES

Report of the EXIOPOL project

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Sonja Gantioler, Graham Tucker and Marianne Kettunen

Institute for European Environmental Policy

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Executive Summary

Overview

This report is a contribution to the FP6 EXIOPOL project on "a New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis". The objective of the EXIOPOL project is to improve the understanding of environmental impacts and external costs related to economic activities and consumption patterns in the EU.

In particular, this study contributes to Work Stream II.3 of the EXIOPOL project, which aims to identify the main benefits created by/related to agricultural biodiversity in the EU, and to assess how they are influenced by different land use and management practises across the Community. Specifically this study aims to **identify and classify the main agricultural biodiversity values.** It focuses on the identification of ecosystems services that are provided by agricultural biodiversity.

The study also mainly focuses on Europe, and agricultural ecosystems are defined as those that are primarily managed to produce food, feed, materials, energy and other goods by the systematic growing and/or harvesting of plants, domestic animals and other life forms. Forestry and aquaculture systems are not included in the study. Agricultural biodiversity is considered to consists of:

- crops and livestock (including the genetic variety of domestic plants and animals); and
- 'wild' flora and fauna associated with agricultural ecosystems.

The project started in March 2007 and will run until March 2011. This component of the project was completed in October 2008.

The classification and identification of agricultural biodiversity values

A wide variety of approaches have been developed to value environmental services, which tend to be based on the types of ecosystem processes and functions that are involved, their benefits or types of benefit, or mixtures of these. These are not reviewed in detail, but two widely used frameworks are described. Firstly, the Total Economic Value framework, which is a method for classifying ecosystems services and goods in terms of the way they are used. This refers to various types of use values (i.e. actual direct and indirect use, and options for future use) and non-use values (i.e. altruistic, bequest and existence). Secondly, the *Millennium Ecosystem Assessment* framework is described, which identifies four interrelated types ecosystem service, i.e.:

- provisioning services;
- regulating services;
- cultural services; and
- supporting services.

Although extremely useful and widely adopted, these frameworks are not ideal for this study, as there are potential overlaps between some of the values and services. Instead it was considered to be simpler to identify and classify the principal values of agricultural biodiversity on the basis of their final benefits.

Each main benefit type is therefore listed in Table 2.5 and described in Chapter 4. A semi-quantitative assessment of the relative value of each benefit is also provided in the table in relation to four levels of agricultural intensification (natural, semi-natural, agriculturally improved and intensive).

However, a drawback of the focus on benefits is that it not does not explicitly consider the core processes and beneficial processes that underpin the provision of benefits. A full ecological description of these processes is clearly beyond the scope of this study, but a short account of pollination, biological control and soil formation processes is given in Chapter 3, as these are of particular importance to agricultural ecosystems.

Non-use values cannot easily be described in relation to specific benefits (as some non-use values can apply to many benefits, whilst others do not clearly relate to any). A short discussion of the potential non-use values of agricultural biodiversity is therefore provided in Chapter 5.

Conclusions

This study has clearly demonstrated that all agricultural ecosystems contain important biodiversity resources (though at differing levels), that provide a wide range of benefits for humankind in Europe (and elsewhere). These range from the most obvious direct provision of benefits from crops and livestock, to recreational uses, indirect benefits (eg flood alleviation) and even non-use benefits through the existence of ancient landscapes and rare species etc. In addition, agricultural biodiversity forms an integral component of essential core and beneficial ecological processes, such as genetic diversification, soil formation, pollination and biological control, which in turn support the provision of agricultural products and other benefits. Thus valuation studies and policy developments need to be mindful of these processes and the wide variety of end benefits.

However, it is clear from this and other studies that agricultural improvements typically result in a loss of biodiversity and associated ecosystem services. Consequently many benefits are reduced or lost altogether as agricultural improvements are implemented. Thus, for example, natural habitats tend to be the most important in terms of providing recreational and indirect benefits (such as carbon sequestration and water resources) and non-use values (e.g. from the existence of 'wild' areas). In contrast, the most intensive systems often contribute to the degradation or loss of biodiversity and its associated services (e.g. through soil erosion and water pollution). They also have impoverished communities of wild fauna and flora and structurally simple artificial landscapes. Such agricultural landscapes are of much lower aesthetic and recreational value. Consequently, the value of agricultural biodiversity in intensive farming systems tends to be concentrated in a few benefits (i.e. food, materials and energy) provided by the few principal agricultural products.

Thus, in conclusion, it is clear that economic evaluations that aim to inform the development of land use policies must carefully consider the full range of services that biodiversity provides in agricultural systems. Furthermore, polices that encourage intensification and other land use changes that reduce biodiversity resources may have significant impacts on ecosystem services, which can have a wide range of socio-economic impacts. Studies, such as those conducted for the report on *The Economics of Ecosystems and Biodiversity* (Sukhdev 2008), have demonstrated that such impacts can be substantial and lead to policies that cannot be supported on economic grounds.

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1 Introduction

1.1 Background

This study is a contribution to Work Stream II.3 of the FP6 EXIOPOL project ("a New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis"). The objective of the EXIOPOL project is to improve the understanding of environmental impacts and external costs related to economic activities and consumption patterns in the EU. These results will be used to analyse important policy questions related to, for example, sustainable development, agriculture and biodiversity. Additionally, the results will contribute to evaluations of the value and impact of past research on the external costs of policy-making in the EU.

The project builds on recent work on the value of the environment to humankind through its provision of ecosystem services, which have been described as flows of goods and services from ecosystems to human systems as functions of nature (Braat & ten Brink 2008; de Groot 1992). Such services have been described in the *Millennium Ecosystem Assessment* (MEA 2005), the more recent study of *The Economic of Ecosystems and Biodiversity* (Sukhdev 2008) and its supporting studies (Balmford *et al.* 2008; Braat & ten Brink 2008; Markandya *et al.* 2008). These studies identify a wide range of services that are provided by various ecosystems, and demonstrate that many are being degraded through damaging human activities, which in turn result in economic losses. But these broad studies do not provide a comprehensive inventory of ecosystem services, particularly in agricultural ecosystems. The benefits of agricultural biodiversity are often tend to be overlooked in environmental evaluation studies because agricultural ecosystems are sometimes considered to be of low biodiversity value because they are artificial, or at least modified by human activities. However, it is being increasingly recognised that the less intensive agricultural systems provide a range of important ecosystem services in addition to their provision of food, fibre and other materials.

1.2 Objectives and scope of the study

This study contributes to the EXIOPOL research component dealing with the valuation of biodiversity in land areas currently under agriculture (Work Stream II.3). This work stream component aims to identify the main benefits created by/related to agricultural biodiversity in the EU, and to assess how they are influenced by different land use and management practises across the Community. Finally, the project will seek to provide estimates of the economic value of agricultural biodiversity benefits in the EU (eg non-market economic value).

As defined in the EXIOPOL project proposal this study will contribute to Work Stream II.3 by "**identifying and classifying the main agricultural biodiversity values**". Although this task is not defined further it is taken to mean the identification of ecosystems services that are provided by agricultural biodiversity. The study therefore provides evidence of the values of agricultural biodiversity, including from valuation studies where these exist. However, it is important to note that an exhaustive review of all the evidence of the qualitative, quantitative and monetary values of agricultural biodiversity is beyond the scope of this study. A more detailed review of some monetary evaluation studies of agricultural biodiversity has been undertaken as part of Task 2 of Work Stream II.3 (SWECO 2008). Later EXIOPOL tasks will attempt to provide monetary estimates of the value of some components of agricultural biodiversity.

The geographical focus is taken to be Europe, but the review also considers evidence of ecosystem services from similar agricultural ecosystems elsewhere (if evidence from Europe is lacking), e.g. from north America, New Zealand and Australia.

In accordance with the Food and Agriculture Organisation (FAO), agricultural ecosystems are defined as those that are primarily managed to produce food, feed, materials, energy and other goods by the systematic growing and/or harvesting of plants, [domestic] animals and other life forms. Thus they include systems that raise livestock (which include a wide range of near-natural to artificial habitats) and/or produce cultivated and permanent crops. Orchards, olive groves and other permanent food crops are included in this definition of agricultural ecosystems. In theory forestry and even aquaculture systems could also be included. However, it is not normal practice to consider these as forms of agriculture and they are therefore not included in this study.

The Conventional on Biological Diversity (CBD) is followed with respect to the definition of biodiversity, i.e. that "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"[1]. The CBD also provides the following definition for agricultural biodiversity in one of its decisions: "Agricultural biodiversity is a broad term that includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes"[2].

This study therefore considers that agricultural biodiversity consists of:

- crops and livestock (including the genetic variety of domestic plants and animals); and
- 'wild' flora and fauna associated with agricultural ecosystems.

[1] Article 2 of the Convention on Biological Diversity www.cbd.org

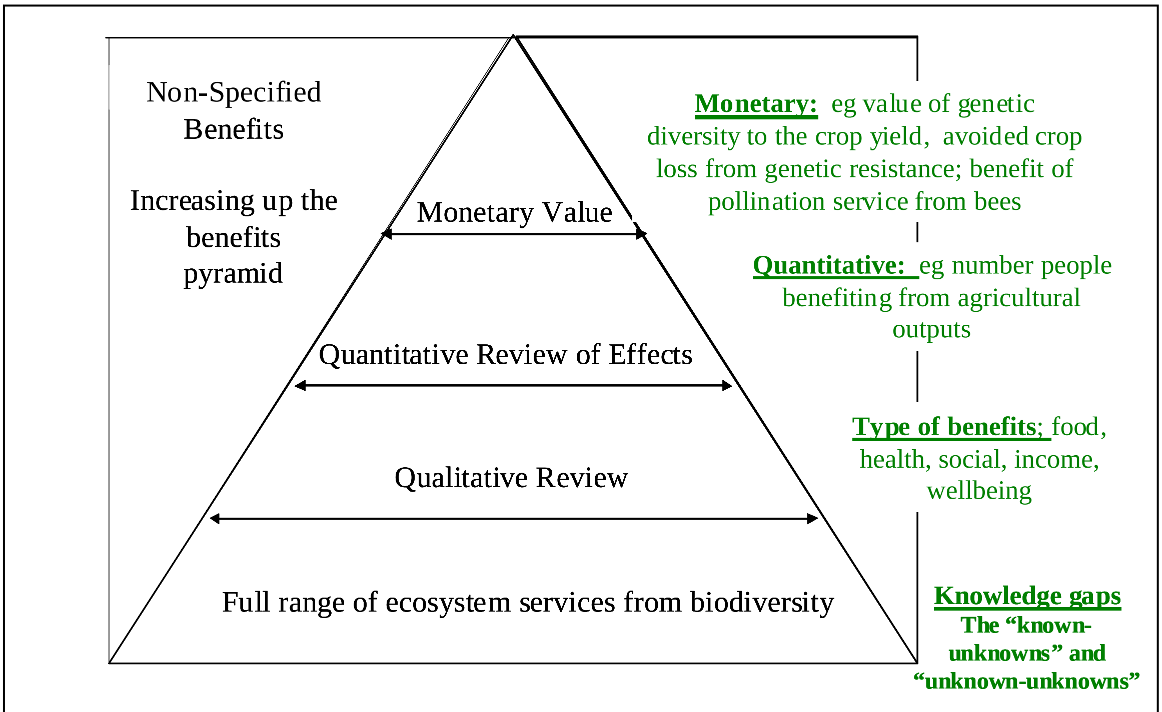
[2] COP decision V/5, appendix, http://www.cbd.int/decisions/?m=COP-05&id=7147&lg=0

2 Classification of agricultural biodiversity values

2.1 Existing classification approaches for ecosystem services

Benefits arising from ecosystems can be described and analysed at three different levels: in qualitative, in quantitative and monetary terms (Figure 2.1). Whereas possibilities for qualitative assessments are rather broad, a quantitative analysis is more difficult and therefore quantitative estimates of ecosystem benefits are rather scarce. Finally, a relatively limited number of those benefits that can be quantified, can be further transformed into monetary values. Importantly there is a tension between public and press interest - often focused on the monetary level - and the availability of information – which is greater at the qualitative level. To ensure that a full picture is presented that can reach different audiences a mix of information across the three levels is important.

Figure 2.1: Benefits Pyramid - valuation and quantification of benefits



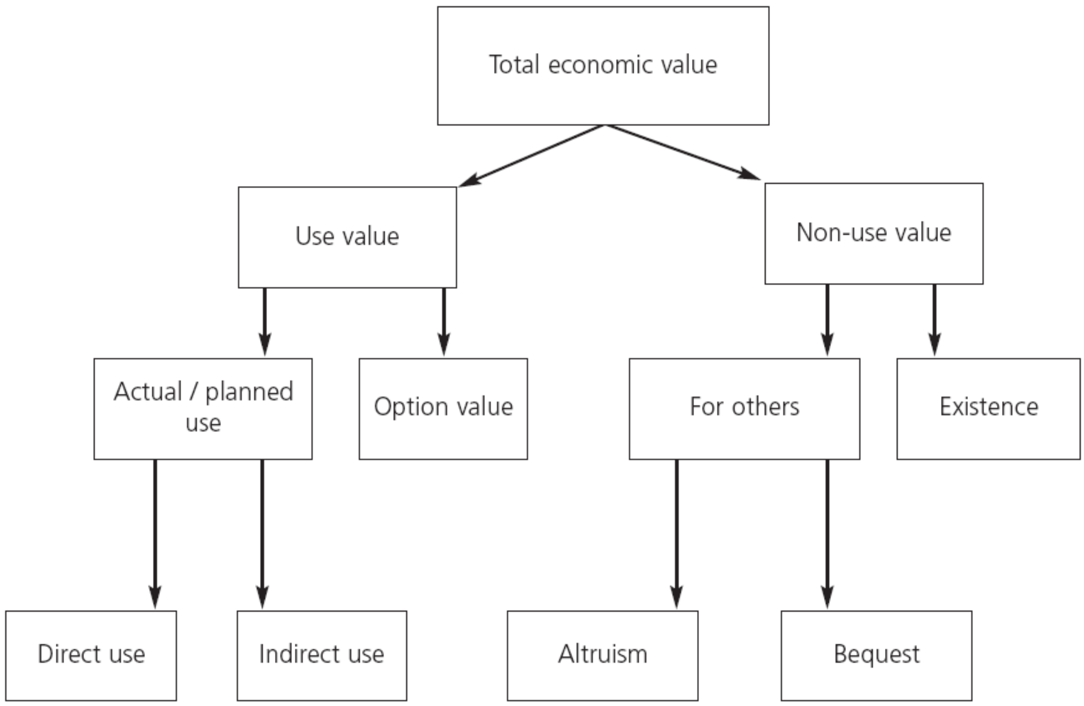
Source: adapted from P. ten Brink: presentation at March 2008 workshop Review of Economics of Biodiversity Loss, Brussels

The present study focuses on biodiversity values from an economic perspective in order to develop a uniform and clear measurement framework that can contribute to the overall aims of the EXIOPOL project. Economic valuations of ecosystems aim to offer a way to compare the diverse benefits that arise from a multitude of services by measuring them and by providing a common denominator, usually a monetary unit. However, it is important to reiterate that biodiversity may have many additional values that cannot be quantified in monetary terms.

Valuation typically focuses on the economic values of the goods and services biodiversity resources and/or functions, but it does not include measuring the economic value of biodiversity as such (CBD, 2007 and references therein). Nonetheless, it helps to raise awareness of the hidden economic values of goods and services provided by biodiversity.

A wide variety of approaches have been developed to value environmental services, which tend to be based on the types of ecosystem processes and functions that are involved, their benefits or types of benefit, or mixtures of these (see Pearce and Warford, 1993; Moran *et al*, Defra, 2007: CBD, 2007; OECD, 2001; Pearce *et al*., 2002; Spagiola *et al*., 2004). One of the most widely adopted approaches is the Total Economic Value (TEV) framework (Pearce and Warford, 1993). It is a method for classifying ecosystems services and goods in terms of the way they are used. The framework refers to use values and non-use values and is described below, according to Defra (2007) and Spagiola *et al.* (2004), and summarised in Figure 2.2.

Figure 2.2: Total Economic Value Framework



Source: DEFRA 2007

Use values include direct use, indirect use and option values.

Direct use values refer to an ecosystem's good and services that are used directly by human-beings. These can include *consumptive* uses, which refers to the use of resources extracted from an ecosystem (e.g. food and materials), and *non-consumptive* use, which does not remove or deplete them from the system (e.g. recreation). Beneficiaries of direct use values include residents (e.g. farmers), visitors and consumers.

Indirect use values refer to benefits resulting from ecosystem services that are not directly used. These services usually include regulating ecosystem services such as air quality, water or natural hazard regulation. Beneficiaries of these services are not only visitors and residents, but also communities outside the ecosystem itself.

Option values are derived from retaining the capability to use ecosystem goods and services in the future, even if they are not currently used. With regard to the conservation of ecosystems, the option value describes the value placed on maintaining ecosystems and their components for potential future use.

Non-use values can be derived from the enjoyment people can experience simply from the knowledge that a natural environment is maintained. The following three types of non-use value are distinguished in the TEV framework.

Bequest values refer to the value people attach to a certain ecosystem good and service because of the fact that it will be passed on to future generations.

Altruistic values derive from the knowledge that a good and service will be maintained to be used by others in the current generation.

Existence values are attached to an ecosystem, its components, and its goods and services simply for their existence, without an actual or planned use.

An example of how some environmental services from agricultural habitats could be applied to this framework is provided in Table 2.1 below.

Table 2.1: Some examples of environmental services provided by biodiversity within agricultural ecosystems in relation to the TEV framework

USE VALUE	**Actual / planned**	Direct	Consumptive: Crops, livestock, wild foods (and their genetic diversity). Non-consumptive: recreational use of ‘green’ space, aesthetic appreciation of traditional landscapes and livestock, nature watching.
		Indirect	Disease regulation Pollination Water retention and purification Soil protection
	Option		Genetic diversity, seed banks
NON-USE VALUE	**For others**	Altruism	Any of the above
		Bequest	
	Existence		Conservation of species, landscapes and cultural aspects of farming

A more recent and very widely adopted framework for the classification of biodiversity values is the ecosystem services approach that is adopted in the MEA. As indicated in Figure 2.3, it distinguishes between

- provisioning services;
- regulating services;
- cultural services; and
- supporting services.

The MEA has raised global awareness of the fundamental importance of biodiversity and its associated ecosystem services to humankind. Importantly, the classification framework explicitly recognises the importance of the underlying ecological processes that support biodiversity and ecosystem services. However, as has been recently pointed out (eg Balmford *et al.* 2008) the MEA framework is not ideal for valuation purposes. This is primarily because some services can be considered to fall within more than one category, which could in principle lead to double counting if not suitably addressed. For example, pollination is recognised as a supporting service, but its value is also captured in some provisioning services, such as the production of crops that rely on other species for pollination. In practice, estimating pollination value remains a good vehicle (because people understand it and it can be measured), for highlighting the importance of the service from the bees and hence their contribution to the provision of food etc.

Figure 2.3: Classification of agricultural ecosystem services

Supporting

Soil fauna supporting soil fertility

Pollination

Plants contributing to organic matter

Plant growth for livestock

Selection processes maintaining genetic diversity

Provisioning

Crops (food, fibre, biomass, biofuel)

Livestock (food, draught animals)

Wild foods

Regulating

Disease regulation

Water retention and purification

Soil protection

Cultural

Open 'green' space / landscapes

Cultural interest (traditional breeds)

Nature watching

Source: adapted from MEA, 2005

Recent work has tried to further develop and refine existing classification systems to provide a more systematic approach to the valuation of ecosystem services and to avoid double counting when valuing benefits from ecosystem services and goods.

Fisher *et al.* (2005), focused on the distinction between intermediate and final services. Supporting services (according to the MEA classification), such as nutrient cycling, have been mainly defined as intermediate services whereas regulating services, such as water regulation, have been classified as final services. However, it is sometimes difficult to define services in this way as they often overlap or depend on their context. For example, water regulation can be considered to be an intermediate service with respect to the provision of clean water that supports fish stocks, but is a final service with respect to the supply of drinking water.

Balmford *et al.* (2008) used a classification framework that distinguishes between processes and benefits. Processes include 'core' ecosystem processes (which correspond to intermediate services defined by Fisher *et al*) that refer to basic ecosystem functions (see examples in Table 2.2). They support 'beneficial' ecosystem processes (corresponding to final services in Fisher *et al.*) that directly impact benefits for humankind (see examples in Table 2.3). Benefits are defined as end products of core and beneficial ecosystem processes, and can, in principle, all be expressed in monetary terms. By analysing the relationship between processes and the benefits, in theory the contribution of a process to the production of a benefit can be distinguished and valued.

Figure 2.4 provides an overview of the processes and benefits described by Balmford *et al.* (2008), and how the classification links to the MEA classification of ecosystem services.

Table 2.2: Types of core ecosystem services

Production: Production of plant and animal biomass.
Decomposition: Reduction of the body of a formerly living organism into simpler forms of matter.
Nutrient cycling: Cycle by which a chemical element or molecule moves through both biotic and abiotic compartments of ecosystems (e.g. nitrogen cycle, phosphorus cycle, carbon cycle).
Water cycling: Cycle of water through both biotic and abiotic compartments of ecosystems.
Weathering/erosion: Weathering is the decomposition (in situ) of rocks, soils and their minerals through direct contact with the atmosphere. Erosion involves the movement and disintegration of rocks and minerals by agents such as water, ice, wind and gravity.
Ecological interactions: Inter- and intra-specific interactions between organisms (e.g. predation, competition, parasitism, and animal-plant interactions such as pollination).
Evolutionary processes: Genetically-based processes by which life forms change and develop over generations (inc. evolution, speciation, adaptation).

Source: Balmford *et al.*, 2008

Table 2.3: Types of core ecosystem services

Biomass production: primary: Production of plant biomass.
Biomass production: secondary: Production of animal biomass.
Pollination: Pollen transport (particularly by organisms). [Seed and fruit dispersal may also be considered]

Biological control: Inter- and intra-specific interactions resulting in reduced abundance of species that are pests, diseases or invasives in a particular ecosystem.

Other ecological interactions: Other inter- and intra-specific interactions, for example competition and predation.

Formation of species habitat: Formation of the physical properties of the habitats necessary for the survival of species (e.g., canopy structure in forests).

Species diversification: The production of genetic diversity across species.

Genetic diversification: The production of genetic diversity within species.

Waste assimilation: Removal of contaminants from the soil in an ecosystem (inc. through biological processes such as decomposition or assimilation).

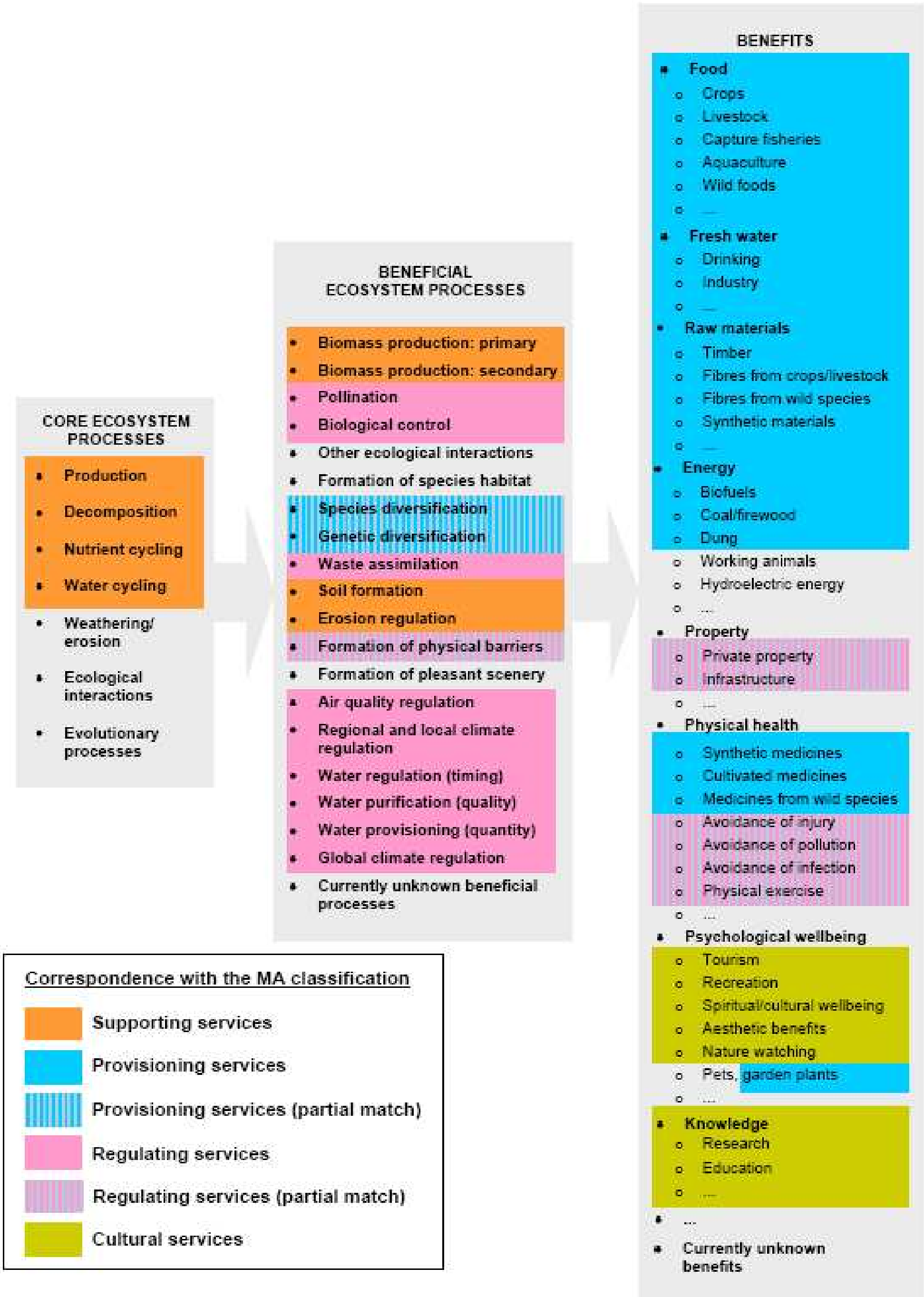
Soil formation: Process by which soil is created (including changes in soil depth, structure and fertility).

Erosion regulation: Control of the processes leading to erosion (e.g. by controlling the effects of water flow, wind or gravity).

Formation of physical barriers: Formation of structures that attenuate the energy of (or block) water or wind flow (e.g., mangroves, dunes, forests).

Source: Balmford *et al.*, 2008

Figure 2.4: Correspondence between the classification into core ecosystem processes, beneficial ecosystem processes, and benefits, and the classification followed by the MEA.



Source: Balmford *et al* 2008

2.2 A classification of values from agricultural biodiversity

Taking into account the above considerations, we have attempted to identify and classify the principal values of biodiversity on the basis of their final benefits as much as possible, thus following the general approach of Balmford *et al* (2008). Each benefit is listed in Table 2.5 (at the end of this chapter) and also classified in terms of the TEV and MEA frameworks. Generic descriptions of each benefit is provided in Chapter 4 together with evidence of their value and examples where relevant valuation studies have been carried out.

The value of ecosystem services varies considerably depending on their context, in particular the type and condition of agricultural ecosystem involved. The classification in Table 2.4 therefore also includes for each benefit type a simple description of the:

- types of agricultural system that may provide such benefits (which range from near-natural ecosystems to near-industrial artificial systems);
- agricultural biodiversity components involved (e.g. crop, livestock, soil); and
- beneficiaries.

This information aims to indicate which benefits tend to be associated with the various levels of farming intensity. The importance of some ecosystem services varies greatly across the different types of farming system within the EU. This is because biodiversity values are highly dependent on the extent to which habitats have been modified as a result of grazing, agricultural improvements (e.g. drainage and reseeding) and intensive use of fertilisers and pesticides. In general biodiversity declines with increasing agricultural improvement and intensification (Aebischer 1991; Billeter *et al.* 2007; Donald 1998; Donald *et al.* 2001) .

Many agricultural improvements tend to be inter-linked, because some are not economically worthwhile or technically feasible unless the system has already been improved to a certain level. As a result it is possible to identify four very broad types of grassland/arable farming system in the EU, as summarised in Table 2.4 and described below.

Table 2.4: A typology of agricultural habitats in the EU

	Natural	**Semi-natural**	**Improved**	**Intensive**
Vegetation	Near natural species & communities	Species-rich, native species plagioclimax communities	Species-poor dominated by non-native species	Monocultures of cultivars
Hydrology	Natural	Natural or minor improvements	Drained if necessary	Drained and/or irrigated if necessary
Cultivation	Never	Never or ancient	Often re-sown	Annual
Fertiliser	Never	Maybe some organic manure	Usually*1	High amounts used annually*1
Pesticides	Never	Never	Usually*2	High amounts used*2
Use	Extensive livestock	Livestock grazing	Livestock	Crops (food, fodder

	grazing & non-agricultural uses	and/or hay	grazing and/or silage	biofuels) or silage, often no grazing
Examples	Montane grasslands, blanket bogs	Wet or dry grasslands, pastoral woodlands	Typical lowland grasslands	Typical arable farmland

Notes: *1 Except organic systems, where only farmland manure is used. *2 Except in organic systems where artificial pesticide use is avoided or highly restricted.

Natural habitats that are dominated by native plants and have near-natural vegetation communities are typically of highest biodiversity value (though not necessarily the most species-rich). These include some grasslands grazed by livestock (or in some cases semi-domesticated species, such as Reindeer), often under traditional low intensity systems. However, such habitats are now largely confined to remote areas, wetlands, mountains and the far north.

Most areas of native vegetation have at the very least been affected by centuries of grazing and other forms of management that have resulted in significant changes in vegetation composition and structure. Nevertheless, such semi-natural communities are often species rich and include a range of agricultural habitats of High Nature Value (Baldock *et al.* 1993; IEEP 2007). Semi-natural permanent grasslands are still widespread in parts of Europe, particularly in the east and especially in hilly and mountainous regions, arid, regions and on areas with poor or wet soils.

However, most semi-natural grasslands have been lost as a result of agricultural improvements such as drainage, fertilisation and re-sowing with species-poor agricultural mixes. Such grasslands are generally of low plant conservation value, but can still support some wildlife of significant conservation importance.

In contrast to permanent grasslands short-term sown grass monocultures (e.g. *Lolium* spp) are often used as silage rather than being directly grazed. The rapid and dense growth of fertilised grasslands and arable crops combined with the use of herbicides precludes the growth of other plants in the crop. The regular tilling of the soil also reduces organic matter and disrupts the soil ecosystem. Consequently intensive grasslands and arable crops support few invertebrates and birds etc and are of very low biodiversity value.

Furthermore, intensive systems tend to increasingly specialise in growing grass (especially in milk production systems) or crops. Crop rotations are also simplified or abandoned. As a result vegetation and structural diversity in intensive farmland landscapes is greatly reduced. Such systems now predominate over much of lowland Europe, especially in the north-west.

The classification in Table 2.5 also provides an indication of the potential for substituting them (e.g. many fibres can be replaced by synthetic equivalents) and a semi-quantitative assessment of their relative value in each type of agricultural system. However, it is important to note that the value of a good or service provided by an ecosystem can differ widely depending on their beneficiaries. For example, benefits that are felt to be important on a global level (e.g. carbon sequestration) might not be seen the same way from a local perspective, where other incentives drive decisions (e.g. crop production and profitability).

A drawback of this classification's focus on benefits is that it not does not explicitly consider the core processes (Table 2.2) and beneficial processes (Table

2.3) that underpin the provision of benefits. Core processes are clearly of fundamental value, but are complex and a comprehensive and meaningful account of them would require a description of all the processes within each agricultural ecosystem, which is clearly beyond the scope of this project. Similarly most beneficial processes are likely to be important within agricultural ecosystems and therefore a full description of these would difficult. However, some beneficial processes, such as pollination have a clear and close link to the biodiversity benefits derived from agricultural systems and are therefore briefly described in Chapter 3 below.

Another drawback is that non-use values cannot easily be described in relation to specific benefits (as some non-use values can apply to many benefits, whilst others do not clearly relate to any). A short discussion of the potential non-use values of agricultural biodiversity is therefore provided in Chapter 5.

Table 2.5: A classification of the values of agricultural biodiversity in Europe according to their benefits to humankind

Key

TEV framework: D = Direct use, -c = consumptive, -n =non-consumptive indirect use, I= Indirect; N = Non-use (bequest, altruistic & existence),

MEA framework: S = Supporting, P = Provisioning, R = Regulating, C = Cultural.

Agriculture type: A = Arable, G = Grass (and other semi-natural habitats), P = Permanent crops, O = Orchards and olives, B = Biomass.

Agricultural component (AGRI COMP): C = Crop, L = Livestock, A = Associated species, LS = Landscape, E = Ecosystem.

Beneficiaries (BENEF): F = Farmer / landowner, V = Visitors, L = Local communities, C = Consumers, G = Global society.

Potential for substitution (SUBS): H = High, M = Medium, L = Low.

Relative value (with respect to each level of agricultural intensity): H = High, M = Medium, L = Low, N = Nil.

BENEFIT	TEV*1	MEA	AGRI TYPE	AGRI COMP	BENEF	SUBS	Relative value			
							Natural	Semi-Natural	Improved	Intensive
Food										
Arable crops (e.g. wheat, barley, oats, maize)	D-c	P	A	C	F,C	L	N	N	L	H
Vegetables (annually cultivated)	D-c	P	A	C	F,C	L	N	N	N	H
Herbs (cultivated)	D-c	P	A	C	F,C	M	N	N	N	H
Wild herbs / plants (foliage & seeds)	D-c	P	All	A	F,V	M	M	M	L	L
Wild fungi	D-c	P	G	A	F,V	M	M	M	L	N
Oils (rape-seed, linseed, sunflower)	D-c	P	A	C	F,C	L	N	N	N	H
Oil & fruit from olives	D-c	P	O	C	F,C	L	L	L	M	H
Grapes (wine & fruit)	D-c	P	P	C	F,C	L	N	N	M	H
Nuts & berries	D-c	P	All	A	F,V	H	M	M	L	L

BENEFIT	TEV*1	MEA	AGRI TYPE	AGRI COMP	BENEF	SUBS	Relative value			
							Natural	Semi-Natural	Improved	Intensive
Perennial fruit (raspberries, strawberries, [melons])	D-c	P	P	C	F,C	L	N	N	N	H
Fruit from trees (orchards)	D-c	P	O	C	F,C	L	L	L	M	H
Livestock (meat & milk)	D-c	P	A,G,O	L	F,C	L	L	M	H	H
Poultry (meat & eggs)	D-c	P	A,G,O	L	F,C	L	N	L	L	H
Semi-domesticated animals (e.g. Reindeer)	D-c	P	G	L	F	H	M	N	N	N
Wild animals (game)	D-c	P	All	A	F,V,C	H	M	M	M	L
Materials										
Fibres from livestock (wool)	D-c	P	G	L	F,C	M	L	M	M	M
Fibres from cultivated plants (e.g. straw, flax, cotton)	D-c	P	A	C	F,C	M	N	N	N	M
Fibres from wild plants (e.g. reed for thatching)	D-c	P	G	A	F,V,C	H	L	L	N	N
Leather, skins, fur (hides) from livestock	D-c	P	A,G,O	A	F,C	M	L	M	M	M
Skins & fur from wild animals	D-c	P	All	A	F,V,C	H	L	L	L	L
Timber (e.g. trees in wood pasture, hedges & shelter-belts)	D-c	P	All	A	F,C	M	M	M	L	L
Cork	D-c	P	A,G,O	A	F,C	H	L	M	N	N
Oils	D-c	P	A	C	F,C	M	N	L	L	H
Other chemicals	D-c	P	A	A,C	F,V,C	M	L	L	L	L
Peat for horticulture	D-c	P	G	E	F,C	M	M	M	N	N
Water										
Clean drinking water, through water	I	R	G	E	F,L	L	H	H	M	L

BENEFIT	TEV*1	MEA	AGRI TYPE	AGRI COMP	BENEF	SUBS	Relative value			
							Natural	Semi-Natural	Improved	Intensive
retention in soil										
Energy										
Biomass (straw, *Miscanthus*, willow)	D-c	P	A	B	F,C	M	L	L	M	H
Biofuels	D-c	P	A	C	F,C	H	N	N	N	H
Firewood	D-c	P	All	A	F,V,C	M	M	M	L	L
Dung for burning	D-c	P	G	L	F	H	L	L	N	N
Dung & waste for methane	D-c	P	A,G,O	C,L	F,C	H	N	N	N	L
Peat for burning	D-c	P	G	E	F,C,L	H	M	M	N	N
Draught animals (e.g. horses, donkeys, mules for transport)	D-n	P	A,G,O	L	F	H	M	L	N	N
Property										
Avoidance of flood damage	I	R	G,P,O,B	E	F,L	M	M	M	L	N
Avoidance of severe wild fires	I	R	A,	C	F,L	M	N	M	M	M
Avoidance of extreme weather from climate change (carbon storage / sequestration)	I	R	G,O,B	C,E	G	L	H	H	L	N (L*2)
Physical health										
Pharmaceutical crops	D-c	P	A	C	F,C	M	N	N	N	M
Pharmaceuticals / herbal remedies from wild plants / fungi	D-c	P	All	A	F,V,L	H	L	L	L	L
Avoidance of injury from floods	I	R	G,P,O,B	E	F,L	M	M	M	L	N
Avoidance of landslides / rockfalls	I	R	G	C	F,V,L	M	M	M	L	N
Avoidance of air pollution (e.g. particulates) from hedge / tree-lines	I	R	All	A	F,V,L	L	M	M	L	L

BENEFIT	TEV*1	MEA	AGRI TYPE	AGRI COMP	BENEF	SUBS	Relative value			
							Natural	Semi-Natural	Improved	Intensive
barriers										
Avoidance of water pollution (contamination)	I	R	G,P,O,B	E	F,L	L	M	M	L	N
Accessible open areas / stimulation for exercise	D-n	C	G,A	LS	F,V	L	H	H	L	L
Avoidance of dangerous climate change (carbon storage / sequestration)	I	R	G,O,B	C,E	G	L	H	H	L	N (L*2)
Psychological wellbeing										
Hedges and trees as visual barriers (e.g. from industry and roads)	D-n	C	All	A	F,V	L	M	M	M	M
Recreation (e.g. walking, mountain-biking, riding, skiing)	D-n	C	All	LS	F,V	L	H	H	L	L
Appreciation of the open landscape / green space	D-n	C	All	LS	F,V	L	H	H	M	M
Spiritual benefits	N	C	G	A,LS	F,V,L,G	L	H	M	L	L
Appreciation of traditional / cultural landscapes (sense of place)	D-n	C	A,G,P,O	L,A,LS	F,V	L	N	H	L	N
Appreciation / observation of wild nature	D-n	C	All	A	F,V	L	H	H	M	L
Appreciation of livestock (esp traditional breeds)	D-n	C	A,G	L	F,V	L	L	M	L	N
Collection of plants as ornaments (cut flowers / garden flowers)	D-c	C	All	A	F,V	H	M	M	L	L
Pets (horses, donkeys)	D-n	C	G	L,A	F,L	M	N	L	L	N
Appreciation of traditional rural activities involving wildlife (e.g. hunting)	D-n	C	All	A	F,V	M	L	M	M	L

BENEFIT	TEV*1	MEA	AGRI TYPE	AGRI COMP	BENEF	SUBS	Relative value			
							Natural	Semi-Natural	Improved	Intensive
Inspiration /subjects for art / photography	D-n	C	All	C,L,A,LS	F,V,C	L	H	M	L	L
Knowledge										
Research opportunities	D-n	C	All	All	G	L	H	H	M	M
Education opportunities	D-n	C	All	All	F,V	L	H	H	M	M

3 Beneficial ecosystem processes

All of the beneficial ecosystem processes listed in Table 2.3 will contribute to one or more of the benefits arising from agricultural ecosystems. However, pollination, biological control and soil formation are clearly of fundamental importance to agriculture and are therefore briefly described below. In addition some issues concerning genetic diversification are addressed in the sections on food, materials and energy in Chapter 4.

3.1 Pollination

Pollination is one of the most important ecosystem services both natural and agricultural systems depend on (Nabhan & Buchmann 1997). This ecosystem's service is most often carried out by insects, including bees, flies, beetles, moths, butterflies and wasps. In addition, vertebrates (particularly birds and bats) can also operate as pollinators for some plant species (Balmford *et al.*, 2008).

In many agricultural systems pollination is actively managed through the establishment of populations of domesticated pollinators, particularly the honeybee *Apis mellifera*. However, the importance of wild pollinators for agricultural production is being increasingly recognised (Balmford *et al.*, 2008 and the reference therein). For a range of crops, studies show that wild pollination increases the size and quality of harvests (Klein *et al.* 2007). Wild pollinators may also interact synergistically with managed bees to increase crop yields (Balmford *et al.*, 2008 and the reference therein). A diverse portfolio of native pollinators increases the long term resilience in the face of year-to-year population variability or loss of specific pollinator species (Balmford *et al.*, 2008 and the reference within). Given recent collapses of managed honeybee populations (Colony Collapse Disorder and abandonment of beekeeping in regions affected by 'Africanization' of honeybees, the importance of wild pollination is likely to increase (Balmford *et al.*, 2008 and the reference therein).

Example

According to Balmford *et al.* 2008, estimating the economic value of pollination is difficult and controversial, but the global value of wild and domestic pollination has been estimated at $120 billion per year (Costanza *et al.* 1997). Similarly, Losey & Vaughan (2006) estimated that wild pollinators (i.e. excluding domesticated honey bees) alone are responsible for about $3 billion of fruits and vegetables produced in the United States. The study bases its estimations of the value of services provided by wild pollinators on projections of losses to crop production that would occur if insects were not functioning at their current level.

3.2 Biological control

Biological control is the process by which one organism reduces the population density of another organism, for example through predation or parasitism. Although predators and parasites do not normally eliminate their prey or hosts, their influence may be sufficient to prevent large and rapid increases in prey populations. Thus they may provide a natural mechanism that regulates pest damage.

Biological control may be totally natural, without direct intervention from man, or it may be enhanced through biological control interventions. Frequently, the term biological control refers to the latter only, when an organism is used *by man* to reduce the population density of another organism (Bale *et al.*, 2008).

In agricultural systems, biological control can play an important role in the regulation of pests and diseases, particularly in semi-natural and organic systems that have no, or low, pesticide use and diverse landscapes with patches of non-cropped habitat. Natural vegetation patches interspersed with crop fields are habitat for many natural enemies of insect pests.

Some modern agricultural systems incorporate integrated pest management strategies to significantly reduce populations of pests through measures that increase the densities of natural enemies, whilst using other additional methods to achieve an adequate level of control. These include, for example, the use of resistant plants, cultural techniques, physical barriers, and, as a last resort, the use of selective chemicals.

Information could not be found within the scope of this study on the value of biological control within Europe. However, it is apparent from studies in the USA that that the presence of natural predator and parasite populations in agricultural ecosystems provide substantial economic benefits (see Box 4.1).

Box 4.1: Overview of the economic losses caused by agricultural pests

Agricultural pests cause significant economic losses worldwide. Globally, more than 40% of food production is being lost to insect pests, plant pathogens, and weeds, despite the application of more than 3 billion kilograms of pesticides to crops, plus other means of control (Pimentel 2008). In the US alone, it is estimated that more than US$18 billion are lost due to insect damage (including more than US$ 3 billion spent in insecticides), of which about 40% attributed to native species and the remaining to exotic pests (Losey & Vaughan 2006). These values, however, would be much higher if biological control was not in place. Losey & Vaughan (2006) estimate that 65% of potential pest species are being suppressed in the US, with a total value of pest control by native ecosystems around US$ 13.60 billion. Through a predator removal experiment, Östman *et al.* (2003) showed that the presence of natural enemies increased barley yields 303 kg/ha, preventing 52% of yield loss due to aphids

Source: Balmford and references within (2008)

3.3 Soil formation

Balmford *et al.*, 2008 identified four main ways in which wild nature contributes to benefits that can be obtained from agricultural crops by improving or retaining farmland soil quality. These are internal effects (soil biota); conversion effects (when non-agricultural land is converted to agriculture); neighbourhood effects (when neighbouring, non-agricultural, systems contribute to soil quality in croplands); and wild fertilisers (e.g. guano).

Internal effects are from the soil fauna and flora, that affect soil properties and therefore the quality of the soil for agriculture. They can affect nutrient fixation (e.g. nitrogen fixation by bacteria); nutrient cycling (e.g. in organic matter decomposition, by fungi, bacteria and dung beetles); soil structure (e.g. by plant roots and termites); water regulation, particularly water holding capacity and drainage (e.g. by plant roots, termites, micro-organisms and earthworms); uptake of water and nutrients (mycorrhizal fungi); erosion regulation (e.g. by vegetation cover and leaf litter); suppression of pests and diseases (e.g. by mycorrhizal fungi).

However, as agricultural intensification occurs, the regulation of functions through soil biodiversity is progressively replaced by regulation through chemical and mechanical inputs (Balmford *et al.*, 2008, and references therein). Conversion effects refer to the expansion of agriculture into areas occupied by natural ecosystems, profiting from the soil quality created by the latter. Neighbourhood effects include the contribution of neighbouring, non-agricultural, systems to improve or maintain soil quality in croplands. Wild fertilisers can be used instead of chemical ones, for example: guano, seaweed, peat and fishmeal.

Further aspects of soil formation are discussed in Chapter 4 with regards to the provision of clean drinking water and the protection of property.

4 Benefits

4.1 Food

The provision of food is typically the principal aim of agricultural ecosystems (though as discussed below, some systems primarily produce materials or energy feedstocks). All of these foods are of course forms of biodiversity, though modern crop varieties and livestock breeds are far removed from their natural forms as a result of selective breeding, and in some cases genetic modification. However, food is also derived from some traditional breeds, semi-domesticated domesticated but otherwise natural species (e.g. Reindeer) and a range of wild flora and fauna. Some foods also provide added medical value which relate to physical health benefits (see Section 4.6).

A key linkage is that the productivity of food production systems (and all other agricultural products) is determined by numerous supporting (e.g. nutrient cycling) and regulating ecosystems services (e.g., water regulation, biological control and pollination), as described in the preceding chapter.

As the provision of food is based on the use of resources extracted from ecosystems, according to the TEV framework food related benefits have a direct and consumptive use value. Furthermore, an option value can be attributed to associated genetic resources and seed banks etc as these may enhance the future potential use of food related benefits (as are all benefits that are underpinned by genetic resources).

4.1.1 Agricultural food crops

While 10,000 to 15,000 plants are considered to be consumable, only about 7,000 have been used in agriculture, not more than 150 plant species are cultivated (Esquinas-Alcázar, 2005) and 30 crops are currently supplying 90% of the global calorie intake (Wood *et al.*, 2005). Within the EU the most common food crops are[3]:

- arable cereals (e.g. wheat, barley, oats and maize);
- root crops;
- fresh vegetables, melons and strawberries;
- pulses
- oil-seed crops (e.g. oil-seed rape, linseed and sunflower);
- olives (for fruit and oils);
- fruit and berry plantations; and
- grapes.

There are now many varieties of these crop types in use as a result of selective breeding etc, but this increase in diversity is often at the expense of older traditional forms, which fall out of favour and may become extinct. The loss of local and traditional varieties leads to genetic erosion by reducing the available gene pool for farmers for future breeding. Crops (and their wild relatives, see further below) provide genetic resources for breeding new crop varieties, through classical breeding or the use of biotechnology. According to Esquinas-Alcázar, 2005 (cited in Balmford, 2008), this diversity provides an important means of responding to environmental and demographic changes. Consequently, the loss of genetic diversity may reduce the resilience of agricultural ecosystems to, for example, climate changes and the appearance of new pests and diseases (Wood *et al.*, 2005).

Despite a general shift from traditional varieties (locally adapted and developed populations) to more widely adapted modern varieties, some farmers continue to use traditional varieties of crops in some parts of Europe (e.g. the Alpine region and eastern European countries). This tends to be in less productive regions and are generally associated with extensive production systems. This is because the use of such varieties provides some benefits, such as spreading the risk of crop failures from uncertain weather patterns and disease, and uncertain markets. This is especially important for low-income farmers, and the use of some traditional varieties may also offer the opportunity to access new markets (Cassman *et al.*, 2005), though they may be small niche markets.

According to the FAO (Wood *et al*, 2005) there is a large potential for improvement and greater use of neglected and underutilised species, but also for the domestication and improvement of new crops, especially regarding fruits, vegetables and industrial crops. The conservation of genetic resources can be achieved by using two approaches. The first approach refers to ex-situ conservation, and mainly includes measures such as the development of seed banks and collecting germplasm. The second approach relates to the conservation of wild crop relatives through the protection of their natural habitat and the maintenance of traditional agricultural landscapes.

Traditional orchards are one such landscape which are increasingly being considered to be of biodiversity conservation importance. They usually hold a high diversity fruit trees, which have been selected by local farmers and thus are adapted to site specific conditions (Herzog 1998). Consequently, there are an

[3] Eurostat http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-ED-08-001/EN/KS-ED-08-001-EN.PDF

estimated 10,000 varieties of apples and 1,000–2,000 varieties of plums in the world (Herzog, 1998 and references therein). In Germany alone, there are about 1,400 varieties of apples and altogether 1,500 varieties of pears, cherries, walnuts and plums (Herzog, 1998 and references therein). By far the largest proportion of these varieties can be found exclusively in traditional orchards, whereas commercial production in intensive fruit plantations is based on only a few dozen genotypes (Herzog, 1998 and references therein).

A recent project, co-financed by the European Commission, examined the parentage amongst well-known grape varieties such as Chardonnay and Syrah and abandoned varieties that were rarely cultivated, but were conserved in grapevine collections. It was discovered that a combination of new and old varieties could produce new high quality varieties (European Communities, 2007), which demonstrates the benefits that the conservation of genetic diversity can offer.

4.1.2 Domesticated and semi-domesticated animals

Livestock and livestock food products (i.e. meat, eggs and milk) are estimated to make up over half of the total value of agricultural gross output in industrialised countries, and about a third of the total in developing countries (Wood *et al.* 2005). Furthermore, production of milk (cattle and buffalo), beef, and mutton and goat meat has increased in relation to population growth rates, whilst poultry meat production has shown a dramatic increase, with a nine-fold increase between 1961 and 2001 (Wood *et al.*, 2005).

Livestock production takes place in a variety of agricultural systems, including extensive semi-natural habitats, other grasslands, orchards, pastoral woodlands and arable systems where grass and other crops may be used as fodder for housed livestock. However, the increase in production of livestock and livestock products has led to widespread intensification and increase in industrial production systems.

As with agricultural crops, the diversity of species in use in agriculture is very small. Of an estimated 15,000 species of mammals and birds, some 30-40 have been used for food production, with fewer than 14 species providing 90 per cent of global livestock production (Wood *et al.*, 2005). Globally, 6500 breeds of domesticated animals exist, including cattle, goats, sheep, buffalo, pigs, horses, chicken, turkeys, ducks, geese, pigeons, and ostriches. A third of these breeds are under near-threat of extinction, with 5,000 domesticated animal and bird breeds lost over the past century (Cassman *et al.*, 2005). The loss of local species and varieties caused by intensified farming systems is continuously reducing the genetic resources available for farmers and the potential for future breeding. Taking into account the increasing global demand for livestock and their products, problems resulting from the diminishing genetic pool are likely to become increasingly important (Wood *et al.*, 2005).

As already mentioned with regard to domesticated crop varieties, the use of traditional breeds still continues in some parts of Europe (e.g., Alpine region, Eastern European countries). Some are retained for cultural reasons or because they are particularly well adapted to specific local conditions. For example, local breeds of cattle in the Zegocina region of Poland were found to be more suitable for the hilly and mountainous conditions than modern breeds (ITDG). The local cattle are also resistant to various diseases and help to protect the landscape from erosion through sustainable grazing. As a result Zegocina has retained the aesthetic values of its landscape that attract visitors, which supports agro-tourism developments. Traditional breeds also provide opportunities for accessing new markets or adding value to existing markets. In addition, their potential contribution to the conservation of a diverse genetic pool for breeding purposes also contributes to the increasing interest in traditional breeds.

Example

A study by Cicia *et al.* (2001) aimed to provide policy-makers with information on the value of genetic diversity derived from traditional animal breeds. It estimated the benefits of establishing a conservation program for the threatened Italian "Pentro" horse, a local horse breed that has been reared for millennia in a Southern Italian wetland where it is now strongly tied to the traditions of the region. Currently it faces extinction as only 150 horses survive. The economic benefits derived from the conservation of the Pentro horse were estimated from choice experiments and contingent valuation survey data. The study included interviews in which the payment scenario to ensure the protection of the Pentro horse were proposed. A brief summary illustrating the present situation for the horse and the conditions necessary to ensure its survival was given and then the financial aspect of the protection program were introduced. In order to make up for the scarce public financial resources the families of the Molise region were requested to sponsor the Pentro horse project by means of a single donation. This resulted in a mean willingness-to-pay (WTP) of 33 Euros per household, which if multiplied by the number of families living in the study region led to an estimate of 3.8 million Euros.

4.1.3 Wild plants/herbs (foliage & seeds) and fungi

Wild plants and fungi provide indirect support to agricultural production through nutrient cycling and soil formation etc, and contribute to the maintenance of genetic resources that may be of importance in the future. Furthermore, wild sources of food such as leafy vegetables, fruits, nuts, berries or fungi can be of cultural importance and may significantly contribute to the diets of some rural populations (Wood *et al.*, 2005).

4.1.4 Wild animals (game)

The harvesting of wild animal products (mainly birds and mammals) can be an important contribution to diets, cultural identify and in some cases the economies of some rural areas of Europe. The main countries game producing countries in Europe are located in Central Europe, and include Poland, Austria, Hungary and Slovenia. Large numbers of game are also shot in Germany, France and Czech Republic and are mainly sold within local/regional markets. The hunting of game is also important in England and Scotland for Red Grouse, Pheasants and Red Deer, and Spain for red deer (Bertolini, 2005). Although the market for and direct value of game in England and Scotland is rather insignificant revenues from paying hunters can be very high as hunting is a high-income related sport rather than a means of obtaining food. Consequently the revenue from Red Grouse hunting can be an important contribution to the economic viability of maintaining livestock production in some upland areas (Hudson & Newborn 1995). Furthermore, the management of moorland for grouse contributes to the maintenance of habitats that are of considerable nature conservation importance (Thompson *et al.* 1997).

Although rural communities may depend most on the use of wild meat, townspeople can also be major wild food consumers in some countries. Going from a rural to an urban environment, wild meat consumption become less a nutritional need and more related to preferences based on tradition and status (Balmford, *et al.*, 2008 and references therein). Accordingly, even if wild meat becomes substantially more expensive than domestic alternatives consumption by urban populations will continue to some extent. Urban demand therefore creates the opportunity for trade, which can become an important source of income for local people (Balmford, *et al.*, 2008 and references therein).

4.2 Materials

The production of a wide range of materials, such as fibres and timber, are important provisioning services of agricultural ecosystems, second only to the provision of food. As with food, these services require fertile and productive agricultural systems, and therefore also depend on core and beneficial processes such as water and climate regulation as well as nutrient cycling and soil formation. Genetic and species diversification are also important contributors to the diversity of the material products produced in agricultural ecosystems.

Materials are resources that are directly extracted from ecosystems and therefore are of direct and consumptive value. Furthermore, an optional value can be derived from their provision due to the potential future value of such goods.

4.2.1 Fibres from cultivated plants and wild plants

Flax (*Linaceae usitatissimum* varieties), Hemp (*Cannabis sativa*), various commercial species of cotton (*Gossiypium* spp) and jute (mainly from *Corchorus capsularis* and *Corchorus olitorius*) are the most important fibres produced from agricultural systems. Although the world fibre production has grown by 63 % in the last two decades (US Department of Agriculture in Sampson *et al.*, 2005), natural (cellulosic) fibres are increasingly being substituted with synthetic non-cellulosic fibres.

Cotton can still be considered to be the single most important textile in the world, accounting for over 40% of total world fibre production. Countries such as China, the United States, India, Pakistan and Russia dominate the global production, while 80 countries around the world produce cotton. The fibre can be produced on irrigated as well as rain-fed cropland. However, cotton demand has led to increasingly intensive agricultural production methods and major irrigation projects throughout the world. Reasons for a declining production in some regions vary between competition for irrigation water, loss of productive soils, increased competition from synthetic fibres and crop pests (Sampson *et al.*, 2005).

Before the growth of the cotton industry, the major source of cloth fibre was flax (in the form of linen. Its production has strongly declined over the last decades, with China, France and Russia being the largest producers today.

Other important fibres derived from crops are hemp and jute. Hemp was commonly used to produce various kinds of cordage, paper, cloth or other products, but its production has dramatically declined in the last decades (Sampson *et al*., 2005). The same applies for jute, which today is mainly produced in India and Bangladesh and used for burlap, twine and insulation.

4.2.2 Timber, cork and other plant materials

Agricultural ecosystems can often include small areas of woodland on farms, ranging from patches of old natural woodland to plantations of non-native tree species and scattered trees in hedgerows and fields. An old form of agricultural production includes wood pastures, which combine open woodland with grassland grazed by cattle, horses or sheep. Traditional *Dehesas* in Spain and *Montados* in Portugal include mixtures of open oak woodland with grassland and low intensity cereals. These are often used by free ranging pigs, which benefit from the oak acorns. Such low intensity habitats have high structural diversity and therefore support high levels of natural biodiversity. Besides being a source of food, wood pasture can support local communities with timber which is used as a building material, and thus represents a second source of income for rural households. Timber from hedges and shelter-belts can also be used for local crafts and provide a wide variety of products such as furniture, toys and decorative objects (Sampson *et al*. 2005). Young trees and coppiced woodland also provides straight and flexible poles that are used for fencing and basket-making etc,

Another important form of agroforestry involves the production of cork from the Cork Oak (*Quercus suber*) in the Mediterranean region. Cork is the sixth highest global non-timber forest product (NTFP in WWF, 2006) export with an estimated annual export value of around USD 329 million. Cork products generate approximately □1.5 billion in revenue annually (Natural Cork Quality Council, 1999, in WWF 2006).

Cork oak landscapes extend over an area of almost 2.7 million hectares, including countries such as Portugal, Spain, Algeria, Morocco, Italy, Tunisia and France, and are an important source of income for more than 100,000 people (WWF, 2006). Cork is mainly used for the production of stoppers for the wine industry, but can also be used for a variety of other products, from clothes and shoes to fishing buoys, roofing material and floor tiles. It is obtained by cutting off layers of bark from the oak tree, which are then naturally restored by the tree. Cork oak trees may be grown in plantations or can be found in *dehesas* and other similar wood pasture landscapes as described above. While supporting biodiversity, soils and water protection, cork oak landscapes are also an important income source for the rural population in the respective regions.

Straw from cereal crops is also a useful material, which is used for animal bedding and in some areas it is commonly used for thatched roofing. It is also being increasingly used in the manufacture of straw-based bricks and insulation materials.

4.2.3 Fibres, skins and fur from livestock

Animal skins and fibres, such as wool, can form an important component of clothing and shelter for many societies (particularly remote rural populations), and are part of the wide range of products that livestock can provide. Due to increasing competition from synthetic fibres, wool production has suffered from a decrease in demand over the last decades (Sampson *et al.*, 2005). At the same time an increase in hide production has taken place, influenced by population growth and intensification of animal agriculture. Skins and hides are usually by-products of meat production, and are therefore influenced by the increasing demand for meat (Sampson *et al.*, 2005).

The importance of agricultural biodiversity with respect to the provision of fibres, skin and hide from livestock is similar to that described for the provision of fibres from cultivated plants. The maintenance of a range of breeds with a diverse genetic pool provides well adapted animals that can used in a wide variety of traditional agricultural systems that can provide a range of products and benefits that can be of importance for rural populations.

4.2.4 Other

Besides fibres, timber, cork and hide, oils extracted from the seeds of plants such as *Linaceae usitatissimum* varieties (flax seed oil) can also be part of the wide range of materials provisioned by ecosystems. They can be used for leather treatment, industrial lubricants, wood finishing products and paint binders.

Plant biomass and oils (e.g. from oil-seed rape is also increasingly used for energy production – see Section 4.4. below.

4.3 Water

Ecosystems such as grasslands and wetlands play important roles in the hydrological cycle, contributing to water provision (*quantity*, defined as total water yield), regulation (*timing*, the seasonal distribution of flows) and purification (*quality*, including biological purity as well as sediment load) (Balmford *et al.*, 2008). These contributions result in the final benefit of clean drinking water, which has direct and consumptive values as well as an optional value due to its value for future use. In addition, the provision of clean water is directly linked to other final benefits such as food production and physical health (see Sections 4.1 and 4.6). Water is essential for sustaining human health, with a basic per capita daily drinking and sanitation requirement of 20 to 40 litres of water that is free from harmful contaminants and pathogens (Vörösmarty *et al.*, 2005 and references therein).

Ecosystems also obviously need water e.g. to support plant photosynthesis, growth and reproduction. The quantity needed can strongly differ amongst ecosystems, with vegetation cover being one of the determining factors. The quantity of water taken up by vegetation, for example, increases when moving from grassland to forest ecosystems. Similarly, invasive alien plants are often intensive users of water as vigorously growing vegetation tends to use more water than mature vegetation. Therefore the value of native vegetation in providing water can be significantly higher than its non-native substitute (Balmford *et al.*, 2008 and references therein).

In addition, vegetation cover increases infiltration of surface water into the ground, thus ecosystems and their vegetation cover can support the recharge of ground water reservoirs during wet/rainy periods. This is also particularly important for agricultural production with regard to irrigation during the dry season (Vörösmarty *et al.*, 2005).

Soil biodiversity plays an essential role in the purification of water within agricultural ecosystem. Soil organisms modify, for example, the physical structure and the hydraulic properties of their surroundings, and their diversity responds to the management of cultivated systems. In general, tillage, monocultural production, pesticide use, soil erosion and contamination have negative impacts on soil biodiversity. In addition, land use changes that compact soils and reduce infiltration are associated with deficiencies in groundwater recharge. On the other hand, practices such as no-till or minimal tillage, the application of organic materials (e.g. livestock manures, and compost), balanced fertiliser utilisation, and crop rotations generally have a positive impact on soil organism densities, diversity, and activity. Farm practices can thus improve soil condition, and even be responsible for the creation of soils (Cassman *et al.*, 2005 and all references therein).

While demand increases, supplies of clean water are diminishing due to increasing pollution of inland waterways and aquifers as well as depletion of fossil groundwater. These trends are leading to a competition over water in both rural and urban areas. Particularly important will be the challenge of simultaneously meeting the food demands of a growing human population and expectations for an improved standard of living that require clean water to support domestic and industrial uses (Vörösmarty *et al.*, 2005).

Example

A study by Travisi and Nijkamp (2008) addressed the negative externalities associated with pesticide use in agriculture. It aimed at estimating the value of reducing the multiple impacts of pesticide use by using a choice experiment as well as a contingent valuation method study. The resulting estimates show that, on average, respondents were willing to accept an increase of the cost for agricultural goods (in particular foodstuff) that are produced in an environmentally benign way. The study found that mean WTP for biodiversity was 4.86 Euros per household per month, 0.43 Euros to protect human health and 1.88 Euros for groundwater protection. The results of the contingent valuation exercise showed that the mean WTP estimate was approximately 20 Euros per household per month for a scenario eliminating all risks associated with pesticide application in agriculture.

The study focuses on the use of pesticides, but a clear link to agricultural biodiversity is not given, which makes it difficult to use the values to describe benefits arising from it.

4.4 Energy

Energy derived from firewood, charcoal, biomass, biofuels, and the use of dung is defined as a provisioning service with a direct and consumptive value for human well-being. Similarly to materials and food, it has an optional value due to its potential future use.

4.4.1 Fuelwood and charcoal

In 2000, the world used approximately 1.8 billion cubic meters of fuelwood and charcoal (FAO in Sampson, *et al.* 2005). People harvest fuelwood by cutting or coppicing shrubs, by lopping branches off mature trees, or by felling whole trees. In many rural areas, local people prefer fuelwood from species that will regenerate after coppicing (Sampson, *et al.* 2005, and references therein). Charcoal consists of remnants of wood that have been subject to decomposition under heat, which creates a less bulky product with double the energy per unit mass , that is more convenient for transport, marketing and sale than fuelwood.

Cooking and heating are the major end uses of fuelwood and charcoal. They can be important for commercial applications such as bakeries, street food, brick-making, smoking foods, and curing tobacco and tea, and an important source of income and employment in many rural areas (Sampson, *et al.* 2005). In some traditional agricultural ecosystems, such as wood pastures, the supply of firewood can provide an important second source of income whilst providing other benefits at the same time (e.g. timber, acorns for livestock, nuts and berries).

4.4.2 Biomass energy (excluding fuelwood and charcoal)

Industrial biomass includes energy systems generating electricity, heat or liquid fuels from fuelwood, agricultural crops (e.g. *Miscanthus*, straw or willow) or manure. Excluding fuelwood and charcoal, in 2000 biomass may have provided 5 % of global world energy (Sampson *et al.*, 2005, and references therein).

Biomass energy crops include short-rotation coppice (SRC) such as willow, and *Miscanthus*, which prefer mild climates and are generally grown at altitudes below 200m. They are most likely to be grown on medium to poor quality agricultural land (McDonald *et al.* 2004).

The current extent of biomass crops in Europe is currently very low. For example, commercial growing of *Miscanthus* and SRC in England Wales in 2007 was only 12,627 and 2,600 ha respectively, which is approximately 0.1% of the area of crops and grassland (Tucker *et al.* 2008). But it is expected that the production of biomass crops will increase considerably in the EU in the near future in response to the EU's greenhouse gas emissions reduction targets and, in particular, its package of climate and energy legislative proposals (which were put forward by the European Commission on 23 January 2008). These proposals include increasing the share of renewable energy in the overall primary energy supply to 20 per cent by 2020; including increasing the share of renewable energy in transport fuels to 10 per cent by 2020 (with some sustainability safeguards). The European Parliament and EU Council are currently considering the adoption of this package of legislation.

However, to meet the EU's increasing demand, it is likely that a significant share of future biomass use will be from imported feedstocks such as woodchips and waste from palm oil processing.

On a small scale the burning of dung and the use of peat can be locally important sources for cooking and heating, especially for rural and remote households without access to gas or electricity supplies.

4.4.3 Biofuels

The term 'biofuels' is applied to all liquid and gaseous fuels derived from organic materials. Most such fuels are liquid and used to power vehicles, although biogas can also be used in stationary plant, most notably for heating and drying on or near farms, or sometimes for electricity production. According to Tucker *et al.* (2008), it is expected that in the future biofuels may be able to be manufactured from a wide variety of organic materials (as described above under Biomass), but current 'first generation' fuels are primarily bioethanol made from sugar cane or agricultural crops containing sugars or starch (principally sugar beet in Europe, and maize in the US); and biodiesel based on vegetable oils (principally rapeseed oil in Europe, but also soya and palm oil elsewhere). Liquid biofuels can be blended into conventional road fuel supplies, or in some cases used in high biofuel blends in dedicated engines.

Agricultural biogas is currently a very small-scale technology, most often produced from dung and other carbo-hydrate based agriculture products, mixed with water, stirred and warmed inside air-tight digesters (Sampson, *et al.*, 2005).

As with biomass, current agricultural biofuel production in the EU is low, with a large proportion of feedstocks coming from imports. For example, from calculations based on monthly biodiesel production (3.88 million litres) and bioethanol production (3.26 million litres) it is estimated that approximately 26,000 ha are used for biofuel production in the UK (6,000 ha as oil-seed-rape and 20,000 ha as sugar beet), which amounts to just 0.57% of the current area of arable crops (Tucker *et al.* 2008).

As with biomass (see above), biofuel production in the EU is expected to rise sharply as a result of its proposed package of energy policies energy. Potentially a large proportion of arable land could be used for biofuel production, although this will depend upon the relative economics of growing biofuel crops in the EU and elsewhere versus food or other end uses. But supply of first generation biofuels is likely to be limited by sustainability concerns over feedstock sources (especially in biodiversity rich regions such as south America and south-east Asia). The European Commission's 10 per cent target for road fuels for 2020 is proving controversial and the Commission itself emphasises that not all of this would come from first generation liquid biofuels.

4.4.4 Other

Another important energy source in some regions is the use of draught animal power. Domestic work animals exist in all regions of the world, and are especially important for food security in smallholder farming systems. Besides being used for transport purposes animals may be used directly for farming operations, especially ploughing. Many different types of animal are employed, particularly cattle, buffaloes, horses, mules and donkeys (FAO). However, the use of animals in farming in the EU is now limited to marginal areas and declining rapidly.

4.5 Property

Agricultural biodiversity can contribute to the avoidance of damage or the reduction of impacts from natural hazards such as flooding, storms, landslides/rockfalls and wild fires. Benefits derived from these services also include physical health (avoided injury) and psychological wellbeing (sense of security), which are discussed later in Sections 4.6 and 4.7. These services can be considered to be regulating services in accordance with the MEA terminology and indirect and option values according to the TEV framework. Here individuals and the communities benefit from ecosystem services that help to avoid damage to property and persons in the present and in the future.

Ecosystems play an important role in modulating the effects of extreme events, and in particular in protecting human well-being from the impacts of natural hazards. They affect both the probability and severity of events, and they modulate the effects of extreme events. Impacts of natural hazards can be lessened through maintenance and management of the environment (e.g. vegetation) and through natural or human made geo-morphological features (De Guenni, 2005).

4.5.1 Flood damage

As already described in Section 4.3, soil biodiversity can have an important impact on the provision of clean water, and is strongly influenced by the intensity of agricultural production. Soil organisms also affect soil structure, which determines its capacity to hold water. Therefore sustainably managed and structurally diverse systems can provide important flood prevention benefits, by increasing water residence time within the ecosystem. Residence time is defined as the time taken for water falling as precipitation to pass through a system. The longer the residence time, the larger the buffering capacity to cope with peak flood events (De Guenni *et al.*, 2005).

4.5.2 Wildfire damages

Several ecosystem conditions are related to fire regulation, with the amount of vegetation playing a major role (De Guenni, 2005). Land cover and land use can affect fuel load, flammability, number of ignition events and the capacity for a fire to spread. Land use practices such as pasture maintenance can lead to a higher number of trigger events, but they can also be used as firebreaks and so contribute to fire management.

For example, Moreira and Russo (2007), focused on the impact of agricultural land abandonment on wildfire events and biodiversity in the Mediterranean region. According to their study, agricultural land abandonment is leading to a recovery of scrubland and forests which are replacing open habitats, thus increasing wildfire events due the higher amount of available fuel.

4.5.3 Storm damage

Besides helping to regulate floods and wildfires, agricultural systems can also help to reduce the impact of storms. Storm damage can be reduced through the maintenance and management of vegetation and through natural or human-made geomorphological features. Information on the effects of agricultural practices on extreme weather in the EU could not be found over the course of this study. However, evidence from elsewhere suggests that appropriate land management can provide important benefits. In 1998, a study (cited in UNEP-WCMC, 2007) analysed the effects of Hurricane Mitch in Nicaragua across sites differing in biodiversity. On average, plots on less intensive farms had more topsoil, higher field moisture, more vegetation, less erosion and lower economic losses after the hurricane than control plots on more intensive farms.

4.6 Physical health

End benefits such as the provision of pharmaceutical crops and pharmaceuticals/herbal remedies from wild plants/fungi are defined as provisioning ecosystem services and can be attributed a direct and consumptive value. Other final benefits related to physical health are either directly linked to regulating services (e.g. avoidance of air pollution) or are defined as cultural services (e.g. recreation). They usually provide direct and non-consumptive use values as well as option values. Processes leading to benefits such as the avoidance of injuries through storm protection, fire resistance or water regulation have been addressed in the section above (Section 4.5 – Property).

4.6.1 Pharmaceuticals and botanical medicines

Bioprospecting (i.e. biodiversity prospecting) is the exploration of biodiversity for new biological resources of social and economic value (Beattie *et al.*, 2005). This can lead to a wide variety of products, including pharmaceuticals and botanical medicines.

A multitude of drugs have been derived from a wide range of organisms, including bacteria and fungi (terrestrial and marine), plants, algae, and a variety of invertebrates. One of the most famous examples is the discovery of penicillin. Others include the derivation of drugs such as quinine, chloroquine, mefloquine, and doxycycline and today artemisinins from the Chinese herb Qinghao, and used for Malaria treatments (Beattie *et al.*, 2005).

Newly developed pharmaceuticals can be based on biochemical components of natural products or synthetic analogues of natural products. On average, 62 % of new, small-molecule, non-synthetic chemical entities developed for cancer research over the period 1982-2002 were derived from natural products. In antihypersensitive drug research, 65% of drugs currently synthesized can be traced to natural structures (Beattie *et al.* 2005, and references therein). It has been estimated that 25% of the drugs sold in developed countries and 75% of those sold in developing countries were developed using natural compounds (Pearce and Puroshothamon, 1995).

Botanical medicines are usually whole plant materials, and their discovery (as well as of new pharmaceuticals) highly depends on indigenous and traditional knowledge of their medicinal effect. In Europe, for example, aspirin was first isolated from *Filipendula ulmaria* (Meadowsweet) because it had long been used in folk medicine to treat pain and fevers (Beattie *et al.*, 2005). Active ingredients of the *Digitalis purpurea* (Common Foxglove, Purple Foxglove or Lady's Glove) are important for the treatment of heart ailments. Its leaves were first used to treat congestive heart failure (Beattie *et al.*, 2005). The plant has been cultivated in many old home gardens in Europe since the 16th century.

Thus it is clear that the retention of wild species of plant, fungi and fauna within European agricultural systems may have as yet unknown pharmaceutical and other health benefits. Furthermore, revenues from botanical medicines can be very large. For example, annual sales of medicinal Ginkgo, Garlic, Evening Primrose, and *Echinacea* in Europe average $350 million (ten Kate and Laird, 1999 in Beattie *et al.*, 2005).

4.6.2 Clean air

Ecosystems can effect the concentrations of many atmospheric compounds (i.e. pollutants) that have a direct human health impacts. Ecosystems are often both sources and sinks for various trace gases that undergo complex atmospheric reactions, simultaneously affecting several aspects of air quality in different ways. It is therefore often hard to quantify the current net effect of ecosystems or of ecosystem change on a particular aspect of air quality (House *et al.* 2005).

A proxy for estimating atmospheric cleansing capacity (or tropospheric oxidizing capacity) is the atmospheric concentration of hydroxide (OH). The reactions are complex but, generally, emissions of nitrogen oxides (NO_x) and hydrocarbons from biomass burning increase tropospheric ozone and OH concentrations. Methane (CH_4) and carbon monoxide (CO) are removed by OH, so emissions of these gases from wetlands, agriculture, and biomass burning decrease OH concentration (House *et al.*, 2005).

According to House *et al.* (2005) the main pollutants and impacts on human health are:

- **Particulates**: particles small enough to be inhaled into the lungs, typically less than 10 micrometers (PM10), are associated with the most serious effects on humans, including respiratory disease, bronchitis, reduced lung function, lung cancer, and other cardiopulmonary sources of mortality and morbidity.
- **Nitrogen oxides** (NO_x): direct respiratory effects and respiratory effects of aerosols.
- **Ammonia** (NH_3): hypoxia, pfisteria, respiratory effects.
- **Sulphur oxides** ($S0_x$): human health: respiratory effects of aerosols.
- **Volatile organic compounds** (VOC): aerosol precursor (terpene), respiratory effects.

Ecosystems provide the “service” of atmospheric cleansing as they function as sinks for the different air pollutions. Plants facilitate the uptake, transport and assimilation or decomposition of many gaseous and particulate pollutants. This leads to reduced amount of pollutants, with a direct effect on people’s health by reducing respiratory diseases (House *et al.*, 2005).

Some agricultural ecosystems can reduce the impacts of these pollutants by intercepting pollutants, such as particulates (e.g. by tall trees in hedgerows, shelter belts and farm woodlands) and absorbing gases such as NOx by grassland and other vegetation. However, in contrast intensive agriculture is a major source of ammonia (mainly from livestock farming), which can lead to significant health impacts. In addition many semi-natural habitats of high conservation are at risk in the EU as a result of nutrient-rich rainfall caused by agriculture related emissions of ammonia {NEGTAP, 2001 #477}.

4.6.3 Others

Further benefits from ecosystem services and goods with impact on physical health include the avoidance of water pollution (contamination), the stimulation and provision of areas for exercise, and balanced diets due to diversification of food sources. They are referred to in the respective sections on water (4.3), physiological well-being – recreation (4.7) and food (4.1).

4.7 Physiological well-being

End benefits related to physiological well-being usually are derived from cultural and social ecosystem services. These include recreation and amenity as well as education. Following the TEV framework, those services provide direct and non-consumptive use values as well as option values. Furthermore, non-use values can be attributed to the benefits described below.

4.7.1 Recreation

A variety of agricultural landscapes in Europe provide opportunities for recreational activities, such hiking, biking, fishing, swimming, camping, horse riding, hunting, bird- and nature-watching. Furthermore, with a growing worldwide population and people having increasingly more leisure time and higher incomes, recreational activities in natural areas and cultural landscapes are also very likely to increase in the future. Tourism is the largest industry in the world economy and it is also one of the fastest growing sectors (de Groot *et al.*, 2005). This will have major impacts on issues such as income, jobs and business opportunities. These impacts may come in three main forms: *direct*, *indirect* and *induced* expenditures (Christie *et al.*, 2005). Direct impacts result from users spending their money on food and drink, accommodation, forest recreation services, souvenirs, equipment, car parking, admission fees and so on. Businesses and public organisations that receive direct expenditures will need to put some of these earnings in the purchase of supplies. Those used in the local economy generate *indirect* impacts. *Induced* impacts arise from the re-spending of wages, salaries and profits earned in the local economy.

However, to reduce the negative impacts that the sector can have on ecosystems, the promotion of a sustainable tourism is essential. Sustainable tourism has been defined as all forms of tourism development, management and activity, which maintain the environmental, social and economic integrity and well being of natural, built and cultural resources in perpetuity" (FNNPE, 1993).

Important drivers for recreation and ecotourism can be aspects such as

- pleasure from the landscape and nature (nature users and convenience users);
- education, religious pilgrimages, social relations (social users);
- adventure, testing personal limits (active users); and
- physical exercise.

It is therefore clear that agricultural landscapes do provide recreational opportunities and these could increase in future, leading to new opportunities for rural incomes etc/. These opportunities are likely to be greatest in areas with large expanses of accessible natural and semi-natural landscape with high biodiversity, aesthetic and cultural values. However, the provision of footpaths, open access and farms visits etc can also provide sought after recreation opportunities in intensively managed farmland.

Example

In an OECD case study in Austria (OECD, 2002), the authors refer to the importance of agricultural landscapes for tourism in the alpine region. They collected statistical data on travelling habits and turnover of tourists. In 1998, 17 % of the Austrians interviewed stated hiking as their main reason for tourism (20 % in 1999); only 1.1 % stated mountaineering. It was roughly estimated that the main motivation for about 20 to 25 % of tourist visits to the Alps is to enjoy the natural and agricultural landscape. Calculated from the turnover for tourism, this brings in about ATS 30 to 40 billion over one year (circa 2-3 billion Euros today).

However, it is impossible to assess what tourism would be like if the agricultural landscapes were not used, maintained and properly managed, and how this links to different types of agricultural uses and corresponding levels of agricultural biodiversity.

4.7.2 Amenity

People all over the world derive at least to some extent aesthetic pleasure from natural environments. The beautifulness of nature is often obvious and self-evident, and very difficult to grasp (de Groot *et al.*, 2005). Increasing deterioration of natural landscapes and the increasing demand for aesthetically pleasing natural landscapes have increased scientific interest in the exploration of the value of cultural services such as an appreciation and observation of flora and fauna; collection of plants as ornaments and the appreciation of open landscapes and green space.

In the MEA de Groot *et al.* (2005) emphasises three important general findings about aesthetic services:

- people's preference for natural over built environments;
- people's preference for park-like settings; and
- the existence of individual differences in preferences for wild versus managed landscapes.

According to several studies, in general people prefer natural over built environment, going so far that even plain grassland is usually considered equally or more beautiful than any built environment (Ulrich, 1983, Kaplan and Kaplan, 1989; Hartig and Evans, 1993). Preferences often strongly depend on the ecological status of the environment, with people especially looking for healthy, lush and green/colourful landscapes. However, this does not mean that aesthetic quality matches the ecological quality of an area. They might even strongly diverge from each other.

A study by Kellert (1993) states that especially European, North American, and Asian population consistently prefer park-like settings with characteristics such as depth, (half)-openness, uniform grassy coverings, presence of water, absence of threats, and a scattering of trees. Wilderness is often seen as something negative and threatening. However, differences in the preferred degree of "wilderness" exist between groups and cultures (Staats, 2003) In particular, farmers and low-income groups have been found to prefer managed natural landscapes with a high degree of human influence, while people from urban locations and high income groups have been found to prefer wild natural landscapes with a low degree of human influence.

The remaining areas of aesthetically valuable landscapes are becoming more important as urbanisation, industrialisation and globalisation are making life for people more stressful (with increasing noise and air pollution), especially in urban areas.

From an examination of studies, de Groot *et al.* (2005) identify the following final benefits that are associated with aesthetic values of nature:

- restorative effects, e.g. decreased levels of stress, mental fatigue, and aggression;
- decreased need for health care services and decreased levels of aggression and criminality due to restorative effects of contact with nature;
- increased health due to increased levels of activity stimulated by the presence of attractive nature in the nearby work and living environment;
- increased social integration due to the function of urban natural settings as social meeting places;
- improved motoric development in children who regularly engage in outdoor activities;
- increased worker productivity and creativity in offices with plants or views of nature;
- economic benefits for society due to enhanced employability, reduced criminal behaviour, and lower substance abuse by disadvantaged youth who participate in wilderness programs; and
- increased value of real estate property in natural surroundings.

Additional benefits provided by contact with ecologically valuable nature, such as wilderness areas, include increased self-confidence and personal growth. Furthermore, these benefits may be of crucial importance to certain groups, such as teenagers from disrupted families.

Example

The following study, included in an OECD report (OECD, 2002) on services provided by agriculture in the Austrian Alpine region, is an example of how strongly amenity services are linked to recreation and tourism, being one of their strongest drivers.

An analysis of the willingness to pay for the management of agricultural landscapes (Pruckner, 1994) was carried out using a contingent valuation method. It was based on questioning over 4,500 holidaymakers in Austria. The empirical part of the study was designed to determine the maximum amount per day a tourist would be willing to pay to farmers to properly manage the landscape. The management work was described briefly in the introduction to the questionnaire, and it was mentioned that the existence of mountain farming was endangered. An average of ATS 9.2 (circa 0.6 Euro today) per holidaymaker per day was obtained for the whole of Austria, which was extrapolated to give a total of ATS 720 million (circa 52 million Euros today). The Austrians' esteem for the management of cultivated landscapes was not directly assessed, but the author stated in 1994 that transferring benefits from another valuation approach, an annual amount of approximately ATS 9 billion (circa 0.6 billion Euros today) would be expected.

4.7.3 Inspiration and culture

Natural environments have a profound influence on cultural identities and value systems, and thus human well-being. As a result of diverse natural conditions a variety of lifestyles, livelihoods, knowledge systems and cultural differences have developed. Cultural services provided by different ecosystems are therefore determined by people's way of seeing the world, which on the other hand is determined by the knowledge system that the individual or the community is part of. For many traditional societies culture and environment are strongly linked, and measures aiming at cultural identity often also promote environmental conservation. Culture and the use of natural resources can be strongly influenced by belief systems of a population. They can attach a spiritual value to an ecosystem (e.g. holy places), species or landscape features (e.g. mountains). Cultural heritage cannot only be associated with buildings or customs, but also with ecosystems, landscapes and traditional breeds of animal. The latter offer specific features, influenced not only by bio-physical factors, but also by human societies and their cultural, social and technological development. Sustainable cultural landscapes should offer both high heritage values and (relatively) stable ecosystem functions (de Groot *et al.* 2005).

Ecosystems can also play an important role in an individual's orientation in time and space, for example in defining a sense of place. They often define a sense of place They provide inspiration for poetry, prose, music, dance, plays, fine arts, design and fashion, and the media in general. And this also applies to agricultural ecosystems. Indeed traditional farmed landscapes have been the subject of many of the greatest works of literature and art in Europe over many centuries.

4.8 Knowledge

Nature is an invaluable resource for science, scientific research and education. Derived from societal experience and perception, developed due to interactions with nature and natural resources, traditional ecosystem knowledge is accumulated. It is strongly linked to the location where it is developed and the value system it creates, focusing especially on food and medicines (Stevens, 1997). It creates cultural identity and at the same time is influenced by it. The loss of cultural identity can lead to a declining understanding of the natural environment and the respect for nature. Rapid industrialisation, globalisation, depopulation or ecosystem deterioration threatens cultural diversity and knowledge due to the loss of traditional lifestyles. Therefore there is an increasing danger of culture-specific land-use systems to be lost. If ecosystem management is deeply rooted in the local cultural value system this can foster cultural identity and reconcile ecology, economics and ethics (de Groot *et al.*, 2005).

It can also act as a 'library of biological information', enabling us to understand important processes, to observe changes in the past to be able to understand potential changes in the future (De Groot *et al.*, 2005). Environmental research might then be used for technological and medicinal purposes. For example, in the field of bionic biological methods and systems available in nature are used for the study and design of engineering systems and modern technology. Bioindicators help to assess and monitor changes in the environment.

Agricultural biodiversity can also play an important role in awareness raising regarding environmental issues, and can offer children an arena in which to get a practical insight into natural processes.

5 Non-use values

As described in Chapter 2, non-use values relate to the value that a beneficiary attributes to components of the natural environment beyond the benefits that they personally gain from their direct or indirect use. They result from the importance that people give to certain ecosystem goods and services in relation to their use by future generations (bequest values), other people within the current generation (altruistic values) or simply the knowledge that they exist even though there is no intention to use or experience them (existence values). Existence values are important because they arise from many people. For example, although very few people will ever see a Tiger, most people will consider that their continued existence is important and hence valuable. Although, existence values might be difficult to attribute to some components of agricultural biodiversity (e.g. genetic diversity), the value attached, for example, to the existence of a local breed or the bequest value of a traditional landscape and associated biodiversity are important aspects that have to be considered in evaluations.

Information on non-use values of ecosystems is scarce compared to that for direct use values arising from food or recreation. This especially applies to agricultural ecosystems. However, results from several valuation studies suggest that non-use values might be the largest part of the total economic value of some biodiversity resources (OECD, 2004). Therefore, it is essential to include those findings and to develop measures that are able of capturing non-values, keeping in mind the necessity for accurate and reliable estimates. Another aspect to consider is that non-use values are often associated with charismatic species or areas of wilderness and not with biodiversity in the broader sense (OECD, 2004 and references therein).

This study did not find estimates of non-use values of agricultural biodiversity components. However, estimates do exist for some species and habitats in Europe that illustrate that some species and near natural and semi-natural types of agricultural landscape may be of significant value. Pearce *et al.* (1995) report a number of non-use value, including the non-use values of Brown Bear, Wolf and Wolverine in Norway, as measured by preference valuation in USD 1990 levels, amount to 15 USD per person. But rivers in Norway were valued more highly, at 59 – 107 USD per person. Nature reserves were valued by experts in the UK at 40 USD per person.

6 Summary and conclusions

The principal aim of this study has been to identify and classify the values of agricultural biodiversity as a contribution to subsequent components of the EXIOPOL project. In particular it is envisaged that the classification framework and each of the identified benefits, as well as supporting core processes and beneficial processes, will be taken into account in the valuation studies.

This study's brief review of evidence has clearly demonstrated that all agricultural ecosystems contain important biodiversity resources (though at differing levels), that provide a wide range of benefits for humankind in Europe (and elsewhere). These range from the most obvious direct provision of benefits from crops and livestock, to recreational uses, indirect benefits (eg flood alleviation) and even non-use benefits through the existence of ancient landscapes and rare species etc. In addition, agricultural biodiversity forms an integral component of essential core and beneficial ecological processes, such as genetic diversification, soil formation, pollination and biological control, which in turn support the provision of agricultural products and other benefits. Thus valuation studies and policy developments need to be mindful of these processes and the wide variety of end benefits.

However, it is also important to recognise that biodiversity resources and their values vary considerably across the range of agricultural ecosystems. It is clear from this and other studies (e.g. MEA 2005) that agricultural improvements typically result in a reduction in biodiversity levels and their associated ecosystem services. Consequently as summarised in Table 2.5 many benefits are reduced or lost altogether as agricultural improvements are implemented. Thus, for example, natural habitats tend to be the most important in terms of providing recreational and indirect benefits (such as carbon sequestration and water resources) and non-use values (e.g. from the existence of 'wild' areas). Natural and semi-naturals habitats also provide food (e.g. wild fungi, honey, nuts, berries and game) and materials (wood) in addition to those under agricultural management. Though in most EU countries these wild foods and materials have relatively low economic values, their cultural values can be important. In some cases income from game rearing and hunting can be substantial and even greater than profits from agricultural uses.

In contrast, the most intensive systems typically lose many ancillary biodiversity benefits and even contribute to the degradation or loss of biodiversity and its associated services, e.g. through soil erosion and water pollution from agro-chemicals and silty run-off. They also have impoverished communities of wild fauna and flora and structurally simple landscapes that are often dominated by large blocks of a few crops. Such agricultural landscapes are of much lower aesthetic and recreational value (which is often exacerbated by access restrictions). Consequently, the value of agricultural biodiversity in intensive farming systems tends to be concentrated in a few benefits (i.e. food, materials and energy) provided by the few principal agricultural products.

Thus, in conclusion, it is clear that economic evaluations that aim to inform the development of land use policies must carefully consider the full range of services that biodiversity provides in agricultural systems. Furthermore, polices that encourage intensification and other land use changes that reduce biodiversity resources may have significant impacts on ecosystem services, which can have a wide range of socio-economic impacts. Studies, such as those conducted for the report on *The Economics of Ecosystems and Biodiversity* (Sukhdev 2008), have demonstrated that such impacts can be substantial and lead to policies that cannot be supported on economic grounds.

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Annex I: Contributors to the report

This report is the result of discussions between all partners in the EXIOPOL consortium. It has been written by the following persons:

Sonja Gantioler, Marianne Kettunen and Graham Tucker

The report develops initial work carried out by Andrew Jones of IEEP and the discussions during two EXIOPOL workshops hosted by FEEM in Venice in January and June 2008.

Patrick ten Brink and Kaley Heart of IEEP provided comments on the draft report.