THE ECONOMIC AND SOCIAL ASPECTS OF BIODIVERSITY

BENEFITS AND COSTS OF BIODIVERSITY IN IRELAND

Report prepared for

Department of the Environment, Heritage
and Local Government

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TABLE OF CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

POLICY

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EXECUTIVE SUMMARY

The Social and Economic Benefits of Biodiversity

This report has been commissioned by the Biodiversity Unit of the Department of the Environment, Heritage and Local Government to identify the nature and scale of benefits that we, as a society, derive from biodiversity. It is important that public goods, including those supplied by nature, are reflected in decision making. It is also important to ensure that the benefits of policies which protect biodiversity are at least commensurate with the costs of such policies. While the scope of this report is far from comprehensive and can only aspire here to a preliminary assessment, it is clear that the benefits of biodiversity far exceed the costs of current levels of biodiversity protection.

Biodiversity is commonly understood to include the number, variety and variability of organisms living on Earth. We have become accustomed to having decisions of protecting nature, or allowing economic development, being presented as an either/or choice. However, as our knowledge of ecology has developed, so too has our realisation that human beings have a dependence on ecological systems. Gradually, this realisation is filtering through to policy makers, particularly now that climate change looks likely to exacerbate the challenges facing both biodiversity and economic development. Consequently, 'biodiversity protection' appears largely to be replacing references to conservation. This reflects not just a tendency to adopt the latest fashionable terminology, but is based on a significant difference in the interpretation of the two terms. As environmentalist and broadcaster Dick Warner recently observed,[1] 'biodiversity' implies that we protect species, not for their sake, but for our own.

Human activity has always had an impact on biodiversity, but in recent centuries this impact has intensified to a position where we are in danger of undermining the primary functions of natural systems and to an extent that could ultimately threaten our own future. Losses of biodiversity have resulted from the destruction of natural habitats, over-exploitation of resources, pollution and changes in the composition of ecosystems due, for example, to the accidental or deliberate introduction of non-native species.

Loss of biodiversity is our loss. The incentive to protect biodiversity does not simply arise from a benevolence towards the natural world. Rather, a high level of biodiversity also ensures that we are supplied with the 'ecosystem services' that are essential to the sustainability of our standard of living and to our survival. This report details a range of critical ecosystem services on which we depend in various economic and social sectors. In agriculture, these include the maintenance of soil structure and the supply of nutrients, pollination and pest control. For water supply, it includes the filtering and purification of rivers and lakes, including the decomposition

[1] 'Wings' Spring 2007, Birdwatch Ireland

of our own pollutants and waste. In the marine sector, there is the obvious direct benefit of a fish catch, but this harvest itself depends on food chains and habitats provided by a robust functioning level of biodiversity.

Crucially, our own health depends on biodiversity, for example as a source of pharmaceutical raw materials, but also in terms of the quality of the food that we eat, opportunities for physical exercise and resistance to disease. The benefits extend to our well-being and quality of life. Not only are we attracted to scenic landscapes that are largely the product of biodiversity, but most of us also value environments and wildlife in their own right, often irrespective of whether we have ever visited or seen them - or, indeed, expect to.

We can mislead ourselves by believing that our agriculture or fisheries can get by without biodiversity. For the past fifty years or more our farming has been sustained by high levels of fertilizers and pesticides, our timber and pulp is provided by plantation forests supplied with a similar intensive diet of inputs, and our wild fisheries can be substituted by aquaculture. Similarly, we have developed a large number of synthetic drugs with which to fight most diseases and we know - or rather before MRSA, thought we knew - how to kill pathogens to ensure high standards of hygiene.

However, very few if any of these activities can be undertaken without some input from natural biodiversity. Furthermore, their long-term sustainability is being compromised by the depletion of ecosystem services or cumulative pollution. Even now, we are peddling harder to stay put as we are forced to replace ecosystem services that we once took for granted. No longer can farmers be sure that their crops will be reliably fertilized by bees. Nor can be still assume that our domestic sewerage will be recycled into the natural environment without accumulating in groundwater or watercourses. In such circumstances, the last news we need to hear is that climate change could yet further undermine the natural systems on which we still depend.

Valuing Biodiversity

Putting a value on biodiversity is no easy task. In recent times, economists have developed techniques to place a monetary value on many aspects of the environment, sometimes to the consternation of ecologists. Nevertheless, everybody would agree that there are some things which are too fundamental or too complex to value in a meaningful way. Ultimately, our survival depends on a functioning biodiversity. Even though we may have habitually taken ecosystem services for granted, they are of potentially infinite value to human society.

For practical purposes, what matters is knowing the approximate marginal value of key ecosystem services at the present time. That is, the value of biodiversity in terms of the incremental benefits or goods to which it contributes. Even in this respect, valuation is a challenging exercise in that we need some understanding of the proportion of these benefits or goods for which ecosystem services are responsible.

A marginal value allows us to begin to determine how much we should be spending on biodiversity protection. If we have an angle on the benefits, then we can assess how far these benefits exceed the amounts that are currently being spent on relevant policies, or vice-versa. Naturally, we also need to know how effective those policies are. Typically, such policies benefit not only biodiversity, but have other purposes such as providing for recreation or protecting of the landscape.

The report presents an assessment of the benefits of selected ecosystem services in the principal social and economic sectors. Although only a preliminary estimate is proffered, the current marginal value of ecosystems services in Ireland in terms of their contribution to productive output and human utility is estimated at over €2.6 billion per annum. This is, however, an estimate that rests on only a few key examples and which necessarily omits other significant services such as the waste assimilation by aquatic biodiversity and benefits to human health.

Agriculture

Despite the prevalence of artificial fertilisers and pesticides, agriculture would be impossible without essential ecosystem services. Biodiversity is essential in the breakdown and recycling of nutrients within the soil. A huge variety of innumerable creatures perform this service, of which we use the example of earthworms as a keystone species. Biodiversity is also essential to the pollination on which a wide range of crops, include forage plants, depend. It is also vital to pest control, without which productivity losses would be far greater. Each of these services is threatened to one extent or another by excessive use of artificial inputs, pollution, non-native alien species, removal of semi-natural habitat or the use of heavy machinery.

Where biodiversity is diminished by inappropriate farming methods, so the need for expenditure on artificial inputs is increased and the prospect for sustainable agriculture recedes. One indication of the value of biodiversity could be provided by the increasing amounts that would need to be spent on these inputs to substitute for ecosystem services together with the external costs of pollution or damage to health that arises from excessive use of fertilizers or pesticides.

Alternatively, the value of biodiversity can be represented by the potential value of output from sustainable systems in which the use of artificial inputs is moderated. Even for Ireland's largely grassland based farming, this value is substantial. This report places a tentative value on the services of the soil biota to nutrient assimilation and recycling of €1 billion per year. Greater reliance on pollination, for example for the more extensive production of clover-based forage or the production of oilseed for biofuels, could raise the value of this ecosystem service to €220 million per year or even €500 million per year. The value of baseline pest control is worth at least €20 million per year before savings on pesticides of perhaps a further €2 million. Estimates of the public utility benefits of the current external benefits of sustainable farming, for example landscape and wildlife habitat, have been put at €150 million per year, but would surely rise significantly if these benefits applied to all farms and were accompanied by improved water quality or health benefits.

Forestry

Commercial forestry depends similarly on nutrient recycling and pest control. Some forests also retain a value for hunting or the collection of wild food (e.g. fungi). In addition, many forests, natural or commercial, are important for human utility, as amenities for recreation and habitat for wildlife. As in agriculture, these forest ecosystem services are threatened by the same mix of intensification of production, pollution and alien species, the latter including some serious pests. At present, the level of ecosystem services is valued at €55 million per year, but this has the potential to rise to €80 million per year if more environmentally sensitive forestry is practiced, or more should the area of broad-leaf trees be expanded.

Fisheries

The ocean, as well as rivers and lakes, provides a provisioning ecosystem service in terms of a fish catch. Fish are harvested directly, but this catch itself depends on a functioning ecosystem that supplies nutrients, prey species, habitats and a desirable water quality. Over-fishing, pollution, destruction of habitat and alien species are amongst the many threats to marine biodiversity.

The present quayside value of the fish catch is €180 million per year, but could be worth twice this amount if fish populations were to be managed sustainably. Aquaculture and the seaweed industry are worth over €50 million and also depend heavily on ecosystem services. The value of assimilation of waste emptied by our rivers or sewerage outflows cannot be estimated, but is certainly substantial. Bizarrely, despite the obvious benefits of marine biodiversity, we are still unable to shake off a policy of subsidising the over-exploitation of fisheries. Although we spent a pittance on the protection of marine biodiversity, lack of political realism and willpower remain the principal constraints.

Water

Within the aquatic environment, biodiversity performs a significant service both in terms of recycling nutrients and ensuring desirable water quality for agricultural use, fisheries and human consumption. Likewise, this same biodiversity assimilates human or animal waste and industrial pollutants. Many aquatic habitats are important for these services, for flood mitigation, recreation or amenity. Our dependence on water quality means that any degradation through excessive pollution is amongst the first adverse human environmental impacts of which we are likely to become aware.

A distinction must be drawn between the huge external cost of water pollution and the value of the ecosystem service. The latter is of value for assimilating excess nutrients from diffuse pollution, but can be overwhelmed. Without full consideration of this service, the value of biodiversity is estimated at up to €385 million per year. The true value would diminish if we managed agricultural and residential pollution better, but rise if fish populations recover or water-based recreational expenditure were to increase.

Human welfare

A very important contribution is made by biodiversity to human welfare. This occurs directly through our appreciation of nature, be this through nature watching or eco-tourism, or simply through the complementary association between environments that are attractive and rich in biodiversity . Biodiversity also has an obvious role in angling and water sports.

Nobody has yet brought together the marginal utility value of all ecosystem services as they contribute to natural environments in Ireland that are used for passive enjoyment or for recreation. Irish inland waters and the coast represent particular omissions. However, from those studies that have been conducted, the utility value (including environmentally-sensitive agriculture as noted above, but excluding health) can be estimated as being at least €330 million per year. Recent work by the Heritage Council suggests an incremental value for policies to enhance the natural environment of €65 million per year.

Health

The connection between biodiversity and health is only beginning to be understood. Clearly, a functioning ecosystem contributes to a supply of nutritious food and water of a quality essential to human health. In addition, it ensures that many diseases, and their vectors, do not get out of hand. Although this may be best understood through reference to many tropical diseases, the importance of these regulatory services in temperate climates is beginning to be understood through instances where natural systems have been disrupted by human interference, bird flu being a probable example. Biodiversity has also been important to the isolation of many important drugs.

Good health has a utility benefit that probably exceeds that of any other sector. The potential health expenditure savings due to high environmental quality are equally sizeable. Although the routes through which biodiversity contributes positively to health are too indirect or multi-dimensional to quantify in this report, they are certainly huge and deserving of more attention.

Policy costs

Policy costs are estimated in the region of €370 million per year. However, only a proportion of these are truly incurred on protecting biodiversity despite the Convention on Biological Diversity to which Ireland is a signatory. Even within the Parks and Wildlife Service only a proportion of spending, i.e. around €35 million per year, is spent directly on biodiversity or habitat protection.

A significant amount of spending is also undertaken by the Environmental Protection Agency (EPA), but while this indirectly benefits biodiversity, its principal aim is to reduce pollution toxicity and to protect environmental quality in conformance with EU Directives.

The Rural Environmental Protection Scheme (REPS) could be identified as a policy that directly benefits biodiversity by protecting species and habitats found on agricultural land. The policy cost is around €280 million per year, although only a portion of this is relevant to biodiversity as REPS supplies other objectives, including aesthetic benefits, food quality and animal welfare. A significant benefit of REPS is as a social transfer to more marginal farmers that coincides with rural development objectives.

Other policies are difficult to identify. Expenditure is incurred by the National Roads Authority (NRA) on measures to protect biodiversity along new roads, but this expenditure has not been estimated by the agency. A new Forest Environmental Protection Scheme (FEPS) has recently been launched by the Forest Service, but initial expectations of expenditure are modest. Although the cost of biodiversity requirements for new plantings are borne by private forestry companies in terms of lost timber production, these costs are recouped in the form of forestry grants.

Net benefits

We are increasingly conscious of the damage that human activities are doing to the environment. Environmental policy is typically evaluated in terms of its success in reducing these adverse impacts. However, we are less accustomed to thinking of what the environment does for us. Even though only a few examples of biodiversity benefits have been estimated - and then only very approximately given the scope of this report and our limited understanding of ecosystem services - it is clear that the benefits far exceed the costs of policies to protect biodiversity.

Amongst the most urgent of the threats we face is that of a total collapse of fish stocks. Hitherto, we have responded to declining fish stocks by attempting to place quotas on those species at risk. Everybody now agrees that, for a variety of reasons, these policies have not been very successful. It is only recently that the relationship between commercial fish stocks and the underlying ecosystem has been demonstrated.

In other areas, there have been recent positive trends in environmental policy. Some formerly polluted rivers are becoming cleaner, natural forests are no longer being felled, agricultural policy is no longer paying farmers to drain wetlands or rip up hedgerows, and previously native species, such as the golden eagle, have been reintroduced. The damage that is continuing to affect natural systems is now more subtle and elusive, for example the accumulation of toxins, nutrification of watercourses and soils, or the gradual attrition of natural habitat. Subtle or not, future generations will face a huge bill in terms of public health, water purity and, ultimately for environmental rehabilitation, if we continue to abuse biodiversity.

The report finds that there are substantial net social and economic benefits from biodiversity when compared with the policy costs. Nevertheless, direct expenditure on the protection of biodiversity is not always necessary. Environmental impact assessment and integrated land use planning can do much to minimise threats to biodiversity. Awareness and political decisiveness are critical too. By designing policies that do not reward people for damaging the environment, and by enforcing these with environmental standards, biodiversity protection need not cost the earth.

INTRODUCTION:

1. BIODIVERSITY: ECONOMIC AND SOCIAL ASPECTS

1.1 THE IMPORTANCE OF BIODIVERSITY

Biodiversity is a fundamental characteristic of life on Earth and encompasses the "whole range of variation in living organisms" (Wilson, 1993). It can be defined in terms of genetic variation, species variation or ecosystem variation. Throughout the EU much biodiversity has been lost in recent decades. For many years in Ireland, biodiversity remained relatively protected by the low economic growth. However, as the economy has raced ahead in the past ten years, so biodiversity is being threatened by built development and changes in land use management. Like all countries, there is also the pervasive risk that climate change will further multiply the problems associated with loss of biodiversity.

Reviewing the state of biodiversity in the EU, Kettunen and ten Brink (2006) identify habitat change and destruction as being the most direct reasons for biodiversity loss. Other significant factors include over-exploitation of resources, pollution and changes in ecosystem composition due to colonisation by non-native plant and animal species.

Biodiversity is not of value for purely esoteric reasons. It is of value to all of us for the ecosystem services that a healthy biodiversity provides. Kettunen and ten Brink categorise these as the provisioning, regulating, supporting and cultural services that underpin our supplies of food, clean water and renewable resources, and which maintain hydrological cycles and, ultimately, our climate. An early reaction to the loss of biodiversity was the recognition that this was eroding our quality of life, an observation that was articulated so well by Rachel Carson in 1962, in her famous book, Silent Spring. However, as the continued loss of biodiversity is threatening to undermine the ecosystem services on which we depend, so the direct economic consequences of this loss are becoming increasingly apparent.

Science has revealed much of the importance of biodiversity, but an economic and social assessment is needed to communicate the fact that biodiversity loss also has an economic and social impact. Considerable costs will be faced in the protection or replacement of ecosystem services, so policy decisions are required if these costs are to be avoided. These decisions need to be guided by both an understanding of the value of biodiversity to current economic and social systems, and an appreciation of what the costs of inaction could be.

Such a valuation does not imply that nature is all good. From a human perspective, many species have a negative impact on our utility, namely agricultural pests or bacterial disease. Taking a wider perspective, however, these pests and diseases are kept in check by a functioning ecosystem. Indeed, many species which may be better known as pests also play a critical positive part in this functioning of the ecosystem through interdependencies and evolutionary adaptation.

Neither does it necessarily follow that high levels of biodiversity are better than low levels. The presence of particular key species or functionality (what we call a "healthy" ecosystem) may be more important than the absolute numbers of species. Generally, though, it is the case that a high level of biodiversity is likely to coincide with overall stability. The more species there are in an ecosystem, the more likely it is that species will be ecologically similar or able to provide the same functions as others in the event of exogenous change to the ecosystem (van Rensburg & Mill, 2006, Vitousek & Hooper, 1993). This stability provides an insurance against sudden change. This concept of insurance is little different from people's own reliance on various income earning skills or their possession of a broad portfolio of investments (Tilman et al., 1995).

1.2 THE NATURE OF BIODIVERSITY

Biodiversity is a public good. That is, it is unpriced by normal market processes. As such, it is subject to 'market failure' in that there are no prices through which to indicate its scarcity. This, in turn, presents issues in relation to the neglect or misuse of natural systems.

To understand the value of biodiversity, it is first necessary to examine and categorise the multiple benefits it provides. Many of these can be quantified in economic terms. They include:

- The underpinning of the provision of ecosystem services, ensuring the productivity of agriculture, forestry, fisheries, water purification and climate moderation;

- Contributing to quality of life by providing utility to people directly through their appreciation of nature or landscapes and through their enjoyment of a type of recreation that depends on a functioning ecosystem, e.g. angling, water sports, hunting.

- Providing economic returns directly in relation to recreation and tourism, including nature tourism.

- Contributing to human health through the recycling of nutrients and decomposition of pollutants (including those that could find their way into potable water supplies), or through benefits to health due to the physical exercise of recreation in undertaken in open spaces.

Table 1.1 ***Classification of Ecosystem Services*** (based on Kettunen & ten Brink, 2006)

TYPE OF ECOSYSTEM SERVICE
Provisioning
Food and fibre
Fuel (e.g. wood, bio-oils)
Biochemicals and pharmaceuticals
Fresh water
Regulating
Air quality
Climate regulation
Water regulation (flood prevention, waste assimilation, evapotranspiration)
Erosion control (ground protection)
Water purification and waste management
Regulation of human diseases

Pest control	
Pollination	
Cultural services	
Social relations, aesthetic values, sensual, spiritual	
Recreation and tourism	
Supporting services	
Primary production	
Nutrient cycling	
Soil formation	

While biodiversity is a public good, it commonly has the characteristic of an open access resource such that many of the benefits are realised as private benefits, whereas the associated costs are shared social or public costs. For example, clean water may be needed by a factory, but that same factory's pollution reduces the quality of water for people and other factories downstream. However, it does not necessarily follow that human activity is inevitably bad for biodiversity. In some cases, biodiversity can be enhanced by human activity. Extensive farming provides a diversity of practices and associated landscapes that, in turn, favour biodiversity (Tscharntke et al., 2005). Indeed, there is concern that the virtual abandonment of some farming areas has reduced biodiversity (Rensburg & Mill, 2006).

However, the net situation that we currently face is one in which biodiversity is being degraded. Where the costs and benefits are not shared equally by the same individuals, as is typical where goods have both private and public attributes, there is the prospect that one decision-maker will trade-off biodiversity loss in return for benefits, for example, higher short-run productivity, without considering the full extent of the future costs or the costs for others. Incomplete information, together with the geographical separation of beneficiaries and losers, raises the possibility of adverse outcomes due to market failure. These impacts are often barely perceptible to begin with as they are gradual or cumulative. The full costs may only be realised after long periods of time or by future generations.

1.3 VALUATION OF BIODIVERSITY

In 1995, a team of ecologists and economists estimated the value of biodiversity to the global economy as being in the region of $US33 trillion annually (Costanza et al, 1995). However, not only does this figure, by its authors' admission, represent a minimal estimate of the value, but knowing that the human race ultimately depends on a functioning ecosystem does not help much with the choice of policies to protect it. Better, therefore, to focus on the value of an additional unit of biodiversity, or the cost of the loss of a unit of biodiversity. The value of the marginal product of biodiversity demonstrates the contribution of the ecosystem to the incremental production of goods, services and human welfare at any one point of time. This information places policy-makers in a better position to judge what trade-offs are necessary between the costs and benefits of policies needed to protect biodiversity (Dickie, 2006).

As things stand, there are many decisions that have biodiversity impacts, but which do not consider the full costs, including those that affect the wider public. Many of these social and economic benefits and costs, be they public or private, can potentially be quantified. Where biodiversity contributes to primary production, its value can be demonstrated in terms of the price of final products such as food or raw materials. Contributions to human utility are also an economic benefit that can be quantified using methods such as stated or revealed preference to demonstrate monetary estimates of these values. Such valuation ensures that impacts to social welfare are treated equally with other financial considerations.

Stated or Revealed Preference Methods

Stated preference relies on survey approaches through which people provide estimates of their willingness-to-pay (or willingness-to-accept) for the protection of biodiversity where this can be shown to contribute directly or indirectly to their quality of life. Instances would be the association with outdoor recreation, or other indirect uses or even non-uses such as a pure appreciation of wildlife or biodiversity. Revealed preference achieves the same objective where this utility can be demonstrated through associated market mechanisms. Examples here would be where property prices capture proximity to an attractive natural landscape, or the costs of travel to a recreational area with high biodiversity.

Production Function Approach

In the production function approach, biodiversity forms an input to an economic process. This requires some detective work to attribute that proportion of the value of product which is contributed by ecosystem services. For instance, although a single type of crop or tree might have value as food or timber, its growth depends on a variety of ecosystem services performed by various species. Similarly, ecosystem services will enhance forage production on a farm and this will contribute to the weight gain of grazing animals and a higher final price.

Cost-based Approaches

Cost-based approaches do not provide estimates of utility, but rather provide a demonstration of the value of biodiversity through a surrogate product. For example:

- 'Replacement cost' examines the amount that would need to be spent to replace the ecosystem services that are provided by biodiversity. Examples could include hand pollination or the use of fertilizers or pesticides.

- 'Damage avoided' looks at the cost of adverse outcomes which could arise in the absence of a functioning ecosystem. This approach could be used to quantify the external costs of activities which ignore or damage biodiversity of which the health impacts of pesticides would be one example.

- 'Preventive expenditure' is related to the above in that it calculates how much would need to be spent to avoid such costs. One example that follows on from the above would be the additional water purification needed to remove pesticide residue.

Methods adopted

In this report, the production function method is used most regularly, albeit rather crudely given the range of ecosystem services which must be considered here. Ideally, it would be necessary to attribute that component of value which is contributed by biodiversity. It is also necessary to avoid double-counting or over-estimating the costs that are truly attributable to biodiversity. For example, the above examples of the replacement cost posed by the purchase costs of pesticides can be added to the social costs of their potentially adverse health impacts as an instance of the cost of lost ecosystem services. However, the costs cannot simply be added to that of the preventative expenditure which must be made on water purification that might remove toxic pesticide residue.

Valuation, of any kind, is not straightforward. Production function or cost-based methods are challenged by the limited scientific understanding of ecosystem functions, including in areas that are highly important to primary production such as soils and the oceans. Imperfect information also applies to the use of stated preference tools based on surveys in that most people have a very limited understanding of biodiversity even where they do value its outcomes. In this case, it could be better to establish people's willingness-to-pay for the protection of particular key species or landscapes, and then to use these values as a demonstration of the value of the biodiversity on which these species or landscapes depend.

Economic valuation can also never be more that partial. Although we can artificially raise short-term productivity or substitute for some loss of biodiversity, productive activities, such as agriculture, are ultimately dependent on biodiversity. The value of biodiversity is therefore essentially equivalent to the total value of the output from agriculture, forestry or fisheries. For a benefit-cost approach to have meaning, it is more practical to focus on marginal values as described above. It is also practical and illustrative to refer to a handful of species which have been identified as being critical to economic activity. To demonstrate the importance of *protecting* biodiversity, it may also be persuasive to choose those species which are endangered. Indeed, this threat to individual species may have arisen because their value has hitherto not been appreciated or accounted for in economic terms.

Where a limited number of example species are used, it is important to remember that these species, in turn, do not exist in isolation but depend on a functioning ecosystem. Bees, for example, do not survive just by pollinating agricultural crops. Rather, they depend on a range of wild plants which, themselves, occupy particular habitat niches or depend on other insects, birds or mammals for their reproduction and dispersion. It is this classic beautiful complexity of nature which can never be quantified entirely.

1.4 STRUCTURE OF THE REPORT

The report is structured as follows. Following this introduction, a synopsis is given of international and European policy on biodiversity. The chapter discusses the political background and motivations for biodiversity protection and the extent to which these policy initiatives are being applied in Ireland.

The following chapters examine the role of biodiversity and of ecosystem systems in our key economic and social sectors, namely:

- agriculture
- forestry
- fisheries
- water quality
- roads and infrastructure
- health
- social welfare and quality of life

The sub-chapters are broadly organised into sections that examine:

- the relationship between the sector and biodiversity
- relevant species and their function
- ecosystem services
- economic and social values
- threats to biodiversity, and
- costs of protection.

The structure is not exactly repeated for each topic as the relationship between biodiversity and activity within each sector inevitably varies, including the role played by ecosystem services.

A summary of the benefits of biodiversity is then provided, together with a broad comparison of the costs in terms of both current and possible policy and the economic implications of failing to protect biodiversity. For the reasons discussed above, this chapter cannot aspire to be a cost-benefit analysis. Rather, it discusses what measures have been introduced by individual government departments to protect biodiversity. It examines the extent to which government departments are conscious of the social value of biodiversity, or whether this consciousness is simply a response to international agreements and European Directives.

This core section of the report is followed by a short chapter on the impact of climate change. Climate change is likely to have a serious impact on biodiversity. Between 30%-50% of species have been identified to be at risk from the changes in climate predicted for this century (CEC, 2007). Furthermore, our capacity to adapt to climate change and to deal with its implications will be strengthened by the presence of a healthy level of biodiversity.

Finally, we bring this information together in a concluding chapter that also contains recommendations for government action on biodiversity.

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2. AN OVERVIEW OF POLICY AND LEGISLATION

2.1 INTRODUCTION – THE GLOBAL CONTEXT

The range of individual policies and policy drivers connected to biodiversity in Ireland is extensive, while their history, relationships, implementation and enforcement issues are complex. The majority of these instruments are directly relevant and of great significance to social and economic concerns on this island, but a full discussion of these aspects would form a large volume of text on its own. Rather than discuss each of these in detail, this section provides a general overview of the over-riding international and national policy context within which biodiversity conservation must be considered. It gives specific consideration to policy drivers of relevance to the Irish economy and society, and highlights some major linkages with current socio-economic issues in Ireland.

2.1.1 Development of modern biodiversity policies

Today's policy framework for environmental protection dates back to the beginnings of the green movement in the mid-1960s. Politically, modern nature conservation policies in Ireland and elsewhere have roots in a number of international summits and treaties of the early 1970s (e.g. the 1972 United Nations Conference on the Human Environment). In the 1980s, the establishment of the UN World Commission on Environment and Development focused global political attention on the connection between environmental quality and economic growth. The concept of Sustainable Development is now firmly fixed into almost all national and international objectives relating to economic and social progress. The phrase itself has, perhaps, been somewhat over used in recent years and it is frequently applied to discussions outside of the socio-economic-environmental context. In the framework of the current report, the definition stated in the 1987 report of the World Commission ("Our Common Future"), is worth repeating:

> "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs".

The World Commission's report stressed an urgent need to achieve this form of sustainability in human development and economic activity. This led to the United Nations Conference on Environment and Development (UNCED, popularly known as the Rio Earth Summit) held in 1992 in Rio de Janeiro. The parties to the Earth Summit recognised that the natural environment (the biosphere) provides both the supporting framework and the raw materials for human life and development, and that a healthy natural environment is absolutely essential to the success of human economic and social development, and to our overall health and well being. At the Earth Summit, the world's governments recognized the need to redirect international and national plans and policies to ensure that all economic decisions fully took into account environmental impacts. The UN Convention on Biological Diversity (CBD), which was opened for ratification at the Earth Summit, is the main international instrument governing the conservation of nature and biological resources, and is one of a number of international conventions concerned with the sustainable use and conservation of the natural world.

The CBD has been ratified by 189 parties (188 countries and the European Union). Ireland ratified the CBD in 1996. The CBD covers key aspects of biodiversity conservation and management, including natural resource management, and the social, cultural and economic values of biodiversity, recognising that the "*conservation and sustainable use of biological diversity is of critical importance for meeting the food, health and other needs of the growing world population*". Biodiversity provides a range of essential goods and services to human societies, which cannot be provided artificially, or for which the costs associated with the development of alternatives is prohibitive. Examples of these "ecosystem services" are provided in **Table 2.1** below.

Table 2.1 **Ecosystem Goods and Services provided by Biodiversity**

Supporting services • Primary production • Nutrient cycling • Soil formation • Decomposition / recovery	Provisioning services • Food • Fresh water • Wood and fibre • Therapeutic compounds
Regulating services • Climate regulation • Disease regulation • Water purification • Flood mitigation	Cultural services • Aesthetic • Spiritual • Educational • Recreational

The three main objectives of the CBD are:

- The conservation of biological diversity
- The sustainable use of its components; and
- The equitable sharing of the benefits arising out of the utilisation of genetic resources.

The main implementing and review body of the CBD is the Conference of Parties (COP), which consists of representatives from each of the ratifying parties, and which meets approximately once every two years. At each COP meeting, based on a review of new biodiversity research and current progress and implementation of the CBD, additional objectives and targets (collectively adopted as "Decisions") are set, to which parties are bound.

The Convention defines biological diversity as:

> "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."

In essence, this definition recognises three interdependent levels – ecosystem diversity, species diversity, and genetic diversity within species. In the wider context of the Convention and related COP decisions, another level should be recognized – the landscape level, constituting the broader biophysical environment and biogeographical patterns which biodiversity has helped to create, and of which biodiversity forms an integral part. The implications of this definition for Ireland will be discussed in more detail in following sections.

A key provision of the CBD is the preparation of national biodiversity strategies or plans, and the integration of biodiversity into all relevant sectors. This recognises that any activity which involves or results in the consumption of natural resources, the production of waste, changes in population movements or demographics, or the removal or fragmentation of natural habitats or other change in land use patterns, can have an effect on biological diversity. This, in turn, will have further direct or indirect effects on human well-being. Article 6 of the Convention requires each Contracting Party to:

> "develop national strategies, plans or programmes for the consideration and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes, which shall reflect, *inter alia*, the measures set out in this convention relevant to the Contracting Party concerned"

and also to:

> "integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies."

Under the strategic plan of implementation of the CBD[2], ratifying states have agreed to significantly reduce the rate of loss of biological diversity by the year 2010. This was further endorsed by international governments at the UN World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, in the same year (often referred to as "Rio +10"). A major outcome of Rio +10 was a broadening and strengthening of the concept of sustainable development, to more completely account for the relationships between economic growth, environmental quality, livelihoods, and natural resource management. This is now the over-riding policy goal relating to the use, management and conservation of natural resources worldwide. The implementation phase of the CBD, working towards the 2010 target, comprises actions under specific thematic areas, based on key ecosystem types and issues which are recognised to have greatest significance to environmental health, economic and social welfare, and to international development. These include agriculture, forests, wetlands, marine and coastal areas, islands, and inland waters.

Under the CBD, Contracting Parties have also agreed to adopt an "ecosystem approach" to biodiversity conservation, and to adapt this approach for policies which may affect biodiversity in relevant sectors. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It recognizes that human societies, with their cultural diversity, are an integral component of many ecosystems, and, when applied in a wider political context, it attempts to encompass the essential structure, processes, functions and interactions between humans and our natural environment.

2.1.2 Biodiversity and international development

Fully sustainable development requires that economic, social, public health, environmental and development concerns are addressed simultaneously and holistically. This will ensure that benefits can be maximised across sectors, and that the implementation of policies in any one area does not negatively affect progress in other areas. It is unfortunate that, in the years since the UNCED, the concept of sustainability has frequently been considered as just an

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[2] Arising from Decision VI/26 taken at the 6th COP meeting, in 2002.

environmental concern. This has generally led to shortfalls in the development and implementation of "sustainable development" policies worldwide. The United Nations has reported that since the 1972 UN Conference on the Human Environment, most environmental trends have worsened. Clearly, ensuring that development is truly sustainable is a major challenge that requires a high degree of inter-disciplinary and cross-sectoral co-operation and understanding. Over the past five years, experience and research in environment, social and economic areas have highlighted the dependency of human development and well-being on biodiversity and ecosystem services, leading to a growing focus on biodiversity loss as a significant threat to international development, economic security and human well-being.

In the year 2000, the UN Millennium Declaration on the fundamental challenges facing the international community in the 21st Century was adopted by the General Assembly and signed by the Heads of State from 152 nations. In 2001, the Secretary General set out a 'roadmap' of Millennium Development Goals (MDGs) for achieving the aims of the Declaration – reducing poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women by 2015. Over the following five years, experience in implementing the goals lead to a growing consensus that the Millennium Goal relating to environmental sustainability is the keystone upon which the success of other goals depend. Biodiversity conservation is a critical aspect of sustainable development, and its importance to human well-being has been emphasised by the reports of the Millennium Ecosystem Assessment (MA), a UN global project which assessed the consequences of ecosystem change for human well-being, and which identified the scientific basis for action needed to enhance the conservation and sustainable use of those ecosystems. The main findings of the MA included the following:

Over the past 50 years, human impacts on ecosystems have resulted in a substantial and largely irreversible loss in the diversity of life on Earth.

Although some of the changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, with negative impacts for some people. These effects include the emergence and spread of disease organisms, reduced livelihood security, loss of food resources, and the exacerbation of poverty. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.

The degradation of ecosystem services is a barrier to achieving the Millennium Development Goals, and could grow significantly worse during the first half of this century.

The challenge of reversing the degradation of ecosystems, while meeting increasing demands for their services, will involve significant changes in policies, institutions, and practices that are not currently under way.

In his statement to the world's first global stakeholders' meeting on the importance of biodiversity to human health and well-being (COHAB 2005, the first International Conference on Health and Biodiversity, which took place in Galway in August 2005), the former UN Secretary General Kofi Annan, said:

> "*If we fail to use and conserve biodiversity in a sustainable manner, the result will be increasingly degraded environments, and a world plagued by new and more rampant illnesses, deepening poverty, and the perpetuation of patterns of inequitable and unsustainable growth. Unfortunately, our actions run the risk of taking humanity down this path… human activities are fundamentally changing the planet, perhaps irreversibly… Over the last fifty years, pollution, climate change, degradation of habitats and overexploitation of natural resources, led to more rapid losses of*

biological diversity than at any other time in human history. Such losses put the livelihoods and health of current and future generations in jeopardy."

In response to the reports of the MA and other international consultations, the UN has incorporated the 2010 biodiversity target as a target within the MDGs, essential to their success and to future global economic development and security.

Some other relevant multi-lateral instruments which Ireland has ratified or is a party to are listed below:

- The International Treaty on Plant Protection (1997)
- The UN Framework Convention on Climate Change (opened at Rio in 1992), and the Kyoto Protocol.
- The Ramsar Convention on Wetlands of International Importance (opened at Ramsar, Iran, in 1972)
- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (in effect since 1975)
- The UN Convention on the Conservation of Migratory Species and Wild Animals (Bonn, 1994)
- Convention concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972)

2.2 THE EUROPEAN CONTEXT

2.2.1 EU Legislation on biodiversity

Legislation on biodiversity and nature protection at European Union level dates back to the Directive on the conservation of wild birds (**the Birds Directive**), which was adopted in 1972. Although several environmental directives of relevance to biodiversity have been implemented since then, the Birds Directive, and the 1992 Directive on the conservation of natural habitats and of species of wild flora and fauna (**the Habitats Directive**) are the most directly relevant in the context of this discussion.

The Birds Directive aims to provide far-reaching protection for all of Europe's wild birds, and identifies 194 species and sub-species as particularly threatened and in need of special conservation measures. EU Member States are under a general obligation to preserve, maintain or re-establish sufficient habitats and ecosystems to support the conservation of all bird species covered by the Directive. In addition, for certain species that are of conservation concern, of European importance or are important migratory species, Member States must designate protected sites known as Special Protection Areas (SPAs). The decision on the selection of sites for SPA designation may take account of economic and social considerations, but the decision must be based primarily on conservation needs.

The Habitats Directive is much broader in scope than the Birds Directive, extending the coverage to a much wider range of rare, threatened or endemic species, including around 450 animals and 500 plants throughout Europe. Its aim is to restore, or maintain, natural habitats and species of wild flora and fauna of "European Community interest" to a favourable conservation status. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right. The Habitats Directive established the 'Natura 2000' network of sites of highest nature value. This consists of Special Areas of Conservation (SAC) designated by Member States, and incorporates the SPAs designated under the Birds Directive. Over 20,000 sites have been included in the network so far (throughout the EU25), covering almost a fifth of Europe's land and water (equivalent to the size of Spain and Italy put together). As part of Natura 2000, the selected areas benefit from increased protection. In principle, Member States must take all the necessary measures to guarantee their conservation and avoid their deterioration.

Under both the Birds and Habitats Directives, two pillars of legislation are identified – the first pillar dealing with protection of habitats (through which Natura 2000 sites are designated) and the second dealing with protection of species listed in the Annexes to the Directives (e.g. through protection of their habitats, nests, eggs and breeding paces, and through the control of capture, killing, harvesting, hunting and trade). Under the legislation, the integrity and conservation status of Natura 2000 sites, and the system of protection for the listed species, must not be negatively impacted by development or other activity, except where there are "imperative reasons of overriding public interest, including those of a social and economic nature".

In EU legislation, the concept of habitats and species of "Community interest" is largely based on conservation criteria – for example, sites which hold high proportions of national or international populations of a given bird or mammal, or which are important for the national or EU-wide conservation of an endangered species, etc. However, under current EU policy, in light of the findings of the MA and following the implementation of many recent EU environmental directives, the concept of Community interest potentially has a wider frame of reference than nature conservation concerns alone. For example, sites may have Community importance not only because of the component flora or fauna, but because of the importance or value of the ecosystem services which they provide. It is likely that future legislation on environmental protection may recognise the relevance of these sites to wider social and economic issues.

Considerations of impacts on biodiversity arising from plans and programmes, including physical development and policy goals, are regulated by two other important EU Directives which should be mentioned here – the Directive on the assessment of impact of certain private and public projects on the environment (the Environmental Impact Assessment, or EIA, Directive) and the Directive on the assessment of the effects of certain plans and programmes on the environment (the Strategic Environmental Assessment, or SEA, Directive).

The EIA Directive applies to impact assessment of certain projects involving physical development, consumption of raw materials and production of wastes, or land use change. This includes, for example, construction, manufacturing, exploration, energy generation and waste management projects. EIA is an important tool for ensuring that the end results of a project have minimal negative impacts on the environment, including biodiversity, or that such impacts can at least be identified, and where possible remedied or remediated.

The EIA Directive is focused on individual projects. Experience throughout the EU has shown that the wider policy framework itself represents a significant barrier to sustainable development, by tacitly allowing specific types of projects in potentially unsuitable circumstances or locations. EIA, when implemented with the Habitats and Birds Directives, should ensure that many impacts on biodiversity are prevented and that development is sustainable. However, the problems associated with subtle, unforeseen, long term, cumulative or additive impacts are often not adequately accounted for by EIA, due to uncertainty, lack of scientific knowledge, or gaps in other relevant policy structures. The implementation of the SEA Directive aims to overcome these issues, by ensuring that certain programmes and plans – including Regional Development Plans, infrastructure programmes and certain other supporting policies – are appropriately assessed for their potential environmental impacts, prior to their implementation. This is a potentially significant development towards the conservation and sustainable use of biodiversity throughout the EU, and has implications for the decision making process across all sectors of government.

Some other EU legal instruments are relevant to the aims of conservation and sustainable use of biodiversity:

- The **Environmental Liability** Directive, which implements the "polluter pays" principle and covers damage to natural habitats protected under the 1992 Habitats and 1979 Bird Directives.
- The **Water Framework Directive**, which has established an EU framework for the protection of all water bodies in the EU in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of floods and droughts.
- The **Aarhus Convention**, which provides for access to environmental information and public participation and access to justice in environmental matters.
- The seven environmental thematic strategies adopted by the European Commission, on the marine environment, soil, the sustainable use of pesticides, air pollution, the urban environment, the sustainable use and management of natural resources, and waste prevention and recycling. They take a long-term (20-25 years) holistic and ecosystem-based approach to these issues, which cut across several policy areas.

2.2.2 Development of the EU's policy framework for biodiversity

The EC Biodiversity Conservation Strategy (ECBS), adopted in 1998, was developed to meet the EC's obligations as a Party to the CBD. The ECBS provides a comprehensive response to the many requirements of the CBD, and aims to anticipate, prevent and tackle the causes of significant reduction or loss of biodiversity at the source. This will help both to reverse present trends in biodiversity reduction or losses and to place species and ecosystems, including agro-ecosystems, at a satisfactory conservation status.

At the Gothenburg Summit in 2001, EU countries recognised that biodiversity loss is continuing at alarming rates with potentially severe consequences for livelihood security and sustainable economic growth throughout the EU and worldwide. The first EU Sustainable Development Strategy (SDS) was adopted at Gothenburg, and special attention was given to the issue of biodiversity conservation. In recognition of the importance of biodiversity to human well-being and economic development throughout the EU, Member States agreed to work towards halting biodiversity loss, (rather than merely to "reduce the rate of loss" as stated in the CBD strategy) by the year 2010 – a significant and ambitious aim which requires intense collaboration within and across all sectors of government and civil society. In order to implement this aim, four Biodiversity Action Plans (BAPs) have been adopted at EU level, outlining in detail what actions are required, and highlighting the need for a cross-sectoral approach. The four areas targeted are agriculture, fisheries, economic and development cooperation, and conservation of natural resources.

During the Irish Presidency of the EU in 2004, the Irish Government convened an international conference in Malahide, Co. Dublin, entitled "Biodiversity in the EU: Sustaining Life, Sustaining Livelihoods". This Conference was the key event in a critical policy review process, which was widely endorsed by Member States and civil society organisations. Discussions focussed on EU action towards meeting the 2010 target, and the Conference prepared a 'Message from Malahide' detailing priority objectives, targets, indicators of success and implementation arrangements.

Following these developments, biodiversity objectives have been further integrated in a wide range of other sectoral policies. This includes the **Lisbon partnership for growth and jobs**, reinforcing the message that biodiversity must be considered in economic and social development policies made by central government or at decentralised level. Recent reform of the **Common Agricultural Policy** (CAP) aims to help mitigate the damaging trends of intensification and the abandonment of high-nature-value farmland and forests. Considerable progress has also been made in integrating biodiversity concerns in the **Common Fisheries Policy** (CFP), which was reformed in 2002. The previous short-term (annual) decision-making approach of the CFP is replaced by multi-annual recovery plans for those fish stocks that are in danger of collapsing and multi-annual management plans for healthy stocks. The new CFP aims to adjust the size of the EU's fishing fleet according to fish stocks and to promote environment-friendly fishing methods.

In 2006, in response to the Message from Malahide and the results of the Millennium Ecosystem Assessment, the European Commission produced a Communication on "Halting the loss of biodiversity by 2010 – and beyond; sustaining ecosystem services for human well-being". The Communication reviews progress in implementation of the EU Biodiversity Strategy and Action Plans and proposes an Action Plan to 2010 and beyond. For the first time, this Action Plan addresses both the EU institutions and Member States, specifying the roles of both levels of governance in relation to each action. It provides a comprehensive plan of priority actions towards specific, time-bound targets, requiring enhanced consideration of biodiversity in planning and development activities across all sectors.

2.3 THE IRISH CONTEXT

2.3.1 Legislation

A number of Legislative Instruments with relevance to biodiversity have been implemented in Ireland. As most of these have roots in the corresponding EU Directives as discussed above, very little additional detail is required here, except to note that some Irish legislation goes further than the requirements of EU law, or provides structures which allow for the greater integration of environmental concerns into non-environment policy areas. Three aspects of note are: the Irish Wildlife Act (1996), which provides for the designation and protection of Natural Heritage Areas to protect habitats and species of national significance; the EPA Act (as amended by the Protection of the Environment Act, 2003), which allows for independent assessment and licensing of certain industrial activities which may impact on the environment; and the various Planning and Development regulations, which require appropriate assessments of potential impacts on biodiversity and the wider environment, arising from various development and economic activities.

2.3.2 The National Biodiversity Plan

As discussed above, each party to the CBD, including Ireland, has agreed to prepare a National Biodiversity Strategy and Action Plan to implement the CBD within their own national boundaries. The Irish National Biodiversity Plan (NBP) was published by the Government in 2002, with a mid-term review published by the Minister for the Environment Mr Dick Roche T.D. in November 2005. A revised NBP is planned for the period 2008 - 2011.

The plan pays special attention to the need for the integration of the conservation and sustainable use of biological diversity into all relevant sectors: "*The full and effective integration of biodiversity concerns into the development and implementation of other policies, legislation, and programmes is of crucial importance if the conservation and sustainable use of biodiversity is to be achieved*."

Amongst other actions, the NBP requires specific actions in the key areas of agriculture, forestry, wetlands and inland waters, and marine and coastal areas, and also calls for the development of "sectoral biodiversity action plans" to ensure that the conservation and sustainable management of biodiversity is actively pursued by each government department and agency. A set of guidelines on production of these plans has been published by the NPWS, and an Interdepartmental Biodiversity Steering Group comprising representatives from all Government Departments has been put in place.

2.3.3 The National Development Plan and the National Spatial Strategy

Ireland's first National Development Plan and Community Support Framework (2000 – 2006) set the national agenda for social and economic growth and regional development, based on four key objectives:

- to continue sustainable national economic and employment growth
- to strengthen and improve Ireland's international competitiveness
- to foster balanced Regional Development
- to promote Social Inclusion.

The Irish Government and the European Commission identified four priority considerations to be factored into the NDP: poverty, equal opportunities, the environment, and rural development. These cross-cutting or horizontal principles supported all Programmes in the Plan, which oversaw significant investment in social improvements, infrastructure developments and scientific and technological research.

The second NDP, for the period 2007 to 2013, was launched in January 2007. This plan outlines a programme for the investment of €184 billion to support environmentally sustainable economic and social growth over the next seven years, including an allocation of €25 billion in "programmes that will directly and positively impact on environmental sustainability". The NDP recognises that "Ireland's biodiversity, which includes our ecosystems, provides environmental services vital to human welfare. These environmental services include the provision of food, fresh water, clean air and nutrient recycling, all of which are essential to human life. Furthermore, our natural environment is valuable and worthy of protection in its own right."

Table 2.2 below highlights some of the principle themes of the NDP 2007 - 2013 for which biodiversity provides important services.

Table 2.2 Biodiversity in principal themes of NDP

Individual aspects of the NDP	Relevance of Biodiversity
Economic and Social Infrastructure	Biodiversity provides basic resources and natural capital required to maintain and increase economic and social development, and presents a range of opportunities for technological innovation and job creation, supporting recreation, social cohesion and protecting and enhancing human and animal health.
Education, Training and Skills Development	Biodiversity supports job security and growth in food production, sport, tourism, construction, healthcare, manufacturing and the arts.
Enterprise, Science and Innovation	Biodiversity both supports and provides the resource base for food production and other manufacturing industries, tourism, and scientific and technological innovation.
Social Infrastructure and Social	Biodiversity and conservation can play an important role in

Inclusion	urban regeneration, community development, social cohesion and integration, poverty mitigation and job creation, and even crime prevention.
All-island Cooperation	Biodiversity in Ireland must be viewed and managed as an all-island resource, particularly due to cross-border linkages created by both natural and man-made infrastructure and development policies.
Development of the Rural Economy	Biodiversity is essential to rural economies, sustaining agriculture, forestry, fisheries, tourism and a range of other indigenous industries.

The National Spatial Strategy for the period 2002 – 2020 is designed as a framework to assist Ireland to achieve "*a better balance of social, economic, physical development and population growth between the regions*". The NSS contains a large focus on the need for sustainable development, and, importantly, recognises that sustainable development is more than just an environmental concept. In addressing the spatial and regional issues for its implementation, the NSS recognises the fundamental importance of Ireland's natural resource base to the economy and to future national development. Furthermore, it explicitly recognises that biodiversity has intrinsic economic and social value, whether through its importance for recreation or tourism, or its relevance to agriculture, forestry, fisheries and other indigenous industries.

Under both the NDP and the NSS, ensuring that continued national economic and social development (in the short, medium and long term) is not jeopardised by negative impacts on Ireland's biodiversity, requires a high level of cross-sectoral understanding and partnership. The Strategic Environmental Assessment process under EU and Irish legislation represents a useful instrument in this regard, although a strong framework for identifying, monitoring and targeting the critical ecosystem services which support development within each sector is still required. The ecosystem approach, when applied to economic and social considerations, can help to set out the basis of this framework. Although the second NDP has not been subjected to a Strategic Environmental Assessment, many of the programmes and policies that follow from it will be subject to the SEA process under EU and Irish law. This is of particular relevance to Development Plans and Settlement Strategies at the local, county and regional level. In line with the EU Sustainable Development Strategy, the Lisbon Agenda and the EU Biodiversity Action Plan, the conservation of biodiversity must be given high priority as an integral aspect of the successful planning and implementation of the Plan.

REFERENCES:

United Nations Commission on Environment and Development (the Brundtland Commission) and the Rio Earth Summit – the Brundtland Commission Report entitled "Our Common Future" is available at http://ringofpeace.org/environment/brundtland.html

The report of the 1992 Rio Earth Summit (UNCED) is available at:
http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm

The United Nations Convention on Biological Diversity (CBD) – the text of the CBD and information on COP decisions can be found at www.cbd.int

The report of the first International Conference on Health and Biodiversity (COHAB 2005) is published by the CBD Secretariat on their website at:
https://www.cbd.int/doc/programmes/areas/agro/agro-cohab-rpt-smry-en.doc

Millennium Ecosystem Assessment – the background and reports of the Millennium Ecosystem Assessment can be found at www.maweb.org

The U.N. Millennium Declaration is available at http://www.un.org/millennium/declaration/ares552e.htm, and information on the Millennium Development Goals can be found at http://www.un.org/millenniumgoals/ and at http://www.undp.org/mdg/

European Policy and Legislation on Biodiversity and Nature Conservation – the EUROPA website of the European Union provides a portal for information on all aspects of EU biodiversity policy and legislation, including full text downloads of EU and European Commission decisions and directives, convention texts etc. Go to: http://ec.europa.eu/environment/nature/home.htm or ec.europa.eu/environment/index_en.htm

Information on Irish Legislation on the Environment and Nature Conservation can be found on the website of the Department of the Environment, Heritage and Local Government at http://www.environ.ie/, and on the website of Ireland's National Parks and Wildlife Service at http://www.npws.ie/WildlifePlanningtheLaw/.

The National Biodiversity Plan is available at http://www.npws.ie/Biodiversity/Ireland/

Ireland's National Development Plan – details of the NDP, including the text of the NDP for 2007 to 2013 and a review of the previous NDP (2000 – 2006) can be found at www.ndp.ie

Ireland's National Spatial Strategy – the text of the NSS can be found at www.irishspatialstrategy.ie.

(All of the above website URLs are correct as of June 2007.)

3. ECOSYSTEM SERVICES IN AGRICULTURE

3.1 THE RELATIONSHIP BETWEEN AGRICULTURE AND BIODIVERSITY

Through agriculture we have learnt to harness ecosystem services to our own interests by increasing the level and reliability of the production of food crops necessary to our survival. As technology has progressed, we have also achieved a degree of independence from natural systems such that high levels of biodiversity are not required for high levels of production. We can selectively encourage those plant or animal species that are of value to us. We can also substitute for the ecosystem services of others through the application of inorganic fertilizers or the use of pesticides. Indeed, it could be argued that it is largely because our agricultural systems are artificial that we need artificial inputs. For instance, agriculture monocultures (single product) supply pest species with a single food crop, providing the opportunity for potential population explosions of pests in the absence of pesticides. By comparison, a natural system has a diversity of habitats and species that ensures that that these same pests are regulated within natural norms and balances.

If there were no natural systems of any kind it would nevertheless be impossible to produce food. In principle, therefore, the value of biodiversity could be represented as the total value of all food production. However, it is easier to understand the marginal value of biodiversity in the sense of the contribution of various ecosystem services to additional agricultural output.

Technology has permitted big advances in agricultural productivity, but it has its limitations. Technology has diminishing returns and there are limits to our capacity to select and substitute. We cannot, for example, supply all the nutrient demands of crops through fertilizers alone. Neither can we hope to control all potential agricultural pests. Applying more and more inputs undermines future sustainability and leads to external costs for others.

1) Sustainability

It is beginning to be appreciated that intensive agriculture cannot be sustained in the long-run without consideration being given to the need to ensure the continuance of ecosystem services. For example, while pesticide formulations have, indeed, improved over the years to better target pest species, they are unlikely to ever to achieve 100% success. Even if they do, they are likely to be depriving other beneficial species of a food source or some other productive interaction. They can also leave behind residues that interfere with the functions of yet other species, many of which are likely to be beneficial to agriculture and often in ways that are, as yet, little understood. As an example, monoculture crop systems reduce the variety of food sources for bees, while pesticides do an equivalent amount of damage to bee populations, as do herbicides by reducing other out-of-season food sources. Yet bees are important to the pollination of some crops grown under monoculture systems such as oilseed rape.

By diminishing biodiversity, intensive agriculture is removing the foundations on which it depends and is placing itself at risk of future catastrophe. The rather biblical scenario is one where the population of a pest species gets out of control due to the reduction in the population of its natural enemies. Equally, the same would be true of less visible pathogens, some of which could threaten the future of domesticated animals or particular crops that have been selectively bred for high productivity and which have often lost much of their natural disease resistance.

Particular uncertainty relates to exogenous factors, the most pressing of which is climate change and the fear that a diminished biodiversity will fail to respond quickly enough with the result that some ecosystem services could be undermined. Crops could be deprived of essential ecosystem services even where the crops themselves have been selected for a modified climate. The risk may be small, but the implications are unknown, though potentially huge. We may not be able to quantify the insurance value of having a high level of biodiversity (Costanza et al. 2000), but a cautious approach represented by the "precautionary principle" would suggest that we ignore biodiversity at our peril.

2) External costs

Secondly, loss of biodiversity due to agriculture leads to externalities, or external costs, for others. Application of fertilizers or pesticides is inevitably imprecise and certain amounts will always find their way into surface or ground water. Pesticides pose a particular threat to human health as their very toxicity can lead to problems such as increased rates of birth defects, infant mortality, cancers or other diseases. Fertilizers lead to the eutrophication of water bodies by providing nutrients to algae which then reduce oxygen levels to the point where rivers and lakes become unsightly or devoid of aquatic life. The chapters on Water and Human Welfare, discuss the value of healthy river/lake systems to society for the purposes of drinking water and recreation or the indirect value represented by people's appreciation of the wildlife wetlands support. Consequently, there are very real and significant economic and social benefits associated with the avoidance of human health problems, recreation and tourism.

In principle, these external costs could be internalised by ensuring that farmers are charged or fined for pollution. However, diffuse pollution is difficult to identify and difficult to control. Government has therefore opted for the alternative of providing incentives to farmers to reduce pollution. Within the Common Agricultural Policy (CAP) these incentives have been provided in the form of agri-environmental policies, represented in Ireland by the Rural Environmental Protection Scheme. REPS was originally designed to reduce the negative externalities of agriculture, but the scheme has evolved over time to recognize the value of biodiversity within farming and of the need to adapt existing measures to protect biodiversity. These benefits are being realised through lower intensity farming or farming in which semi-natural systems are preserved. Such systems can often provide for higher levels of biodiversity than purely wild systems.

It would be a fallacy to presume that REPS does not have a useful income transfer function as well as an environmental function. Neither is the scheme entirely directed at protecting biodiversity. However, to an extent, the amount spent on REPS, at upwards of €280 million per year, does provide an indication of the minimum value that society places on both good environmental management and biodiversity.

3.1.1 Valuing Biodiversity within Agriculture

The value of biodiversity is at a maximum where an agricultural system is designed to be sustainable. Where the system is more intensive, this value may appear to be less, but future output will depend on some restoration of biodiversity. A closed-system organic farm in which no inputs are imported would represent the ultimate example of a sustainable system.

The problem is that output is lower on organic farms and the price premia of organic produce does not generally compensate for lower yields in terms of higher revenue. Relative produce prices are still determined by supply and demand of all food products as much as by production costs.

Intensive agriculture is capable of producing a higher output. Although ecosystem services have distinct value, it is worth remembering that high intensity systems with low biodiversity dependence are commonly being selected by farmers the world over. Many farmers have clearly decided that the opportunity cost of protecting biodiversity, for example by setting aside areas of natural vegetation, is less than the economic benefits of a more intensive system (Ghazoul, 2007). Aside some from fundamental processes, the associated value of biodiversity therefore appears to be low. This situation may arise because of a lack of awareness of the benefits of ecosystem services. It can also arise because biodiversity is a public good that often requires protection at community level, whereas agricultural output is a private benefit. Scientific opinion is that intensive agriculture is not sustainable in the long-term (Ryan, 1999), but farmers are not always in the position of being able to consider the environmental damage or the costs to future generations.

As an alternative, a broadly sustainable, but non-organic system would have a stronger relationship with biodiversity. A two-tier intensive/extensive agricultural sector is now the rural development prospect for Ireland and much of the EU (Binfield et al, Agri-Vision 2015). The extensive scenario has employment and social benefits and is likely to be represented mainly by smaller farms that are partly dependent on rural development payments. These payments reflect policy support for a scenario that favours farming systems which benefit the environment, rather than a system that ensures that high-output farming systems conform to environmental criteria. The former farms will not be able to match the high yields of the more intensive sector, although they are often capable of producing higher quality food. Before taking into account the social costs and benefits, ecosystem services may appear to be more valuable on these extensive farms than they would be for those with a greater dependence on artificial inputs.

A sustainable, high biodiversity system may not produce the gross quantity of output of an intensive farm. However, the value of biodiversity is best represented by its capacity to support a sustainable farming system with its associated environmental and social benefits.

A broadly sustainable agriculture of the kind envisaged under Rural Development Policy may still depend on external inputs and produce some waste, but to a lesser extent than the intensive alternative. These wastes should be of a quantity that could be assimilated by the environment. Where nitrates or phosphates accumulate due to ecosystem services having been diminished or over-whelmed, the cost of "clean-up" or of "damage avoided" provides a measure of the benefits of a functioning biodiversity.

Consequently, the value of biodiversity within a broadly sustainable agricultural system is represented by both the value of the crop and the benefit of damage avoided.

Amongst the problems which may arise when the ecosystem is damaged, is eutrophication. Eutrophication of surface waters due to phosphates and, to a lesser extent nitrates, is amongst the principal problems facing the Irish environment. A reduction in human welfare arises from eutrophication due to phosphates. Human health risks also arise where excess nitrates are not removed from drinking water. This is rarely done in Ireland despite elevated levels in parts of the South and South-East (GSI 2000).

In the UK, the benefits of dealing with all sorts of diffuse pollution to water have been estimated to be worth £250 million per year (Environment Agency, 2002). A measure of the value of a functioning biodiversity is the avoidance of the external costs from this pollution. A whole-farm sustainable system that is more dependent on biodiversity provides a more continuous supply of nitrogen to plants and pasture with far less wastage than fertilizers. Indeed, leaching of these nitrates is typically 25-50% less on more sustainably managed or organic farms.

As the welfare element is considered elsewhere in this study, it is worth addressing the costs of physical removal of pollutants. For example, the annual cost of nitrate removal in the UK has been estimated at between £24 and £38 million (Redman, 1996, Cobb et al. 1999. Defra, 2004). Adjusting these estimates for the number of households in Ireland and the size the arable sector suggests that at least €2 million per year should be spent to avoid additional external costs. In fact, the Department of Agriculture is spending €39 million per year on the Nitrate Directive via the Farm Waste Management Scheme and those elements of REPS directed at nutrient management. There will be private costs too for some farmers, most especially pig and poultry producers who must comply with IPC licensing.

3.1.2 Ecosystem Services

It is neither practicable nor entirely possible to deduce the relevance of all biological diversity in agricultural systems. This is because there are few studies in this area and global knowledge on the topic is very sparse. Most studies have focused on the adverse impact that agriculture is having on biodiversity, rather than the positive impact of biodiversity to agriculture. To illustrate the value of biodiversity, we can focus three principal ecosystem services, namely:

1. Pollination
2. Soil nutrient recycling,
3. Pest predation and parasitism.

In recent years, ecological thinking has edged away from the concept of "keystone species" responsible for such ecosystem services. Instead, there has been a recognition of the functional inter-relationships that exist between all species together with renewed attention to the issue of whether 'high biodiversity = stability', therefore providing the insurance required for sustainability. This, in turn, has led to increased interest in the concept of "redundancy", i.e. where the same ecosystem services can be provided by more than one species (Bolger, 2000). Within this hypothesis, it is accepted that the extent to which a species is *redundant* may depend on environmental circumstances at any one time.

Nevertheless, there is some evidence to suggest that those species that are most important, and which exhibit low redundancy, are the same species that could be lost first to environmental change (Larsen et al. 2005). The concept of keystone species therefore still has some validity and is, at least, of illustrative value.

3.2 POLLINATION

3.2.1 RELEVANT SPECIES AND FUNCTION

Amongst the most well-known services performed by a healthy biodiversity is pollination. Of pollinators, bees are the keystone species. As nectar is collected for both the colony and for the benefit of the individual bee, bees make more flower visits than any other insect. In Britain, honey bees (*Apis mellifera*) are presumed to be responsible for 80% of pollination, but bumble bees (*Bombus terrestres*) are the more efficient pollinators from a human perspective. Bumble bees are more active in our cool, wet climate. They are also the more willing to fly further from field boundaries into larger fields (Santorum & Breen, 2004). Their longer tongue length means they are able to pollinate a wider range of plants. While there are 13 true bee species in Ireland, the population of bumble bees, in particular, has unfortunately declined in recent decades. In parts of Britain and other European countries, this decline is now regarded as being quite serious.

3.2.2 RELEVANT SPECIES AND FUNCTION

Agricultural crops

Bees have an important, and often critical, role in the pollination of many horticultural and fruit crops. Ireland's agriculture also benefits from this pollination service, although our climate does mean that a lower proportion of agricultural output is represented by these crops than in most other European countries.

While Ireland may not be a big producer of fruit or horticultural crops, it does have a dependence on one crop whose association with pollination could easily be overlooked. Clover is very dependent on bees for pollination. Clover is a forage crop that fixes nitrogen from the air and so contributes both to animal weight and growth (Nolan & Grennan, 1998). Furthermore, clover is a substitute for nitrogen fertilizers on extensive and organic pastures. It could yet attain renewed importance given EU controls on artificial nitrogen fertilisers and expected trends towards extensification. Seeding depends on bees at a quantity of up to 15 colonies per hectare. Both honey and bumble bees can fertilize the agriculturally important white clover, but the latter's readiness to travel longer distances makes them the more useful pollinator in larger fields. For red clover, the length of the flower means that only bumble bees can "trip" the flower.

Of other crops, Ireland may not be a big producer of fruit, but some pollinated crops are nevertheless locally important, including tomatoes, strawberries and smaller quantities of apples and berry crops such as blackcurrant. Organic production of each of these crops is becoming more common. Apples have a high dependence on pollination by bees and between 0.6 and 5 colonies per hectare are required. Blackcurrants are also highly dependent on both honey and bumble bees. In the case of strawberries, pollination is of most value to increasing seed number. Bee pollination also contributes to improved quality and fruit size.

Bee pollination is less important for tomatoes as pollination is achieved by wind, aided by the physical shaking of the flowers. Bees do, however, improve the efficiency of this process by vibrating the flower. Bee pollination is also of only modest importance to oilseed rape. However, it is reported to improve the timeliness and evenness of crop maturity (Williams et al, 1987). Furthermore, oilseed rape could yet become a very important crop in the future for biofuel.

Domesticated bees

Of course, given past trends towards agricultural intensification, it is no surprise to find that bees too have been domesticated for the purpose of pollination. The services of wild bees have in many cases been replaced by the provision of hives. In fact, this is a long established practice in orchards and the mutually beneficial relationship between beekeepers and farmers has been the subject of key economics papers (Coase, 1965). Due to natural population fluctuations, together with the decline in numbers of wild bees, this service has now become artificially available in glasshouses and polytunnels. Beginning with honey bees in the eighties, domestication of the more useful bumble bee has now become common. Bumble bees are less manageable than honey bees, although the latter are notoriously unreliable in tunnels, often choosing to escape once vents are opened.

Wild plants and gardens

Despite some domestication, wild bees will continue to be essential to the success of clover and of other crops grown on larger fields. Furthermore, as well as agricultural crops, bees are of obvious value to many wild plants. As can be expected, many of these plants provide food or habitat for other species, including those that are valuable, in some way or another, to ourselves. Some of these wild plants could be considered weeds by farmers but, in fact, provide nectar for the bees outside of those times then their services are required by commercial crops.

Naturally, bees also have an important role in gardens, including those where vegetables and fruit are grown. In turn, this makes bees essential to the output of the valuable garden centre trade.

3.2.3 ECONOMIC AND SOCIAL VALUES

International estimates

In the US, Robinson et al. (1989) have estimated that 31% of the value of US agricultural production is dependent on bees. This contribution is conservatively valued at over €9 billion per annum. Morse and Calderone (2000) are less cautious and estimate pollination to be worth up to €14.6 billion. Similarly, an estimate for Canada has been placed at C$1.2 billion per annum (Winston et al, 1984).

In the EU the contribution of wild bees has been estimated at €5 billion per annum, and €4.25 billion for domesticated bees (Corbett et al, 1991).[3] For the UK, Carreck and Williams (1998) apply a weighting system for different crops. Using this method, they estimate a value of

[3] Original estimates were in ECUS. All figures would need to be adjusted upwards for inflation.

£172 million for outdoor crops and £30 million for those under cover. On the same basis, they estimate the average value of each honey bee colony to be £12.

The Economic and Social Value to Ireland

Bees provide a service to production that can be estimated directly in economic terms. An approximate estimate of the current pollination benefit of bees in Ireland would be €85 million per annum. This figure would represent a reduction on previous years given the increasing use of polytunnels and domesticated bees for much fruit and tomato production, in part because of the declining bee population. Domestication of bees has become far more widespread since the early nineties and provides something of a guarantee against natural fluctuations in bee populations despite the greater efficiency with which wild bees fertilise plants. As tunnels provide effective climate control, only rather small areas of outdoor strawberry production remain.

Table 3.1: **Direct benefits of pollination**
(Applying the pollination weightings used by Carreck and Williams, 1998)

	weighting	Area (ha.)	Value	Value of pollination
Clover (weight gain direct & indirect)	0.5	10% area 20% wt gain 5-8% sheep	€1,479mn (cattle) €1,323mn (milk, etc.) €190mn (sheep)	€29mn.
Oilseed rape	0.1	3,400	€5mn.	€1mn
Peas, beans.	0.1	3,400	€50mn.	€5mn.
Apples	0.9	631	€2.6mn.	€2.3mn.
Strawberry	0.1	150 (450 indoor)	€4mn.	€0.4mn.
Blackcurrant	0.9	200	€0.1mn.	€0.09mn.
Other soft fruit	0.1 – 0.9	225	€28mn.	€14mn.
Total value				**€53mn**

Gross values before subsidies. 2005 values (CSO).

There is no specific information on the marginal value of bees. However, it would not be unreasonable to attribute a portion of the additional input cost represented by the provision of domesticated colonies to the decline in the wild bee population as an indication of the benefit of this ecosystem service. Moreover, the relative value of wild bees is increasing as the population declines and farm systems change. Demand for biofuels is expected to bring about a doubling of the area of oilseed rape across the EU (Doyle, 2007). Bees are also important to the cross-pollination of an increasing production of hybrid crops, including fruits.

Furthermore, the role of bees in the pollination of clover may mean that this ecosystem service becomes yet more important given that clover is a natural substitute for polluting nitrogen fertilizer. Were clover to play a greater role beef and dairy production given trends to more rigorous environmental criteria including nitrate management, the biodiversity contribution of pollination could be worth far more in the future. Currently, grassland farmers account for two thirds of the €250 million spent annually by Irish farmers on nitrogen fertiliser (CSO, 2006). In the UK the external costs of excess nitrogen application, in terms of human health and acidification, have been estimated at between £0.5 and £1 billion per year (Hartridge and Pearce, 2001).

In that bees are also important for parks and gardens, they also perform an important economic role in helping to supporting Ireland's 380 garden centres and an amenity/plant industry that is worth around €300 million of which the farmgate value of nursery stock is €50 million. Gardens have a very important social role too, of course, and one that certainly has economic, social and health benefits. The bees contribution is, though, of more value to vegetables than for blooms.

Of ultimately more importance, is the equivalent economic and social benefits that are associated with countryside recreation. Bees ensure the survival of many wild plant species and are vital as food or habitat for Irish wildlife as well as being a fundamental element of the familiar rural landscape that is valued by so many people. The size of this public good is unknown, but is obviously considerable. According to Corbet et al. (1991), 27% of the 321 bee-pollinated wild plant species are endangered.

3.2.4 THREATS

Pollination is an ecosystem service that is under threat from the falling bee population. As well as falling absolute numbers, there has been a decline in the diversity of species recorded on farms. Bumble bees, in particular, have declined significantly. Already, in Britain, field beans often have to be pollinated by hand because of the shortage of bees. In Ireland, crops grown under cover are already dependent on domesticated bees. Orchard owners are taking pro-active steps to ensure pollination given both the decline in wild bees and falling interest in beekeeping.

The exact reasons for the decline in many bee species are unknown, although the usual suspects present themselves. Insecticides and herbicides are certainly two culprits. So too has been a viral disease that has been slowly spreading northwards across the country. More insidious, perhaps, is the trend to monoculture using uniform seeding supported by fertilizers and large field size. These practices have reduced the variety and continuity of the bees' food sources. Bees are noticeably less common and diverse on intensive farms (Santorum & Breen, 2004).

Ultimately, a healthy wild bee population is essential to the renewal of the domesticated population. In the United States, honeybee populations have declined from around 3.4 million colonies in 1989 to 2.5 million in 2004 (USDA 2006). In 2006, beekeepers witnessed a massive and sudden decline in domesticated populations known as "colony collapse disorder". Although the problem affected between one quarter and a half of beekeepers, the cause of the problem remains unknown (Reilly, 2007).

3.2.5 COST OF PROTECTION

REPS contains a field boundary measure and another to protect field margins and streams from chemicals. Growing recognition of the biodiversity benefits of field margins, and the direct contribution that this habitat can make to on-farm productivity, means that REPS is being redesigned to better support biodiversity explicitly. Much, however, depends on implementation as attempts at ensuring a good mix of hedgerow plant species can be undermined by careless crop spraying and nutrient management (Feehan, 2002).

Measures that protect hedgerows and leave field margins uncultivated may not be sufficient on their own, but they will help to combat the decline in the bee population. Banaszak (1997) recommends that 25% of farm area should be preserved as semi-natural habitat to ensure bees' survival.

3.3 SOIL MIRCO-ORGANISMS, INVERTEBRATES AND FUNGI

3.3.1 RELEVANT SPECIES AND FUNCTION

The soil biota is the most species rich component of the terrestrial ecosystem (Bolger et al, 2000). One gram of soil alone contains several thousand species of bacteria and other micro-organisms (Torsvik et al, 1994). Macrofauna such as earthworms physically break up the litter from vegetation such as dead grass and leaves, while also releasing some nitrogen to plants and benefiting soil structure. Mycorrhizal fungi, microbes and smaller invertebrates then take over and are responsible for final decomposition and the essential supply of nitrogen. This organic life ensures that the soil is the second biggest store of carbon after the oceans.

Rather little is known about the smaller species and microbes, for instance springtails (Collembola), mites and nematodes, on which very little research has been conducted in Ireland. Likewise, little is known about the complex positive and negative inter-relations that prevail between species, the vulnerability of these relationships, or levels of redundancy (i.e. where various species perform the same functions).

3.3.2 ECOSYSTEM SERVICES TO AGRICULTURE

Soil biodiversity is critical to agriculture. Without the ecosystem services provided by the soil micro-organisms, farming would not be possible. The absolute value of biodiversity could therefore be quantified as the value of all agricultural output as a minimum. It is true that intensive agriculture can do without the services of some organisms by replacing their contribution to nutrient recycling with a supply of inorganic fertilizers (just as domesticated bees can partially replace wild bees). However, doing so at sustained high levels ultimately risks undermining other ecosystem services that cannot be substituted. It also contributes to water pollution in that inorganic fertilizers remain in the soil only for short periods before being flushed out by rain. Only a maximum of 50% of soil nitrogen can ever be derived from artificial inputs (Robertson & Swinton, 2005).

Amongst soil fauna, the contribution of earthworms is perhaps the most familiar and understood. Earthworms are most at home in broad-leaf woodland, in mixed farms and on pasture. The last of these can support between 10-15 species and as many as 390 individuals (per square metre). Despite all this activity, the direct contribution of earthworms to nitrogen provision could be less than 1%. However, earthworms are essential to the initial process of litter removal and its fragmentation for use by other soil organisms. Their burrowing and cast formation is also of great value to maintaining a good soil structure which allows water infiltration and aeration.

Ploughing drastically reduces the population of earthworms, particularly where the land is given over to monoculture (Schmidt et al, 2001). However, where the use of mechanical methods is minimized, earthworm numbers can actually be higher on more intensive than on low input fields, at least where subject to field rotations and possibly due to the higher harvesting waste that is left behind (Bailey et al., 1999; Cole et al., 2006). Only in the case of intensive monoculture systems is there unanimous agreement that agriculture can have an adverse impact on the soil biota. Earthworm populations can also help rehabilitate previous tillage land where this has been left fallow and can even be purchased for this purpose (Schrader & Larick, 2003). Where earthworms are absent, organic acids in the soil can increase leading to increased soil acidification.

Relating the ecosystem service of earthworms with agricultural productivity is an unreliable approach given that earthworms are but one part of the web of inter-related ecosystem services. To begin with, different earthworm species provide varying functions at different soil depths. Another factor is that the various ecosystem services which are performed varies depending on the agricultural activity. For example, earthworms have been observed to lead to a significant uptake of nitrogen in wheat systems not subjected to ploughing, but make an indistinct contribution where wheat is grown with nitrogen-fixing clover (Schmidt, 1999). Indeed, the relative contribution of earthworm and clover is difficult to pin down precisely, although earthworms do benefit clover by aiding germination and increasing the availability of phosphates.

The results of experiments performed in field plots often vary. However, New Zealand or the Dutch polders provide large-scale laboratories in that earthworms were formerly absent. In New Zealand, Stockdale (1966) found dry matter production increased by 19% in two years after introduction of *A. catiginosa*. Long-term improvements were of the order of 25-30% in New Zealand (Lacy, 1977) or 10% on the Dutch polders (Hoogerkamp et al, 1982).

Where earthworms have diminished, dramatic reductions in soil porosity have been identified with consequent lower water infiltration (Lee, 1985). Westeringh (1972) observed a significant build up of un-decomposed surface matter on Dutch farms where the earthworms and other soil fauna were no longer present.

3.3.3 ECONOMIC AND SOCIAL VALUES

Soil biodiversity was far and away the highest biodiversity value estimated by Costanza et al. (1997) at over $17 billion. Estimating the contribution of one species is near impossible given that the contribution of each single species is complementary to that of others. For earthworms, the relationship with dry matter growth is itself subject to many factors. Nevertheless, this keystone species has a clear value in both releasing nutrients to the ecosystem and in removing dead matter that would otherwise choke new growth or harbour disease and pests.

Bailey at el. (1999) examined the value of earthworms through the relative costs and productivity returns of two arable systems, one based on ploughing and seeding, the other on direct drilling which relies on earthworms for aeration and mineralisation. Comparing the relative populations of earthworms, they arrive at a value of between £0.08 and £0.48 per kilo of earthworms. At a minimum earthworm biomass of 125kg/ha., this would be equivalent to between £10 and £60 per hectare per year.

Losey and Vaughan (2006) focus on a particular obscure, but nevertheless valuable function, namely dung burial. While this might seem a little peripheral, it is worth noting that each cow can produce over nine tonnes of waste per year. It is also worth bearing in mind that, in Australia, dung beetles needed to be imported at an early stage in the country's settlement so to deal with the accumulation of sheep and cow manure that would otherwise have taken many more months to disappear from the landscape while meanwhile providing a micro-habitat for parasites. In Ireland, this service is performed by both earthworms and beetles. Losey and Vaughan estimate the value of their work in the US to be €380million per annum based on the value of beef cattle alone. Dung beetles also assimilate most of the nitrogen from the dung (2%) which would also be lost to the atmosphere.

Another route to identifying the value of soil biota is through its more efficient and continuous supply of nutrients to plants. Artificial nitrates are quickly leached into the subsoil and external environmental costs follow in terms of the pollution of watercourses. As noted above, this cost can be estimated in terms of the cost of nitrate removal from drinking water and from the external cost of eutrophication of waters that are valued for angling or amenity. Bailey et al. (1999) estimated that the more intensively farmed fields in their survey experienced excess leakage approximately twice that of the low input system.

Economic and Social Values in Ireland

If the approach of Bailey et al. were to be transferred to Ireland, the benefits would amount to £18 million per year if the same conditions apply. However, the overwhelming majority of agriculture in Ireland involves animals. Nitrogen recycling is still critical to grass production, but nitrogen losses are less as Ireland's more permanent ground cover reduces erosion and leaching. Phosphates from slurry applications are the greater problem.

The Losey and Vaughan study of cow pats is of relevance as earthworms are important to their disposal in Ireland. In a similar European context, Holter (1982) found that an average population of earthworms in Denmark was responsible for the disposal of at least one third of the mass of cow pats. However, high grass growth and trends to reduced stocking density mean that the fouling of pasture is a less serious problem here than in some other countries.

For Ireland, it is perhaps easier to consider the contribution that earthworms make to the overall production of vegetative dry matter (forage). Average baseline conditions in Ireland support over one livestock unit (roughly one adult dairy or beef cow) per hectare. The soil fertility that makes this possible could, in principle be replaced through artificial inputs. However, continuous artificial nitrogen input would reduce the transformation properties of the soil (Fromm, 2001). Furthermore, the soil biota has the virtue of providing a constant stream of nitrogen. If results from New Zealand or the Netherlands apply to Ireland, then earthworms contribute to up to 25% more forage production than would be achieved in their absence at this baseline. Hence, the presence of earthworms could be said to contribute up to €723 million per year in terms of the value of livestock production.[4] Adding a comparable contribution to tillage and horticultural crops (value €1.3bn) - noting especially the important services that earthworms provide to soil structure - could raise this value to over €1 billion. The figure would still be modest in relation to the value of the whole soil biota.

In practice, some artificial nitrogen fertilizer is used even in low intensity cattle farming. Rather than considering the soil biota's capacity to replace nitrogen fertilizers, it may be more pertinent to consider its capacity to quickly recycle nitrogen from slurry whose inefficiency as a fertilizer means it is prone to pollute watercourses. Indeed, an active soil biota has the potential to replace slurry in association with a grazing system that employs clover. Clover is both forage and fixes nitrogen from the air. It is difficult to manage, but could be more widely adopted by farmers in response to new nitrate regulations that now limit the application. Nearly 40% of dairy farms with intensities less than 2 livestock units are affected by the nitrate regulations. More widespread adoption of clover could replace a small portion of the 300,000 tones of artificial fertilizer which is applied each year at a cost of €270 million

[4] Irish beef, dairy and sheep output (2005) was respectively valued at €1,417mn, €1,335mn and €192million. Exports (less live imports and milk products) totalled €2,573mn.

(McQuinn et al, 2005). However, a potentially greater benefit could follow from any replacement of slurry which, as a waste product, costs nothing, but imposes a far higher cost on the environment.

3.3.4 THREATS

Many useful species are clearly reduced in numbers by intensive agriculture, particularly tillage on large fields where pesticides and herbicides are used. The low level of recovery in earthworm populations following intensive tillage has alarmed some researchers (Curry et al, 2002). On the other hand, there are species, e.g. *M. minuscule*, which do appear to thrive on cultivated land (Schmidt & Curry 2001).

Earthworm populations have been threatened by the importation of exotic species, notably the New Zealand flatworm (*Arthurdendyus triangulatus*) which predates on earthworms. However, the evidence to date is that flatworm populations have largely been confined to gardens and have struggled to sustain high populations away from this favourable habitat. Ultimately, flatworms cannot survive without their prey. However, they are an additional unwanted source of instability to an ecology that is already threatened by disruptions due to climate change and chemical residues.

Tunnel warfare

Earthworms in Ireland are under attack from deadly alien Australisian flatworms whose choice of attack is to inject poisonous enzymes into their prey before eating them alive. Such a vicious end is hardly deserving of a creature which has a justified reputation of the gentle good guy of the soil community. However, it seems that once transplanted to new surroundings, earthworms can very quickly become the destructive boyz-in the hood. While, at home, the common earthworm *Lumbricus terrestris* is content to labour away at turning over the nutrients from leaf and other vegetable litter, this enthusiasm has run wild in North America where earthworms were not previously to be found. In the maple forests of the eastern United States, the familiar flowers and other flora of the forest floor depended on a thick layer of leaf litter or “duff”. Unfortunately, where European earthworms have established themselves, the forest floor has been reduced to bare earth. As though this is not bad enough, *terrestris* may soon have a new territorial battle in its new home in the form of a yet more voracious competitor belonging to the Asian genus *Amynthas*, once better known to anglers as good fishing bait, it harbours aggressive territorial ambitions.

New Scientist 3/03/2007

The concept of redundancy comes into its own in relation to the soil biota given the great number of species present. Some ecologists favour a more profound impact for macrofauna such as earthworms (Cole et al., 2006). Another observation is that redundancy is less prevalent in soils with low biodiversity (Bardgett, 2002; Cole et al., 2006). Beare *et al.* (1995) accept that there is a high level of redundancy within single functions, but that a suite of species is necessary to ensure that these functions are continued under changing environmental conditions, within multiple micro-habitats and at various depths (Griffiths et al., 2000; de Ruiter et al., 2002). Climate change could cause major disruptions to these species assemblages and inter-dependencies which could undermine familiar ecosystem services while also permitting the release of soil carbon into the atmosphere with compounding consequences for temperatures. Soils are the largest reservoir of carbon after the oceans.

3.3.5 COST OF PROTECTION

No specific measures have been introduced to protect the soil biota despite its fundamental importance to agriculture. Certainly, REPS measures play a part by promoting better nutrient management and by reducing the incentive to apply chemicals. Nitrate regulations could also lead to farmers playing greater attention to the natural supply of nutrients through the soil biota. In the UK, increasing attention is also being given to soil erosion, especially given the prospect of climate change induced drought and flash flooding. Conservation tillage in which use of ploughing is minimised is reported to reduce erosion losses by 90% (CIW, 2006). It would also help to protect earthworms and other invertebrates which, in turn, play an important role in naturally supporting soil structure and improving water infiltration.

3.4 PEST CONTROL

3.4.1 RELEVANT SPECIES AND FUNCTION

A healthy level of biodiversity ensures that insect and animal pests are more likely to be controlled by their natural enemies. More intensive farming in which pesticides and other chemicals are used removes the food source of many natural enemies while herbicides and removal of field boundaries reduce their habitat. Insecticides keep pest populations low, but do so at the risk of environmental pollution and with the possibility of destabilizing the system such that pests could experience a sudden increase in population in the absence of predators. Indeed, pest species may become resistant to some insecticides in the long run.

Insectivorous birds provide an important service in terms of pest control. So too do predators such as ground-dwelling spiders and carabid beetles, flying species such as gall midges (*Cecidomyiidae*), hoverflies (*Syrphidae*) and ladybirds (*Coccinellidae*). In addition, there are thousands of parasitoid species such as wasps which infest host species with their eggs.

3.4.2 ECOSYSTEM SERVICES TO AGRICULTURE

In Ireland, fungus presents the greatest risk to agricultural production. Therefore, indiscriminate use of and fungicides, followed by herbicides, are the main problems for biodiversity. Losses to insects are less than in some other countries, but are not insignificant. For example, aphids are major problem and also a common prey or host for other insects. Schmidt et al (2003) found that aphid populations were 70% higher in the absence of flying predators and parasitoids. They were 172% higher when both these and ground-dwelling predators were removed. Pasasitoids appear to be most effective. Indeed, most pests are not controlled by pesticides, but by their natural enemies. Providing artificial habitats, such as “beetle banks” of dead wood, can be highly effective in controlling these farm pests (MacLeod et al., 2004; Thomas et al., 2000).

Predators and parasitoids are of most benefit to horticulture and cereal farming. As these crops represent a lower proportion of Ireland’s agriculture than in many other European countries, the overall relevance of predators and parasitoids is less. Even so, aphids and other pests can cause serious losses for arable farmers by their feeding on roots, shoots or pollen, or through the spread of fungal and viral disease.

3.4.3 ECONOMIC AND SOCIAL VALUES

International studies

The economic benefits of predator and parasitoid populations obviously depend on the level of aphid infestation and the type of crop. Schmidt et al's experiment was performed on winter wheat for which a threshold level of economic damage has been estimated by Giller et al (1995) at five aphids per shoot.

Few other studies have quantified these benefits. In the US, Losey and Vaughan (2006) estimate crop losses due to insects to account for 15% of the value of production. They further estimate that 65% of any additional loss is being avoided through the use of pesticides or predatory natural enemies. By assuming that 39% of this loss is due to native pest species, they arrive at an estimate of the benefit of natural pest suppression to be €4.5 billion per annum.

Integrated pest management (IPM) can be used to manipulate predator populations in order to control pests without resort to pesticides. In one such system for a celery crop in the US, Reitz et al. (1999) report the use of 25% less pesticide and lower pest management costs. Studies in the UK have shown that IPM systems can reduce costs with little if any reduction in output. At present, in eastern England, around £100 per hectare is spent by arable farmers on agro-chemicals other than fertilizer (Defra, 2000).[5] In the UK, Hartridge and Pearce (2001) have estimated the costs of physical removal of pesticides from drinking water to be £125 million per year, with the additional costs of food and water monitoring, as well as farmer sick days to be £10.8 million per year.

As well as the potential monetary savings on pesticide use, there are also significant benefits to human health from IPM as such chemicals have been implicated in various diseases and birth defects. There is also the avoidance of further losses of biodiversity. Pesticides have been implicated in the decline of species such as grey partridge and corn bunting. In the US, health and biodiversity costs have been estimated as being twice those of the actual expenditure on pesticides (Pimental et al. 1992). Most European studies have produced more conservative estimates of external costs, although, for Germany, these have still been placed at US$148 million per year, or 20% of pesticide expenditure (Waibal & Fleisher, 2004).

Economic and social values in Ireland

Aside from the Losey and Vaughan estimate, the capacity of predatory or parasitoid species to reduce significant outbreaks of pests does not appear to have been demonstrated in economic terms. Some evidence of relevance for Ireland is available from the use of IPM or similar systems in North-West Europe. Bailey et al. (1999) report on the use integrated agricultural production (IAP) in a farm in Scotland where reduced levels of pesticides were used in a system of managed input reductions. They find that the integrated system provides higher returns (31%) than a conventional agricultural system. Output is lower, but so too are variable costs, mainly due to the lower use of chemical inputs. Bailey et al. report that 20% less pesticide was used on the IAP farm.

Around 2,800 tonnes of chemicals were used by Irish farmers per annum in 1994 (Taylor & O'Halloran, 1999), a figure that is since likely to have increased based on UK trends and the larger area of oilseed rape. In Ireland, annual cereal pesticide sales are €600,000, but additional amounts are spent in horticulture and in gardening, bringing the total figure to over

[5] Pesticide is often taken to include both herbicide and insecticide. In this section, the term is taken as being equivalent to insecticide.

€3.3 million. Pyrethroids are the most commonly used insecticide. A 25% reduction in pesticide usage due to improved protection and recognition of the role of natural enemies in pest management could therefore account for benefits of half a million euro in saved expenditure and the public benefit of avoided external costs to health. However, a greater benefit is realized in terms of damage avoided through the existing level of predation.

3.4.4 THREATS

Inevitably, intensive agriculture reduces populations of predatory and parasitoid species, particularly where pesticides are used. Possibly the scale with which agro-chemicals are used may be more critical than their actual toxicity (Purvis & Bannon, 1992). By relying on large fields, monoculture also has the detrimental affect on predatory species by removing the hedgerows and other on which they depend. Specialized parasitoids often have smaller ranges than their hosts are therefore be vulnerable to any fragmentation of habitat or loss of habitat diversity which reduces the variety of food sources and the potential to disperse (Zabel & Tscharntke, 1998; Tscharntke, 2005). Carabid beetles are an exception that can recover from insecticide attacks due to their capacity to disperse.

Supplies of pollen are often an alternative food source for many parasitoid species which may depend on only a single pest host. Other species, such as spiders and predatory beetles, are influenced by the landscape mix at a larger spatial scale (Symondson et al, 2002).

3.4.5 COST OF PROTECTION, CURRENT MEASURES AND FUTURE STRATEGY

The capacity of particular species to recover from environmental shocks varies. Important means to preserve key species include maintaining a network of field boundaries and a continuation of diverse food supply though mixed or intercropping or crop residue. Unadulterated field margins appear to be especially important. Although these can also provide a habitat for pest species (van Emden, 1965), the evidence is that predatory species benefit proportionately. In a review of various studies, Bianchi et al. (2006) report that predatory species were 74% higher, and pest species 45% lower in varied landscapes.

3.5 IMPLICATIONS OR BIODIVERSITY LOSS IN AGRICULTURE

3.5.1 BIODIVERSITY CHANGE

The rural landscape is changing over time. In the more productive areas, this change was quite dramatic in the early years of membership of the European Common Agricultural Policy. The more distinct changes have arisen from changes in farming practice, with implications for natural vegetation and habitats. As natural habitats have become more fragmented, the populations of widely seeding species and their associated host species are vulnerable. Numbers of bees and other beneficial insects have declined dramatically largely because of the lower diversity of farming systems and loss of habitat, for instance hedgerows. In turn, natural plant species which depend on animals and insects for seed dispersal or pollination are themselves in danger of extinction. Formerly common farmland bird species have either disappeared or been forced into more marginal habitats. Many of these species, including corncrake (*Crex crex*), corn bunting (*Miliaria calandra*), yellowhammer (*Emberiza citrinella*) and grey partridge (*Perdix perdix*) are associated with mixed farming systems. As Irish farming has become more specialized, there is a lower variety of food sources to support these species, particularly as grassland systems have become more dominant.

3.5.2 IMPLICATIONS FOR AGRICULTURE

The loss of biodiversity on Irish farms has been well-documented (for example, Jones et al. 2003). Biodiversity loss has implications for our own social and economic well-being, and for agricultural productivity. If plant diversity is being reduced over time, then the consequences of this extend beyond the habitat of wildlife alone. Tilman et al. (2005) refer to numerous studies that have demonstrated that lower plant diversity leads to less primary productivity, less carbon storage and greater leaching of nitrates.

Farming systems high in biodiversity can have a productivity that matches, or even exceeds, that of systems supported with high inputs. A linear relationship between grassland plant species richness and plant productivity can be demonstrated, at least initially (Finn et al, 2000, Gross et al, 2000). This productivity, in terms of forage production, in turn contributes to weight gain by herbivores. The gain may be less than that which can be achieved through deliberate intervention to improve sward diversity, for example through the seeding of productive grasses or clovers, but is achieved without polluting inputs and with the benefit of sustainability and high biodiversity. In Britain, Bullock et al (2001) have reported increases in hay yields of 60%. Although the costs of the seed exceeded the value of the production gain in the first years, these higher yields continue for subsequent years. Furthermore, part of the higher long-term yield also derives from an associated portfolio effect. That is, the diversity of vegetation is less vulnerable to changes in external conditions such as exceptionally wet or dry years (Tilman, 1996).

Agriculturalists understand that a diverse covering of vegetation provides herbivores with naturally diverse and nutritious grazing. Many farmers too recognize the benefits of both vegetation and crop diversity. They are aware that combined sheep/cattle grazing systems can be more productive than ones based on simple species. Sheep reduce the amount of clover but increase the amount of *Poa trivialis*, whereas cattle tend to increase the relative amount of clover to grass (Conway et al, 1972, van Rensburg, 2006). Unfortunately, artificial support policies have tended to favour specialization.

Research by De Falco and Perrings (2005) confirms the benefits of diversity in terms of both revenue and risk aversion in cereal production. High levels of stocking, supported through the application of inputs and additional food supplements, will impact on the more palatable species, leaving behind less palatable and nutritious grasses such as *nardus* or *mollinea* in the case of upland grazing (Hulme *et al.* 1999). Early appearing grass species that are important for spring nutrition are also suppressed by heavy grazing (Silva, 1987). Even after 30 years, fields that have been previously been fertilized with phosphates (15-30kg/ha), have been found to still be dominated by single species such as *L. perenne* with only low levels of nutritious *Agrostis tenuis* and *Poa triviales* (Culleton et al, 2001).

3.5.3 POLICY OPTIONS

Policy is now changing. Significant changes have been foisted on the CAP in response to budgetary constraints and pressures to achieve consensus on world trade. REPS has encouraged more environmentally friendly farming and is incorporating new measures that are more pro-active. Even aside from REPS, all farmers are now being supported through area-based payments rather on output. This reduces the incentive to over-production and leaves open more options for enlightened policy support.

There is, however, no evidence, as yet, that agri-environmental measures such as REPS, are having any significant impact on biodiversity (Feehan et al, 2002), an observation that appears to be mirrored elsewhere in Europe (Kleijn, et al, 2001). Part of the problem is that agri-environmental schemes only operate at farm level whereas biodiversity really requires policies that operate at the wider landscape level. At this level, Haines-Young et al. (2003), in a major UK study of all farm types, find positive trends towards more extensive (lower input) farming in the uplands, an overall lessening of the conversion of semi-natural habitats, and an increase in woodland cover. At the same time, though, they report a decline in the quality of these habitats and a widespread loss of biodiversity on lowland farms. Similar trends have probably been occurring in Ireland.

Looking ahead, there is still the risk that smaller Irish farms will disappear and that those that remain will be yet more homogeneous and dominated by grass. Marginal farming areas could be farmed very extensively or virtually abandoned (Binfield, et al. 2003). Such trends could further reduce biodiversity.

The positive factor is that Irish farmers have shown themselves to be responsive to policy incentives. Just as in the past, policy led to a loss of low-intensity mixed farming, so it can be re-tuned to support more sustainable farming and better agri-environmental policies that could deliver on biodiversity. One option is a landscape level approach, rather than a conservation led approach, that maintains biodiversity in complex landscapes containing areas of natural and semi-natural habitat that compensates for more intensive activity elsewhere (Tscharntke et al., 2005).

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