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7. Biodiversity: Ecosystem Services

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Contents

Executive Summary

This report provides an assessment of the ecosystem services impacts which may be expected to result from the three schemes shortlisted by the Airports Commission:

- Gatwick Airport Second Runway (Gatwick 2R) promoted by Gatwick Airport Ltd (GAL):
- Heathrow Airport Northwest Runway (Heathrow NWR) promoted by Heathrow Airport Limited (HAL); and,
- Heathrow Airport Extended Northern Runway (Heathrow ENR) promoted by Heathrow Hub Limited (HH).

The ecosystem services approach considers the environment in terms of the benefits it brings to people. It considers the environment in a holistic way, by identifying different ecosystems such as farmland and woodland, and then identifies the different services that these provide including:

- Provisioning services: including food production and raw mineral resources;
- Regulating services: including natural climate and flood regulation;
- Cultural services: including aesthetic enjoyment and education; and
- Supporting services: including natural disease resistance and pollution control.

By considering the value of these services, it is possible to calculate a monetary value associated with each ecosystem. This can then be factored into economic assessments for comparison of options.

For each scheme, the potential habitats impacted by the proposals have been identified, and changes in the value of the ecosystem services they provide due to the proposals are monetised based on a broad habitat approach. This approach is considered appropriate based on the level of information present and the nature of the assessment as a high level commentary on multiple proposals.

It should be noted that there are some limitations to the approach: without a sufficient level of detailed information it is difficult to assess the level of ecosystem service provision from a given environmental stock; and given the non-linear relationship between the change in environmental stock and the change in ecosystem service provision, effects are difficult to predict. A benefit transfer value approach is adopted which enables ecosystem services to be valued based on broad habitat type. Although not a bespoke approach to valuation, an indicative range of monetised values is produced that is useful for high level assessment.

The assessments are conducted independently of the promoters' submissions and largely makes use of the findings of the Biodiversity Assessment (Jacobs, 2014a), especially with regard to quantified land take and mitigation. The impacts are streamed over a 60 year assessment period for each scheme to determine a total present value of the change in land use.

Gatwick Airport Second Runway

The total net present value of lost ecosystem services is estimated to be between £6.0 million and £9.2 million over the course of the 60 year assessment period. Aside from ecosystem services supporting agriculture, the highest valued loss of an ecosystem service is that of opportunities for recreation.

Heathrow Airport Northwest Runway

The total value of ecosystem loss is estimated to be between £6.3 million and £15.8 million. This is spread amongst several ecosystem services including aesthetics, opportunities for recreation, waste treatment, lifecycle maintenance and fresh water supply.

Heathrow Airport Extended Northern Runway

The overall value of ecosystem services loss is estimated to be between £5.5 and £16.4 million over the 60 year assessment period. The most significant ecosystem services based on the monetisation are aesthetics, opportunities for recreation, regulation of water flows, climate regulation and fresh water supply.

1 Context and Methodology

1.1 Context and scope

Ecosystem services are the life sustaining processes which provide the environmental goods and services on which human life is dependent and also which enhance the quality of life. A perspective of the environment which focuses on these services and the functioning ecosystems which provide them, instead of focusing on the environment as a static asset, better acknowledges the essential nature of the environment to human societies. In recognition of this, the UK Government has in recent years been encouraging the adoption of an Ecosystem Services Approach (ESA) to environmental assessment and management.

The Airports Commission has encompassed ecosystem services in their approach to assessment of the three proposals for expansion of air travel capacity in the UK. It has explicitly stated the intention to consider the potential impact on ecosystem services of the shortlisted airport expansion submissions as part of their assessments in the Airports Commission Appraisal Framework.

This report develops the ESA to assessment, as outlined within the Appraisal Framework, to establish a consistent methodology for the appraisal of the three proposals. The assessment of the cost and benefits of the effects from the proposals is an important feature of this methodology.

Although there is no single agreed mechanism for these types of assessments, a generic framework for ecosystem services has been identified for incorporation within policy appraisal and guidance. It is largely based on Defra guidance (2007), the Supplementary Green Book Guidance (Dunn, 2012), the UK National Ecosystem Assessment (UKNEA, 2011) and the Institute of Environmental Sciences report on ecosystem services assessment (Everard and Waters, 2013).

Within literature and common understanding, ecosystem services are widely accepted to fall under the following four categories:

- Provisioning services – these are physical goods such as food, biomass for energy generation and water resources.
- Regulating services – these are benefits obtained from the regulating function of ecosystem processes, such as the regulation of water quality and water flow, the filtration of air and the sequestration of carbon.
- Cultural services – these are non-material benefits that people obtain from ecosystems, such as a sense of place or inspiration and recreational benefits.
- Supporting services – these are the services that are necessary for the production of all other ecosystem services, including biodiversity. For example, pollinating insects provide a supporting service that contributes to the delivery of provisioning services such as food.

These categories help form the basis of the assessment and are used to identify the ecosystem services present.

1.2 Methodology

The methodology adopted here follows from the Airports Commission Appraisal Framework. This assessment is high level and uses readily available information from other assessments (such as biodiversity) and published information on the locations under assessment. The Appraisal Framework states in paragraph 7.24 the following steps involved with defining effects on ecosystem services:

- Defining the environmental stock - a process which is likely to rely on previously produced high-level habitat maps, such as those created in conjunction with Natural England's work linking National Ecosystem Assessment to broad habitat types;
- Identifying the environmental services (i.e. ecosystem service benefits) that flow from that stock;
- Identifying the environmental impact of a scheme to those services;
- Estimating costs or benefits, in terms of the change to ecosystem services at a strategic, qualitative level. The aim is not to undertake an exhaustive assessment, but to identify potential key impacts at a high level; and,
- Sensitivity analysis if necessary.

In line with the Appraisal Framework, the assessment will focus at a high level on two key drivers of ecosystem change:

- Primarily land use change, resulting from construction of infrastructure (airport and surface access); and
- To a lesser degree hydrological change and pollution, resulting from changes in surface access and air traffic.

In addition, the assessment will offer supplementary analysis providing estimates of the monetised value of the ecosystem services impacted. These estimates should be seen as indicative only and are subject to the limitations described at the end of this chapter.

1.2.1 Inputs

The ecosystem services assessment primarily makes use of land take data derived for the habitat and biodiversity assessment, and geographical information relating to the footprint of the schemes and the wider study area in relation to the relevant ecosystems which are present. Relevant readily available literature was consulted with regard to the presence of ecosystem services within the different identified environments, and likely effects on the provision of ecosystem services resulting from disturbance of these environments was inferred. It should be noted that a detailed assessment of the change in ecosystem services at the individual level has not been conducted due to the complex nature of ecosystems and a current lack of detailed information at this level; rather, a loss of land reflects a total loss of ecosystem service.

Reference is made to the scheme proposals submitted by the three shortlisted options as a means to cross reference baseline information and results. While the assessment here is conducted independently, cross referencing allows for the identification of any gaps, and the comparison in methodology and findings to improve confidence in the results as well as to support analysis.

1.2.2 Method

The methodology described below builds on the guidelines within the Airports Commission Assessment Framework and sets out an approach for independent assessment of the promoters' schemes to be used as a basis to high level comment on their submissions.

Data has been collected on the habitats and ecosystems present in the locations likely to be impacted by the schemes, in order to create the baseline. Assumptions on the presence of ecosystem services are made based on examples and accepted typologies from existing studies and literature. This baseline level of services is used as the standard from which to measure change.

As a high level study seeking to identify indicative levels of ecosystem services change only, the analysis focuses on the quantification of large scale impacts from land take in order to inform the assessment of the effects to ecosystem services. As the relationship of the impacts on environmental assets to effects on environmental service provision is not explicitly known, to a large degree the assessment is based on interpretation of these effects.

The methodology expands on the Airports Commission Appraisal Framework by endeavouring to demonstrate indicative monetised values of the ecosystem services loss derived with the use of transfer values from similar ecosystems based on broad habitat types. It is important to note that these estimates should be interpreted with caution and in line with the limitations expressed below.

The steps to the ecosystem services assessment described below are in line with the Appraisal Framework Approach, with the addition of step 'e' on monetisation.

(a) Defining the Environmental Stock

Defining the environmental stock is fundamentally a process of determining what physical environment is currently present within the scheme boundaries. This process primarily relies on previously produced high-level habitat studies which assist in understanding and identifying the presence of ecosystems within the study area, such as those created in conjunction with Natural England's work linking the National Ecosystem Assessment to broad habitat types. This results in a list of the ecosystems in the footprint and close proximity to the scheme.

The environmental stock identified is categorised under four broad habitat categories to assist in the identification and assessment of ecosystem services. These are Rivers and Lakes, Woodlands, Inland Wetland and Grassland. These categories have been selected to best reflect the present ecosystems and broadly match categories found in relevant ecosystem services literature. In addition, agricultural land is considered.

(b) Identifying Ecosystem Services

The ecosystem services provided by the environmental stock fall within one of the four categories of provisioning, regulating, cultural and supporting. Professional judgement along with evidence from the literature base on the likely services provided by different habitat and ecosystem types is used to identify the presence of ecosystem services. While there are several checklists of potential ecosystem services, the list developed by Natural England for use in its National Character

Area (NCA) profiles is adopted here as the approach that has been proposed by the Airports Commission.

Note that while both UK National Ecosystem Assessment (2011) and Natural England's National Character Areas have been used to identify and assess ecosystem services, the categorisations of ecosystem services found in these sources have been rationalised to be in line with results presented by The Economics of Ecosystems and Biodiversity (TEEB)[1] study, a European Commission launched and United Nations hosted project. This global initiative is a meta-analysis, a systematic collation of data from a number of independent sources, of academic studies on ecosystem services and its categorisations are adopted here in order to create consistency in reporting and to assist in the monetisation element of the assessment as discussed in part (e).

As part of the process of identifying ecosystem services, a judgement is made as to their likely prominence in relation to the associated environmental stock. This is done at a high level with a '+' denoting a higher degree of prominence and a '-' denoting a lower degree of prominence in relation to other ecosystem services, with those unmarked thought to be of neutral or ambiguous prominence.

Defining the environmental stock and identifying ecosystem services comprises the baseline of the assessment, with the following steps undertaken to complete the impact assessment.

(c) Assessing the Effect on Ecosystem Services

Impacts on ecosystem services are assessed at a high level primarily in terms of the two key drivers of ecosystem change: land use change, resulting from construction of infrastructure (airport and surface access); and to a lesser degree, hydrological change and pollution, resulting from changes in surface access and air traffic. Note that surface access land take is estimated by Jacobs as reported in the Biodiversity assessment and that these footprints are estimates subject to revision as the detailed design progresses.

There are two key steps to assessing the ecosystem services impacts. Firstly, the impact on the environmental stock is determined. This makes use of the impact data from land take determined in the Biodiversity Assessment report (Jacobs, 2014a) which identifies the physical effect on the environmental stock. Secondly, the impact of the change in environmental stock with regards to the provision of ecosystem services is estimated at the habitat level based on assessment criteria and professional judgement.

Impacts on environmental stock are quantified based on data supplied from the Biodiversity assessment. There is not necessarily a direct correspondence between a marginal impact on the environmental stock, and the marginal ability of that environmental stock to provide ecosystem services, though were the land is lost the ecosystem services are also lost. The application of criteria helps determine the sensitivity of the ecosystem services and the magnitude of the impact on the provision of the ecosystem service are based largely on professional judgement.

Paragraph 5.25 of the Appraisal Framework states that judgement on whether an impact will be 'substantial' may be based on a range of considerations, which are interpreted in this assessment as being related to the sensitivity of the receptor and

[1] http://www.teebweb.org/

the magnitude of the impact. This is modified below for the purposes of determining the overall significance of the effect on ecosystem services.

With regard to the ecosystem services of the broad habitat under consideration, the following is considered in determining sensitivity:

- Its importance to people;
- The scale of benefits provided;
- Its strategic importance;
- Its intrinsic value;
- Its susceptibility to change; and
- Its uniqueness or replaceability.

With regard to the nature and magnitude of the impact on the ecosystem service likely to occur, the following is considered in determining a value for the broad habitat:

- The extent of how the change in provision of the service will impact people;
- The probability of the impact occurring;
- The spatial scale of predicted impacts;
- The duration of the predicted impacts;
- The durability or reversibility of any predicted impacts; and
- Cumulative impacts.

The sensitivity of the receptor and magnitude of the impact are both scored on a scale of negligible, low, moderate or high. The score of the sensitivity of the receptor is largely based on interpretation of qualitative information, while the magnitude of impact will make use of quantitative data on the impact to the environmental stock. Note that impacts can be either beneficial or adverse. The scores are then used to determine the overall significance of effect. The assessment criteria in Tables 1.1 and 1.2 are adopted from the Heathrow Hub proposal as fit for purpose.

Table 1.1 - Levels of receptor sensitivity

Receptor Sensitivity	
Negligible	The service is of negligible value to beneficiaries and the environmental and human receptors are highly resilient
Low	The service is of low value to beneficiaries and the environmental and human receptors are moderately to highly resilient Alternatively, the service is of moderate value to beneficiaries and the environmental and human receptors are highly resilient
Moderate	The service is of moderate value to beneficiaries and the environmental and human receptors are moderately resilient Alternatively, the service is of high value to beneficiaries and the environmental and human receptors are highly resilient
High	The service is of high value to beneficiaries and the environmental and human receptors have low resilience Alternatively, the service is of moderate value to beneficiaries and the environmental and human receptors have low resilience

Table 1.2 - Magnitude of impact

Impact magnitude	
Negligible	The impact is within the normal range of variation of the ecosystem and will not give rise to any material, lasting change in service provision or well-being of any beneficiaries
Low	The impact results in a small reduction in the availability or functionality of the ecosystem but is unlikely to give rise to any material, lasting change in service provision or well-being of any beneficiaries and will not impact on proposed development operations
Moderate	The impact results in a moderate reduction in the availability or functionality of the ecosystem which may give rise to a change in service provision and the well-being of any beneficiaries and/or may compromise proposed development operations
High	The impact results in the loss of all or a material proportion of the availability or functionality of an ecosystem service which is likely to give rise to a material change in service provision and the well-being of any beneficiaries and/or will compromise proposed development operations

The assessment against these criteria is then used to determine the significance of the impact as described in the costs and benefits section below; aside from the assessment of agricultural land which is considered only as direct loss and valued separately from the broad habitats as discussed in the monetisation section below.

(d) Estimating Costs and Benefits

The assessment identifies the effects on ecosystem services in terms of the change in service capacity, whether beneficial or adverse. This allows the identification of potential key impacts at a high level, primarily qualitatively. The scale and direction of effects on ecosystem services can be used to inform the estimate of costs and benefits of the proposals in terms of the change to ecosystem services at a strategic, qualitative level. It must be noted that the aim is not to undertake a detailed or exhaustive assessment, but to identify potential key impacts at a high level.

The Appraisal Framework, in paragraph 5.24, defines the performance of the indicator (ecosystem services) in presence of the proposals as follows:

- Highly supportive: positive impacts are substantial, or substantially accelerate an improving trend, or substantially decelerate a declining trend.
- Supportive: positive impacts are notable, or accelerate an improving trend, or decelerate a declining trend.
- Neutral (or Negligible): no impacts, or on balance (taking account of positive and negative impacts) a neutral outcome occurs, or impacts are thought to be present but below a threshold level which falls within the likely assumption error.
- Adverse: negative impacts are notable, or decelerate an improving trend, or accelerate a declining trend.
- Highly adverse: negative impacts are substantial, or substantially decelerate an improving trend, or substantially accelerate a declining trend.

In the case of ecosystem services, these descriptions are applied as an overall indicator by broad habitat in impact assessment table; these are based on the sensitivity of the ecosystem services present and the magnitude of the impact on the environmental stock, as described above. For the purposes of assessing costs and

benefits, ecosystem services with negligible or minor effects are considered negligible, while moderate and major effects are valued as Supportive/Adverse and Highly Supportive/Highly Adverse respectively.

The scores for receptor sensitivity and impact magnitude for the ecosystem services are used to determine the significance of overall effect on the broad habitat according to the relationship in the matrix presented in Table 1.3. Note that as the impact may be either beneficial or adverse, the effect may also be either beneficial or adverse.

Table 1.3 - Significance of effect

		Impact Magnitude			
	Score	Negligible	Low	Moderate	High
Receptor Sensitivity	Negligible	Neutral	Neutral	Adverse / Supportive	Adverse / Supportive
	Low	Neutral	Adverse / Supportive	Adverse / Supportive	Adverse / Supportive
	Moderate	Adverse / Supportive	Adverse / Supportive	Adverse / Supportive	Highly Adverse/ Supportive
	High	Adverse / Supportive	Adverse / Supportive	Highly Adverse / Supportive	Highly Adverse / Supportive

A summary table highlights the estimated costs and benefits of each proposal qualitatively, in terms of ecosystem services provision based on these criteria.

(e) Monetisation

As a supplementary component to the analysis described above, the assessment makes use of transfer values from other studies to derive estimates of the monetary value of the effects on the identified ecosystem services impacted by the scheme.

This is primarily done based on transfer values derived by meta-analysis and presented in the TEEB in-depth study on ecosystem services[2]. These values are given for over twenty identified ecosystem services by presenting a value range based on relevant studies for a number of broad habitat categories. Four of these broad habitat categories are used here; rivers and lakes, woodland, inland wetlands and grassland.

TEEB valuation data is applied to area of land impacted, as identified within the Biodiversity report, to estimate a monetary value for the effect on the various ecosystem services. These annual values are then streamed over the assessment period of 60 years, beginning with the initiation of project construction in the year 2019, to generate a present value estimate of the gain or loss expected. Losses are considered to be realised in year one, while mitigation is assumed to be realised in years 5 (rivers and lakes), 10 (inland wetlands and grassland) and 25 (temperate rainforest and woodlands) respectively. These assumptions are the professional judgement of ecologists, and reflect ecosystem maturation periods.

[2] Groot R. et al. (2010). Appendix C: Estimates of Monetary Values of Ecosystem Services. The Economics of Ecosystems and Biodiversity. http://www.es-partnership.org/esp/80763/5/0/50

In addition, the value of services provided through the provision of mitigation habitat is reduced by 50% to account for the Loss Aversion effect, established by Kahneman and Thaler[3], by which a given loss is valued more than a corresponding gain of the same scale. The assessment of mitigation habitat is based on the level of mitigation proposed as appropriate in the Biodiversity assessment for consistency amongst the proposals.

The valuation data is uplifted to 2014 prices and discounted at the UK Government published rate to show present value (PV) figures. All figures are shown in present day (2014) values.

The full range of values found in TEEB, are applied to the ecosystem services within the assessment and result in a range of overall potential values being estimated. The value ranges should be considered alongside the qualitative information to support decision making. While useful as indicative and for relative comparison, these values are highly subject to the limitations described in the relevant section.

The approach to monetisation of impacts on agricultural land is different to that outlined above. As a proxy for the ecosystem services that support the production of food, the market price of that food captures peoples' willingness to pay for these services[4]. The loss of agricultural land results in a direct loss of this productive capacity, and the price of agricultural land is a function of is productive capacity over time. Thus, the market value of the agricultural land lost is a reasonable proxy for the willingness to pay for the lost ecosystem services.

The Multi-Colour Manual Handbook (Defra, 2014) identifies that a permanent loss of agricultural land should be valued at its market value, which it provides as £15,000 to £18,000 per hectare in 2014 prices. These values have been applied to monetise the loss of ecosystem services from agricultural land lost as a result of the proposals.

1.3 Assumptions and Limitations

As a high level analysis of impacts which can have complicated pathways, much of this assessment is based on considered assumptions and professional judgements. In particular this applies to the level of ecosystem services provided by a given environmental stock, and to the level of change in that service from a change to the stock. As this assessment is desk based, it has not been possible to verify on the ground the information provided by map tools to determine how well the specific ecosystems match their categorisations.

The somewhat limited detail of the available data means a full assessment of the effects on the ecosystem's functionality is not possible and so the assessment is based predominantly on the level of environmental stock, measured as hectares of broad habitat type, rather than the level of functioning of the ecosystem in their current state.

[3] This effect is well established in economics with experimentation showing that the perceived value of something lost is greater than the perceived value of the same good gained in terms of willingness to accept and willingness to pay (Kahneman, D.; Knetsch, J.; Thaler, R., 1990).though the principle is not without its criticisms and detractors. Loss Aversion is applied here as it is assumed to apply to the environmental goods; the gain of an environmental stock through mitigation is assumed to be valued at half the value as the loss of a similar environmental stock through land take.

[4] For more information on the use of market values as a proxy see O'Gorman, S. and Bann, C. (2008).

There is not a linear relationship between environmental stock and ecosystem services as certain thresholds are assumed to exist, under or over which an ecosystem may provide an unknown level of services. Overall wider ecosystem thresholds are not known at the specific sites and so the qualitative assessment assumes that threshold levels are not crossed. However, we can assume that a loss of land signifies a total loss of ecosystem services, even though we don't know what the extent of the services to be lost is.

Additionally, there are limitations to the monetisation aspect of the assessment. By valuing ecosystem service benefits through the use of transfer values, a high level and indicative value of the potential effects on ecosystem services is presented. The results should not be interpreted as representing a financial value, but rather an indicative economic value of the potential change in ecosystem service benefits. In addition, it is necessary to note the following:

- The values used are transfer values and not bespoke to the specific conditions of the proposals[5];
- The values are based on broad habitat types as aggregated through the meta-analysis of academic studies from various habitats around the world. As such they do not incorporate the subtleties of ecosystem variance at the individual level and the value of ecosystem services in the specific region, and thus the full range of values has been applied; and
- This approach largely neglects threshold values and the significance of change at the margin, the non-linear relationship between the loss of stock and the loss of ecosystem service is not captured, though the focus of the assessment on land take and the total loss of services bypasses this to a degree.

In regards to the monetisation aspects, along with the above methodological issues, gaps are present in both the physical baseline data and valuation data used for the assessment. This is due to limitations in the availability of detailed data in regards to the functioning of environmental assets, and gaps in the adopted literature for certain ecosystem services transfer values.

The valuation uses the majority of the ecosystem services for which valuation data is provided as not enough information is currently known about the specific ecosystems present at the proposal sites to make decisions on exclusions of certain services for the valuation. Likewise, an accurate judgement of the relative value of the ecosystem services within the range of valuation data adopted is not possible at this time, so the full range of values is used. Future work may be able to more accurately assess the ecosystem services present and impacts by addressing the issues discussed above.

A more in depth study at a later stage could take advantage of the greater availability of information developed as part of the more detailed design and environmental assessment as required for the next phases of the project. This would allow for a more bespoke approach to be adopted better able to assess the level of environmental stock and ecosystem service change, as well as to allow benefit transfer values to be applied more accurately, in order to further inform the decision making and planning process.

[5] This is the nature of the Benefits Transfer approach, in which benefits that have been quantified for one specific ecosystem are used as transfer values to an ecosystem of sufficiently similar characteristics.

2 Ecosystem Services Assessment

2.1 Gatwick Airport Second Runway

2.1.1 Scheme introduction

At Gatwick Airport, a second runway and a third terminal is being proposed in order to expand as an international gateway for London and the Southeast. Though in close proximity to Greater London, the location is primarily rural meaning there is a lack of onsite constraints and relatively limited population which may reduce the potential sensitivity in terms of ecosystem services and social impact.

Gatwick is located to the south of London within the Low Weald National Character Area (NCA) as classified by Natural England (2013). Overall the Low Weald is considered important for biodiversity and is generally wet and woody while being dissected by flood plains.

The Gatwick proposal may impact the local environment through loss of habitats such as woodland and hedgerow and disturbance to waterways. It may also have the potential to enhance the provision of some ecosystem services through mitigation measures.

2.1.2 Baseline

As noted above, Gatwick is located within the Low Weald and also within the Upper Mole catchment area which drains to the north. This NCA is mainly low lying and predominately in a semi-rural setting, supporting agricultural activities such as pastoral and arable farming (Natural England, 2012) and occasional small settlements, where the main urban centres include Horley and Crawley. The agriculture to the south of the Airport includes grasslands and fields boarded by hedgerow and to the west/ southwest, areas of woodland. Habitats include lowland woodlands (some ancient woodland), veteran trees, grassland, hedgerows, watercourses (rivers and brooks) and standing open water (ponds).

Within close proximity (approximately 15km) to Gatwick airport there are two Special Areas of Conservation (SACs) (Ashdown Forest SAC and Mole Gap to Reigate Escarpment SAC) and one Special Protection Area (SPA) (which has the same boundary as Ashdown Forest SAC) which could be impacted upon. Also there are 35 Sites of Special Scientific Interest (SSSIs) within 15km of the scheme and four SSSIs within 5km. There are four Local Nature Reserves (LNRs) and 46 non-statutory Sites of Nature Conservation Importance[6] within 5km of the scheme boundary and several Areas of Natural Beauty (AONBs).

The Baseline data primarily used in this assessment in terms of specific sites within the proposal areas and quantities of both land take and mitigation is taken from the Biodiversity Assessment (Jacobs 2014a) prepared alongside this assessment.

As described above there is a wide range of designated areas and each helps to support various ecosystem services. Natural England provides a focus on some of the ecosystem services present within the Low Weald NCA. These are identified as follows:

[6] Based on Biological Records data provided.

Provisioning

- Food provision – Livestock and dairy farming traditionally are present within the area but are on the decline, though arable and horticultural farming remains important
- Timber provision – Despite a history of wood supply, the area doesn't supply a large quantity of wood
- Water availability – The area contains large reservoirs which supply many communities in the area
- Genetic diversity – Some old and traditional orchards and remnants of the hop-growing industry survive and contain important local varieties, and the Sussex cattle breed and Southdown sheep were bred in the region and descendants of these original herds are still present

Regulating

- Climate regulation – Longstanding woodland is abundant in the Low Weald and is a good carbon store along with the undisturbed soil beneath.
- Regulating water quality – Water quality is particularly important in the reservoirs that provide water for the surrounding area.
- Regulating water flow – The Low Weald is susceptible to flooding due to its low-lying nature and predominantly clayey flood plain soils.
- Pest regulation – The significant proportion of ancient woodland makes this NCA especially vulnerable to pests and diseases.

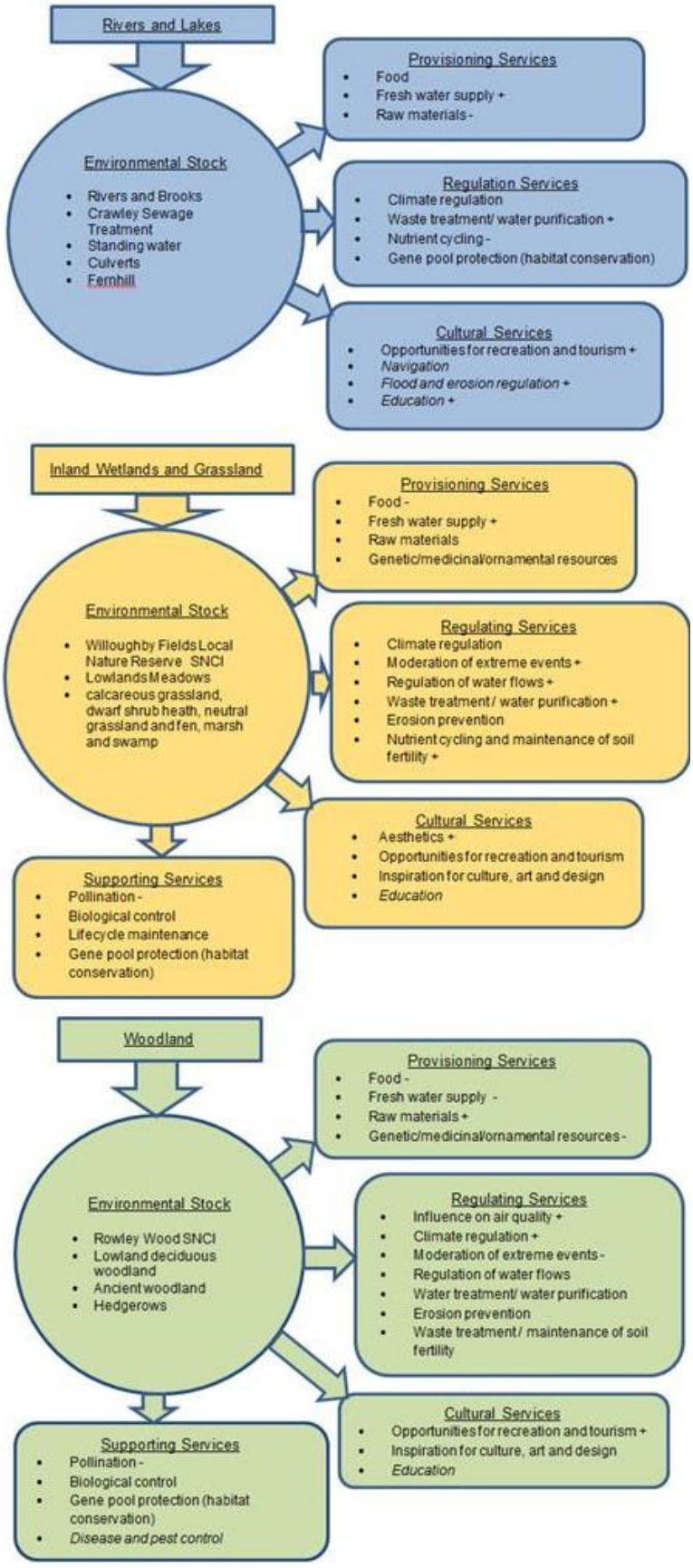
Cultural

- Sense of history – The Low Weald has a strong sense of being an historically settled and farmed landscape also influenced by remnants of the Wealden iron industry as well as historic parkland.
- Tranquillity – The Low Weald is a predominantly pastoral and wooded landscape that is still largely rural.
- Recreation – Supported by public rights of way as well as angling and bird watching along the reservoirs.
- Biodiversity – Arlington Reservoir supports diverse habitats for bird species, while the Low Weald is the most important area for spiked rampion in England and important for several other species including woodpeckers, nightjar, woodland butterflies and bats.

Figure 2.1 outlines the environmental stock and ecosystem services thought to be present within the proposal boundary area. The table rationalises the ecosystem services described above as found within the Low Weald NCA by Natural England, with those identified by TEEB as used in the monetisation exercise.

The ecosystem services are marked with a '+' where thought likely to be of particular prominence and '-' where thought likely to be of lesser prominence within the given stock, with those unmarked thought to be of neutral or ambiguous prominence, though not enough information is known to make an estimate on actual levels. Ecosystem Services in italics are thought likely to be present, but are not valued within the monetisation aspect of the assessment due to lack of valuation data, and do not appear on TEEB list of ecosystem services.

Figure 2.1 - Ecosystem service baseline for Gatwick 2R



2.1.3 Impact Assessment

(a) Impact on ecosystem services

The impact of the proposal on ecosystem services is assessed at a high level in Table 2.1. The table displays impact on the environmental stock, proposed mitigation, a narrative on ecosystem services, the sensitivity of the broad habitat in terms of ecosystem services provision in aggregate, the magnitude of impact on the broad habitat in terms of ecosystem services, and the overall significance of the residual effect assessed at a high level.

Although each ecosystem service was reviewed individually, a habitat approach is adopted as not enough information is known about the baseline provision of individual ecosystem services; thus the assessment is based on the overall collective impacts on the broad habitats. The ecosystem service narrative describes likely effects of land take on specific ecosystem services which are considered to be significant.

(b) Monetisation

This part of the assessment should be seen as separate, though related, to that which has come previously. The monetisation of effects on ecosystem services makes use of transfer values and is based solely on land lost and habitats gained through mitigation and does not consider any issues around quality or changes at the margin. Therefore, though related, the overall results should not be seen as directly corresponding to the Impact Assessment table in the previous sections. The values produced here are indicative only and subject to the limitations stated in section 1.3.

Monetisation makes use of transfer values sourced from TEEB, attached here in Appendix A. Table 2.2 provides the value range, in 2014 prices, for the change in the provision of benefits from ecosystem services (where data is available and where transfer values are present). The wide range is reflective of the variability of the value of ecosystem services due both to the specific ecosystem characteristics of the broad habitat, such as habitats of particular distinctiveness or vitality, and also of the value placed on them by the recipients of the benefits. Monetary values are shown in aggregate for ecosystem services within the broad habitats below. Annual value, assessment period loss and assessment period mitigation are shown as absolute values of the ecosystem services while assessment period net value shows the net effect with negative numbers implying a loss.

Table 2.1 - Ecosystem service impact assessment by broad habitat for Gatwick Airport Second Runway

Description of Impact	Mitigation	Ecosystem Service Narrative	Sensitivity	Magnitude	Effect
Rivers and lakes • 7.2km of rivers/ streams lost and several kilometers diverted • Adverse effect on standing waters including 6-8 ponds • Hydrological change not thought to significantly impact flow rates or sedimentation levels	Rivers and lakes • 29 hectares of additional riparian ecosystem is to be created, though the precise location is not known	• Fresh water supply likely to be disrupted to some degree • Waste treatment/water purification capacity loss due to loss of habitat • Opportunities for recreation to be reduced for local users	**Moderate**	**Moderate**	**Adverse**
Inland Wetland and Grassland • Although this habitat is not to be directly lost to land take, loss from Willoughby Fields Nature Reserve and Site of Interest for Nature Conservation to lose which will likely indirectly impact the present calcareous grassland, dwarf shrub heath, neutral grassland and fen, marsh and swamp	Inland Wetland and Grassland • Mitigation not explicitly planned for this broad habitat type	• Ecosystem service loss from direct land take to be minimal • Indirect impacts on amenity of Nature Reserve likely due to proximity of expansion and increased noise	**Moderate**	**Low**	**Adverse**
Woodland • Almost 4ha taken from Rowley Wood Site of Nature Conservation Interest (SNCI) • 62.1ha of lowland deciduous woodland, including 14ha of ancient woodland and hedgerows, and an additional 13.4ha from surface access requirements • Loss of ancient hedgerows	Woodland • The Biodiversity assessment proposes 222ha of woodland habitat mitigation • Possible enhancements at sites such as Glovers Wood SSSI but doesn't specify	• The mitigation of woodland cannot compensate for the loss of ancient woodland, thus a high rating for sensitivity • Aesthetic value and amenity is likely to be the most effected ecosystem service	**High**	**Moderate**	**Highly Adverse**
Agricultural Land • Loss of 421.3ha including loss from scheme land take and potential loss or change of use from surface access		• Ecosystem services commonly act together to support the production of food crops from agricultural land, the loss of land is a loss of these services • The sensitivity is moderate due to the replicability of agricultural ecosystems but also the importance of food production	**Moderate**	**High**	**Highly Adverse**

Table 2.2- Monetisation of ecosystem services by broad habitat effects for Gatwick Airport Second Runway

Broad Habitat	Total Land Lost / Gained (ha)	Annual Value per Hectare of Broad Habitat (2014£)	Total Assessment Period Loss (PV, '000 2014£)	Total Assessment Period Mitigation (PV, '000 2014£)	Total Assessment Period Net Value (PV, '000 2014£)
Rivers and Lakes	14ha loss / 29ha gain	£1,279 to £10,285	£698 to £5,616	£508 to £3,991	-£190 to -£1,625
Inland Wetlands	-	£706 to £32,217	-	-	-
Grasslands	-	£214 to £2,763	-	-	-
Woodlands	76ha loss / 285ha gain	£12 to £5,027	£33 to £14,447	£32 to £13,897	-£1 to -£549
Sub - Total					**-£191 to -£2,175**
Agricultural Land	421ha loss	£15,225 to £18,270	£5,823 to £6,987	-	-£5,823 to -£6,987
Total					**-£6,014 to -£9,162**

Table 2.3 aggregates the monetary values by ecosystem service from each of the broad habitats. The total values are the same as presented in Table 2.4, however in this case the likely range of values of the ecosystem service change as a result of the proposal is provided.

Table 2.3 - Total monetised ecosystem service effects for Gatwick 2R in Present Value at 2014£

Ecosystem services	Low Value Estimate	High Value Estimate
Food	-£1,288	-£25,307
Fresh water supply	-£54,440	-£266,235
Raw Materials	-£550	-£51,941
Genetic Resources	£-	£-
Medicinal Resources	£-	£-
Influence on Air Quality	£-	-£6,288
Climate Regulation	-£707	-£36,430
Moderation of Extreme Events	£-	£-
Regulation of Water Flows	£-	£-
Waste Treatment / Water Purification	-£14,552	-£292,611
Erosion Prevention	£-	-£3,851
Nutrient Cycling	£-	-£143
Pollination	£-	£-
Lifecycle Maintenance	£-	-£78,836
Gene Pool Protection	£-	-£32,571
Aesthetics	£-	-£307,092
Opportunities for Recreation and Tourism	-£119,784	-£1,073,342
Inspiration for Culture	£-	£-
Total Ecosystem Services from Broad Habitat	**-£191,322**	**-£2,174,647**
Agricultural Land Loss	-£5,822,742	-£6,987,291
Total Ecosystem Services	**-£6,014,064**	**-£9,161,938**

2.1.4 Commentary on proposer's submission

The Gatwick Airports Limited (GAL) proposal takes an optimistic standpoint on the degree of ecosystem loss due to the scheme and to the effectiveness of mitigation, finding that overall:

''The effects are either neutral or where there is scope for an adverse effect, with appropriate mitigation and compensation will be neutral. For a number of services there is potential to achieve a supportive effect post mitigation and/or compensation''

The proposal itself does not provide enough detail of mitigation plans to claim that it will fully compensate for loss and so this text is interpreted as aspirational. This aspiration may be overly optimistic, as even in the presence of mitigation the ecosystem service loss happens instantaneously with the loss of the environmental stock, while mitigation habitats take additional time to establish into functioning ecosystems. This discontinuity will create a gap in ecosystem service provision which should be considered in the assessment of the impact of the scheme.

This is especially relevant with regard to ecosystem services loss in woodlands, which can take 25 years or longer to re-establish. Thus for mitigation to compensate for lost ecosystem services, focus will be required on early establishment of functional ecosystems to the best extent possible. In addition, mitigation will not be able to fully compensate for the loss of certain habitats such as ancient woodlands.

Although the GAL proposal qualitatively describes an approach to mitigation, it does not quantify it. The mitigation proposed by the Biodiversity assessment as appropriate is used to value this aspect of the above assessment for consistency.

2.1.5 Conclusions

The loss of 14 hectares of rivers and brooks and nearly 76hectares of woodland, including 14 hectares of ancient woodland, is the main cause of ecosystem service loss from the Gatwick Airport Second Runway scheme. The proposed mitigation for this loss from the Biodiversity assessment is 29 hectares of rivers and brooks and over 220 hectares of deciduous woodland and 60 hectares of hedgerows, though due to the length of time required to establish woodland ecosystems, the loss of irreplaceable ancient woodland, and the general reduced perceived value of environmental gain compared with losses, mean that even this level of mitigation may not fully compensate for ecosystem service loss.

Additionally, 421ha of agricultural land will be lost. In the Gatwick 2R proposal, this is the most significant source of lost ecosystem service value. This is a significant area of land which supports ecosystem services on which food production relies.

The total net present value of lost ecosystem services is estimated to be between £6.0 million and £9.2 million over the course of the 60 year assessment period. Aside from ecosystem services supporting agriculture, opportunities for recreation is the ecosystem service with the highest valued loss. It would be reasonable to expect the real value to be somewhere towards the higher end due to the presence of dense population in proximity to the site and the wealthy nature of the UK.

2.2 Heathrow Airport Northwest Runway

2.2.1 Scheme introduction

The Heathrow Airport Northwest Runway (NWR) scheme is an expansion to the existing Heathrow Airport to increase its current capacity so that the growing need for air travel can be met. The development is planned to the north-west of the Airport as it stands and includes a 3,500 meter runway, two new terminal buildings, aircraft movement areas/taxiways, aircraft stands, additional car parking and ancillary uses.

With the large expansion of the Airport within the landscape as described above, the proposed development may impact on the ecosystem services present through the creation of new assets (such as fens, marshes and swamp), the loss of existing ecosystems (such as areas of arable land) and hydrological change and pollution.

2.2.2 Baseline

Heathrow Airport is located within the Thames Valley National Character Area (NCA) (Natural England, 2012). The area is mainly low lying with a diverse landscape of urban and suburban settlements, infrastructure networks, fragmented agricultural land, woodland and reservoirs etc. It is dominated by hydrological features providing essential water supply services for London and the surrounds (Natural England, 2012). A number of these waterbodies are also components of the South West London Waterbodies Special Protection Area (SPA) and Ramsar site and function as important feeding and roosting sites for wintering wildfowl.

Other areas that may be directly or indirectly affected by the airport expansion include: wetlands in Old Slade Quarry Local Wildlife Site which provides functional supporting habitat for the South West London Waterbodies SPA, five Special Areas of Conservation (Windsor Forest and Great Park, Richmond Park, Burnham Beeches, Thursley, Pirbright and Chobham, Ash and Wimbledon Common), the Thames Basin Heaths SPA and eight Sites of Special Scientific Interest (SSSIs) including Staines Moor.

Within close proximity (approximately 15 km) to the Heathrow NWR scheme, there are a total of eight sites of importance to biodiversity at International (European). There are also 34 SSSIs and four National Nature Reserves within 15km and seven SSSIs within 5km, with Wraysbury Reservoir SSSI and Staines Moor SSSI being within 2km of the scheme boundary. There are nine Local Nature Reserves and 80 non-statutory sites[7] that have been identified within 5km of the scheme boundary.

The Baseline data primarily used in this assessment in terms of specific sites within the proposal areas and quantities of both land take and mitigation is taken from the Biodiversity Assessment (Jacobs 2014) prepared alongside this assessment.

As described above there is a wide range of designated areas and each contains various ecosystem services. Natural England provides a focus on some of the ecosystem services present within the Thames Valley NCA. These are identified as follows:

[7] Based on Biological Records Centre data provided

Provisioning

- Food provision – the gravel beds of the upper tideway are an important nursery ground for several fish species (note that this would usually be considered a supporting ecosystem service).
- Biomass energy – the potential for crops conducive to bioenergy is high.
- Water availability – The Chilterns aquifer feeds water supplies but the area is under pressure from London and largely over abstracted.
- Genetic diversity – Concentrated in the Royal Botanic Gardens at Kew and a few remnant orchards containing local varieties.

Regulating

- Regulating water quality – Groundwater is generally assessed as poor with most of the NCA's rivers classified as achieving only moderate ecological status.
- Regulating water flow – Flood regulation is a key issue in the area and policies include measures to store water and manage run-off while providing environmental benefits.

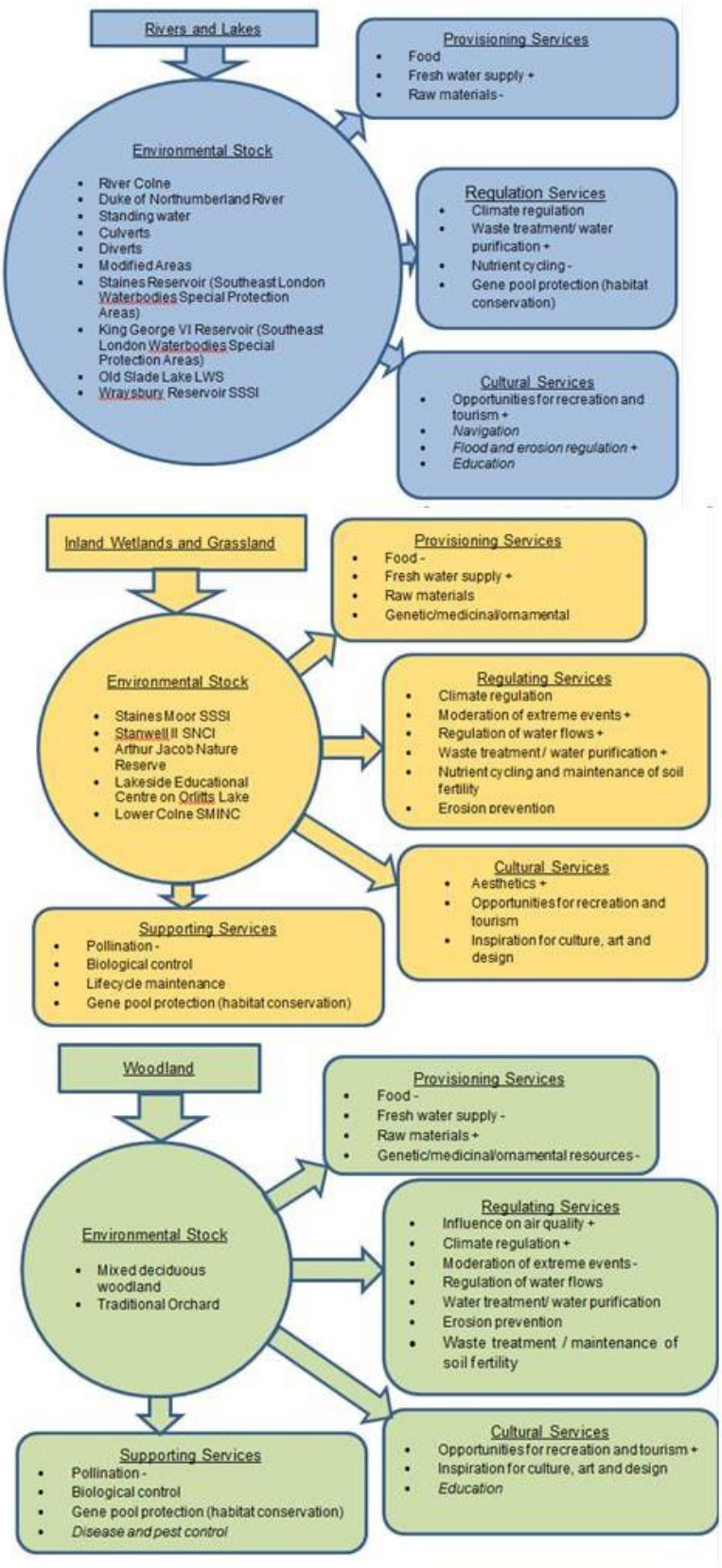
Cultural

- Sense of place/inspiration – A sense of place is supported by water throughout the area and the landscape has been described in the works of some of the most famous writers of British literature.
- Sense of history – Historic buildings, including Windsor Castle, are present within the NCA along with historic parklands.
- Recreation – Recreation is supported by over public rights of way such as Thames Path National as well as the areas open green spaces.
- Biodiversity – There is a large variety of flora and fauna in the NCA including in the 7,000 ha of historic parklands which provide rich habitats.

Figure 2.2 outlines the broad habitat types and ecosystem services identified within the proposal boundary. The table rationalises the ecosystem services described above as found within the Thames Valley NCA (Natural England, 2012), with those identified by TEEB.

The ecosystem services are marked with a '+' where thought likely to be of particular prominence and '-' where thought likely to be of lesser prominence within the given stock, with those unmarked thought to be of neutral or ambiguous prominence, though not enough information is known to make an estimate on actual levels. Ecosystem Services in italics are thought likely to be present, but are not valued within the monetisation aspect of the assessment due to lack of valuation data, and do not appear on TEEBs list of ecosystem services.

Figure 2.2 - Ecosystem service baseline for Heathrow NWR



2.2.3 Impact Assessment

(a) Impact on ecosystem services

The impact of the proposal on ecosystem services is assessed at a high level in Table 2.4. The table displays impacts on the environmental stock, proposed mitigation, a narrative on ecosystem services, the sensitivity of the broad habitat in terms of ecosystem services provision in aggregate, the magnitude of impact on the broad habitat in terms of ecosystem services, and the overall significance of the residual effect assessed at a high level.

Although each ecosystem service was reviewed individually, a habitat approach is adopted as not enough information is known about the baseline provision of individual ecosystem services; thus the assessment is based on the overall collective impacts on the broad habitats. The ecosystem service narrative describes likely effects of land take on specific ecosystem services which are considered to be significant.

(b) Monetisation

This part of the assessment should be seen as separate, though related, to that which has come previously. The monetisation of effects on ecosystem services makes use of transfer values and is based solely on land lost and habitats gained through mitigation and does not consider any issues around quality or changes at the margin. Therefore, though related, the overall results should not be seen as directly corresponding to the Impact Assessment table in the previous sections. The values produced here are indicative only and subject to the limitations stated in section 1.3.

Monetisation makes use of transfer values sourced from TEEB, attached here in Appendix A. Table 2.5 provides the value range, in 2014 prices, for the change in the provision of benefits from ecosystem services (where data is available and where transfer values are present). The wide range is reflective of the variability of the value of ecosystem services due both to the specific ecosystem characteristics of the broad habitat, such as habitats of particular distinctiveness or vitality, and also of the value placed on them by the recipients of the benefits. Monetary values are shown in aggregate for ecosystem services within the broad habitats below. Annual value, assessment period loss and assessment period mitigation are shown as absolute values of the ecosystem services while assessment period net value shows the net effect with negative numbers implying a loss.

Table 2.4 - Ecosystem service impact assessment by broad habitat for Heathrow Airport Northwest Runway

Description of Impact	Mitigation	Narrative on Ecosystem Services	Sensitivity	Magnitude	Effect
Rivers and Lakes • several kilometers of culverts and modified areas lost • 12.3km of rivers/ streams diverted • 8ha of Old Slade Lake affected	Rivers and Lakes • Diverted river channel with waterside planting • Diverted river and Colne Valley Way through enhanced existing woodland • New river channel and park enhancements • Wildlife ponds and wetland habitats with educational visitor centre, boardwalks and dipping platforms. • Enhanced Poyle Channel with new riverside planting and footpath • River Crane corridor access and biodiversity enhancements	• Old Slade Lake is a functional supporting habitat for SPA harbouring bird life • Fresh water supply likely to be disrupted to some degree though mitigation likely to compensate • Waste treatment/water purification capacity loss initially due to land take but over time mitigation will establish and renew capabilities • Opportunities for recreation to be reduced for local users initially but mitigation provided in the form of footpaths will compensate to a degree	**Moderate**	**Moderate**	**Adverse**
Inland Wetlands and Grasslands • Loss of 6ha of Stanwell II SNCI and 51ha of Lower Colne Site of Metropolitan Importance for Nature Conservation (SMINC) to indirectly impact habitats • Loss of lakeside educational centre on Orloitts Lake • Loss of 9ha of lowland meadows	Inland Wetlands and Grasslands • Several flood storage areas managed for biodiversity, with wet meadow and biodiversity enhancements, ponds, boardwalks and footpaths for public access • Biodiversity report proposes at least 18ha of lowland meadows to mitigate direct loss	• Ecosystem service loss from land take both direct and indirect • Mitigation in terms of ecosystem services enhancements to flood storage areas creating functional ecosystems over time	**Moderate**	**Low**	**Adverse**
Woodland • 57ha of mixed deciduous woodland and 3ha of traditional orchard lost within the scheme footprint and potentially affected by surface access	Woodland • Diverted river and Colne Valley Way through enhanced existing woodland • Landforms, pasture and hedgerows • Biodiversity report proposes 115ha of woodland as compensation for loss	• The mitigation of woodland cannot compensate for the loss of traditional woodland • Aesthetic value and amenity is likely to be the most effected ecosystem service, though climate regulation and influence on air quality and provision of habitat likely	**Moderate**	**Moderate**	**Adverse**

Description of Impact	Mitigation	Narrative on Ecosystem Services	Sensitivity	Magnitude	Effect
Agricultural Land • 431 Loss including loss from scheme land take and potential loss or change of use from surface access		• Ecosystem services commonly act together to support the production of food crops from agricultural land, the loss of land is a loss of these services • The sensitivity is moderate due to the replicability of agricultural ecosystems but also the importance of food production	**Moderate**	**High**	**Highly Adverse**

Table 2.5 - Monetisation of ecosystem service effects for Heathrow Airport Northwest Runway

Broad Habitat	Total Land Lost / Gained (ha)	Annual Value per Hectare of Broad Habitat (2014£)	Total Assessment Period Loss (PV, '000 2014£)	Total Assessment Period Mitigation (PV, '000 2014£)	Total Assessment Period Net Value (PV, '000 2014£)
Rivers and Lakes	25ha loss / 49ha gain	£1,279 to £10,285	£1,923 to £9,594	£874 to £6,865	-£319 to -£2,729
Inland Wetlands	<1ha loss / 1ha gain	£706 to £32,217	£8 to £367	£6 to £286	-£2 to -£81
Grasslands	9ha loss / 18ha gain	£214 to £2,763	£75 to £964	£58 to £752	-£16 to £212
Woodland	60ha loss / 120ha gain	£12 to £5,027	£26 to £11,467	£13 to £5,869	-£13 to -£5,598
Sub - Total					**-£350 to -£8,619**
Agricultural Land	431ha loss	£15,225 to £18,270	£5,954 to ££7,145	-	-£5,954 to -£7,145
Total					**-£6,304 to -£15,764**

Table 2.6 aggregates the monetary values by ecosystem service from each of the broad habitats. The total values are the same as presented in the table above, however in this case the likely range of values of the ecosystem service change as a result of the proposal is provided.

Table 2.6 - Total of monetised ecosystem service effects for Heathrow NWR in Present Value at 2014 British pounds

Ecosystem services	Low Value Estimate	High Value Estimate
Food	-£2,310	-£186,030
Fresh water supply	-£100,398	-£474,420
Raw Materials	-£6,381	-£534,067
Genetic Resources	£-	-£20
Medicinal Resources	£-	-£159
Influence on Air Quality	£-	-£76,164
Climate Regulation	-£7,712	-£412,057
Moderation of Extreme Events	-£427	-£7,980
Regulation of Water Flows	-£25	-£16,876
Waste Treatment / Water Purification	-£24,393	-£974,097
Erosion Prevention	-£2,099	-£41,988
Nutrient Cycling	-£47	-£37,940
Pollination	£-	-£29
Lifecycle Maintenance	-£18	-£804,881
Gene Pool Protection	£-	-£74,563
Aesthetics	-£150	-£3,135,866
Opportunities for Recreation and Tourism	-£204,633	-£1,840,898
Inspiration for Culture	-£1,016	-£1,428
Total Ecosystem Services from Broad Habitat	**-£349,608**	**-£8,619,463**
Agricultural Ecosystem Services	-£5,954,041	-£7,144,849
Total Ecosystem Services	**-£6,303,649**	**-£15,764,312**

2.2.4 Commentary on proposer's submission

The Heathrow Airport Limited (HAL) proposal identifies an applicable approach to ecosystem service assessment but does not conduct the actual assessment due to a lack of data availability at this stage of the development of the scheme. The proposal does provide a basic assessment of impacts on ecosystem services by 'making a number of assumptions about the extent of key assets that will be lost or gained' to produce a 'preliminary set of indicative findings'.

The table is laid out by ecosystem service with key assets as sub-categories, as opposed to this report which categorises by broad habitat type which is more amenable to monetisation. By rating 'key assets' (environmental stock) per ecosystem service, the HAL submission displays how different environmental assets impact each ecosystem service, but does not indicate an overall impact in terms of loss of environmental stock. Though of a different format, the tables appear to broadly agree with the assessment provided here.

The proposal provides quantified information about mitigation which appears favourable to overall ecosystem service provision. This is largely based on a number of enhanced flood storage sites. The realisation of this level of potential benefits is entirely dependent on the eventual existence of established and functional ecosystems through mitigation. Thus, focus should be placed on the correct approach to ensuring the right habitats are established through the proposed mitigation. While the HAL proposal describes a number of mitigation measures, the level of mitigation proposed by the Biodiversity assessment as appropriate has been used to value this aspect of the above assessment for consistency.

2.2.5 Conclusions

The Heathrow NWR scheme would lead to the loss of designated habitats including woodland and hedgerow, rivers and brooks and some lowland. Old Slade Lake in particular is a functional supporting habitat harbouring wildlife. Overall the loss of woodland leads to the greatest potential loss in ecosystem services, largely due to the lag in ecosystem maturation of the proposed mitigation.

Agricultural land loss of 431ha due to the scheme will lead to an estimated loss in ecosystem services of approximately £6 million to £7 million. This is similar to the value of ecosystem services lost from woodland habitat and more than double that potentially lost from rivers and brooks and inland wetlands.

The total value of ecosystem loss is estimated to be between £6.3 million and £15.8 million. This is spread amongst several ecosystem services including aesthetics, opportunities for recreation, waste treatment, lifecycle maintenance, raw materials and fresh water supply. It would be reasonable to expect the real value to be somewhere towards the higher end due to the presence of dense population in proximity to the site and the wealthy nature of the UK.

2.3 Heathrow Airport Extended Northern Runway

2.3.1 Scheme introduction

The Heathrow Airport Extended Northern Runway (ENR) proposal is to extend one of Heathrow's existing runways west into land that is currently wooded and grassland. This expanded runway would be able to accommodate landing and take-off in both directions extending Heathrow's capacity and allowing for the airport to expand.

With the lengthening of the runway into the surrounding environ, the proposed development may impact on the ecosystem services present through the loss of existing ecosystems (such as areas of arable land) and hydrological change and pollution, though the creation of new assets (such as fens, marshes and swamp) through mitigation is also proposed.

2.3.2 Baseline

Heathrow is located within the Thames Valley which is classified as a National Character Area (NCA) by Natural England (2012). The area is mainly low lying with a diverse landscape of urban and suburban settlements, infrastructure networks, fragmented agricultural land, woodland and reservoirs etc. It is dominated by hydrological features providing essential water supply services for London and the surrounds (Natural England, 2012). A number of these waterbodies are also components of the South West London Waterbodies Special Protection Area (SPA) and Ramsar site which function as important feeding and roosting sites for wintering wildfowl.

Other areas that may be affected by the airport expansion include: wetlands in Old Slade Quarry Local Wildlife Site, five Special Areas of Conservation (Windsor Forest and Great Park, Richmond Park, Burnham Beeches, Thursley, Ash, Pirbright and Chobham and the Thames Basin Heaths SPA) and eight Sites of Special Scientific Interest (SSSIs) such as Staines Moor.

Overall, in close proximity (within 15km) there are eight sites of importance to biodiversity at International (European) level, 39 SSSIs and four NNRs with eight of the SSSIs within 5km, with the following four of these within 2km of the proposed boundary: Wraysbury Reservoir SSSI, which is within the proposed scheme footprint; Wraysbury and Hythe End Gravel Pits SSSI; Wraysbury No 1 Gravel Pit SSSI; and, Staines Moor SSSI.. There are eight Local Nature Reserves and 85 non-statutory sites[8] within 5km of the scheme boundary.

The Baseline data primarily used in this assessment in terms of specific sites within the proposal areas and quantities of both land take and mitigation is taken from the Biodiversity Assessment (Jacobs 2014a) prepared alongside this assessment.

[8] Based on Biological Records Centre information

As described above there is a wide range of designated areas and each contains various ecosystem services. Natural England provides focus on some of the ecosystem services present within the Thames Valley NCA. These are identified as follows:

Provisioning

- Food provision – the gravel beds of the upper tideway are an important nursery ground for several fish species (note that this would usually be considered a supporting ecosystem service).
- Biomass energy – the potential for crops conducive to bioenergy is high.
- Water availability – The Chilterns aquifer feeds water supplies but the area is under pressure from London and largely over abstracted.
- Genetic diversity – Concentrated in the Royal Botanic Gardens at Kew and a few remnant orchards containing local varieties.

Regulating

- Regulating water quality – Groundwater is generally assessed as poor with most of the NCA's rivers classified as achieving only moderate ecological status.
- Regulating water flow – Flood regulation is a key issue in the area and policies include measures to store water and manage run-off while providing environmental benefits.

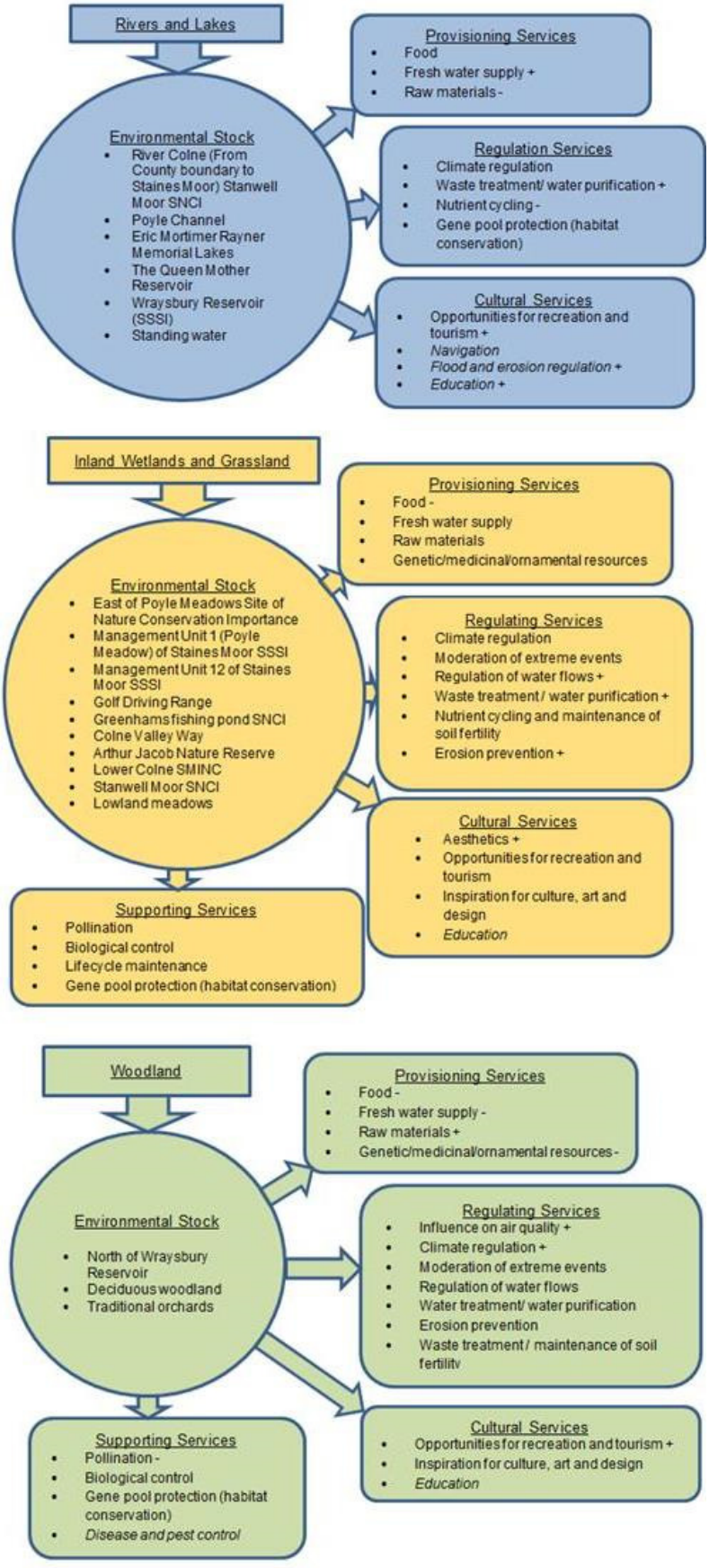
Cultural

- Sense of place/inspiration – A sense of place is supported by water throughout the area and the landscape has been described in the works of some of the most famous writers of British literature.
- Sense of history – Historic buildings including Windsor Castle are present within the NCA along with historic parklands
- Recreation – Recreation is supported by over public rights of way such as Thames Path National as well as the areas open green spaces.
- Biodiversity – There is a large variety of flora and fauna in the NCA including in the 7,000 ha of historic parklands which provide rich habitats

Figure 2.3 outlines the broad habitat types and ecosystem services identified within the proposal boundary. The table rationalises the ecosystem services described above as found within the Thames Valley NCA (Natural England, 2012) with those identified by The Economics of Ecosystems and Biodiversity as used in the monetisation.

The ecosystem services are marked with a '+' where thought likely to be of particular prominence and '-' where thought likely to be of lesser prominence within the given stock, with those unmarked thought to be of neutral or ambiguous prominence, though not enough information is known to make an estimate on actual levels. Ecosystem Services in italics are thought likely to be present, but are not valued within the monetisation aspect of the assessment due to lack of valuation data, and do not appear on TEEBs list of ecosystem services.

Figure 2.3 - Ecosystem service baseline for Heathrow ENR



2.3.3 Impact Assessment

(a) Impact on ecosystem services

The impact of the proposal on ecosystem services is assessed at a high level in Table 2.7. The table displays impact on the environmental stock, proposed mitigation, a narrative on ecosystem services, the sensitivity of the broad habitat in terms of ecosystem services provision in aggregate, the magnitude of impact on the broad habitat in terms of ecosystem services, and the overall significance of the residual effect assessed at a high level.

Although each ecosystem service was reviewed individually, a habitat approach is adopted as not enough information is known about the baseline provision of individual ecosystem services; thus the assessment is based on the overall collective impacts on the broad habitats. The ecosystem service narrative describes likely effects of land take on specific ecosystem services which are considered to be significant

(b) Monetisation

This part of the assessment should be seen as separate, though related, to that which has come previously. The monetisation of effects on ecosystem services makes use of transfer values and is based solely on land lost and habitats gained through mitigation and does not consider any issues around quality or changes at the margin. Therefore, though related, the overall results should not be seen as directly corresponding to the Impact Assessment table in the previous sections. The values produced here are indicative only and subject to the limitations stated in section 1.3.

Monetisation makes use of transfer values sourced from TEEB, attached here in Appendix A. Table 2.8 provides the value range, in 2014 prices, for the change in the provision of benefits from ecosystem services (where data is available and where transfer values are present). The wide range is reflective of the variability of the value of ecosystem services due both to the specific ecosystem characteristics of the broad habitat, such as habitats of particular distinctiveness or vitality, and also of the value placed on them by the recipients of the benefits. Monetary values are shown in aggregate for ecosystem services within the broad habitats below. Annual value, assessment period loss and assessment period mitigation are shown as absolute values of the ecosystem services while assessment period net value shows the net effect with negative numbers implying a loss.

Table 2.9 aggregates the monetary values by ecosystem service from each of the broad habitats. The total values are the same as presented in the table above, however in this case the likely range of values of the ecosystem service change as a result of the proposal is provided.

2.3.4 Commentary on proposer's submission

The Heathrow Hub Limited (HH) proposal provides a relatively in-depth assessment of ecosystem service impacts from the scheme. The assessment criteria developed are considered fit for purpose and are applied by ecosystem service to the area impacted. However, the scoping report excludes all but six ecosystem services, which may undervalue the impact on ecosystem services overall, as it is likely that the impact of the proposal will encompass a broader range of effects than is implied.

Table 2.7 - Ecosystem service impact assessment for Heathrow Airport Extended Northern Runway

Description of Impact	Mitigation	Narrative on Ecosystem Services	Sensitivity	Magnitude	Effect
Rivers and Lakes • River Colne (from County boundary to Staines Moor) to lose 1.25ha • 10.4 ha of rivers and brooks • Lower Colne SMINC and Greenham's Fishing Pond SNCI to lose marginal land	Rivers and Lakes • Biodiversity assessment proposes 41.6ha of rivers and brooks to compensate for loss	• Fresh water supply likely to be disrupted to some degree though mitigation likely to compensate over time • Waste treatment/water purification capacity loss initially due to land take but over time mitigation will establish and renew capabilities • Opportunities for recreation to be reduced due to loss of existing rivers and brooks which mitigation may not fully replace	**Moderate**	**Moderate**	**Adverse**
Inland Wetlands and Grassland • Loss of 8ha of reed bed and 39ha of lowland meadows • Land take from East Poyle Meadows Site of Nature Conservation Importance, Staines Moor SSSI, Arthur Jacob Nature Reserve and Lower Colne SMINC to impact habitat	Inland Wetlands and Grassland • Scheme proposes mitigation through creation of swamp, wet woodland, species rich neutral grassland, fen compensation and lowland meadows • 78ha of grassland and 17ha of reed bed proposed as compensatory mitigation by the Biodiversity report	• Ecosystem service loss from land take both direct and indirect • Water services, nutrient cycling and climate regulation through carbon sequestration likely to be lost • Lost recreational opportunities may be difficult to mitigate due to indirect losses from adjoining designated areas	**Moderate**	**Moderate**	**Adverse**
Woodland • Over 56ha of deciduous woodland to be lost to land take and potentially affected by surface access	Woodland • 1ha of traditional orchard mitigation proposed • Biodiversity assessment proposes 122ha of mitigation woodland	• Aesthetic value and amenity is likely to be the most effected ecosystem service, though climate regulation and influence on air quality and provision of habitat likely	**Moderate**	**Moderate**	**Adverse**
Agricultural Land • 371ha loss including loss from scheme land take and potential loss or change of use from surface access		• Ecosystem services commonly act together to support the production of food crops from agricultural land, the loss of land is a loss of these services • The sensitivity is moderate due to the replicability of agricultural ecosystems but also the importance of food production	**Moderate**	**High**	**Highly Adverse**

Table 2.8 - Monetisation of ecosystem service effects for Heathrow Extended Northern Runway

Broad Habitat	Total Land Lost / Gained (ha)	Annual Value per Hectare of Broad Habitat (2014£)	Total Assessment Period Loss (PV, '000 2014£)	Total Assessment Period Mitigation (PV, '000 2014£)	Total Assessment Period Net Value (PV, '000 2014£)
Rivers and Lakes	21ha loss / 42ha gain	£1,279 to £10,285	£1,009 to £8,112	£739 to £5,805	-£269 to -£2,307
Inland Wetlands	8ha loss / 17ha gain	£706 to £32,217	£222 to £10,140	£173 to £7,908	-£49 to -£2,232
Grasslands	39 loss / 78 gain	£214 to £2,763	£315 to £4,076	£246 to £3,179	-£69 to -£897
Woodland	57 loss / 123 gain	£12 to £5,027	£25 to £10,828	£14 to £6,020	-£11 to -£4,809
Sub - Total					**-£441 to -£13,015**
Agricultural Land	371ha loss	£15,225 to £18,270	£5,122 to £6,146	-	-£5,122 to -£6,146
Total					**-£5,521 to -£16,391**

Table 2.9 - Summary of monetised ecosystem service effects for Heathrow ENR in Present Value, 2014£

Ecosystem services	Low Value Estimate	High Value Estimate
Food	-£2,701	-£275,764
Fresh water supply	-£125,860	-£764,324
Raw Materials	-£8,135	-£581,816
Genetic Resources	£-	-£548
Medicinal Resources	£-	-£4,386
Influence on Air Quality	£-	-£106,178
Climate Regulation	-£8,492	-£679,885
Moderation of Extreme Events	-£11,811	-£220,775
Regulation of Water Flows	-£698	-£466,916
Waste Treatment / Water Purification	-£24,987	-£1,104,807
Erosion Prevention	-£8,876	-£48,867
Nutrient Cycling	-£1,296	-£353,338
Pollination	£-	-£797
Lifecycle Maintenance	-£498	-£735,588
Gene Pool Protection	£-	-£242,133
Aesthetics	-£4,136	-£2,881,991
Opportunities for Recreation and Tourism	-£173,071	-£1,737,346
Inspiration for Culture	-£28,108	-£39,520
Total Ecosystem Services from Broad Habitat	**-£398,668**	**-£10,244,980**
Agricultural Ecosystem Services	-£5,122,023	-£6,146,428
Total Ecosystem Services	**-£5,520,691**	**-£16,391,407**

The approach provides qualitative analysis based on the area in question, though in some cases the analysis appears to be based on the general area rather than site specific. The findings suggest significant residual impact for only a few ecosystem services and would seem to primarily consider mitigation in a generalised way as impact reduction during the construction phase. The qualitative approach is in contrast with the monetisation provided in this assessment, which finds a larger range of impact due to the change in land use impacting a number of ecosystem services.

The HH proposal describes a number of mitigation measure but these largely fall short of the level of mitigation proposed by the Biodiversity assessment, the findings of which are used to value this aspect of the above assessment.

The analysis undertaken by HH takes a broad approach with its qualification criteria based assessment which captures a wide range of impacts. Although it is not always site specific, it does offer an appreciation of a broad range of potential impacts on the identified ecosystem services.

2.3.5 Conclusions

The Heathrow Airport Extended Northern Runway scheme results in a loss of a range of habitats including over 50ha of woodland, nearly 40ha of grassland and 8ha of inland wetlands. A number of designated sites will also be impacted through land loss. While a range of mitigation measure are proposed, the lag in establishment periods and the perceived preference for environmental endowments over mitigation means an overall loss in ecosystem services value is expected.

Agricultural loss is also significant at 371ha. This area leads to an estimated loss in ecosystem services of approximately £5 million to £6 million. This is similar in scale to the estimated value of lost ecosystem services from woodlands, and approximately twice that from rivers and lakes and inland wetlands.

The overall value of ecosystem services loss is estimated to be between £5.5 and £16.4 million over the 60 year assessment period. The most significant ecosystem services based on the monetisation are aesthetics, opportunities for recreation, regulation of water flows, climate regulation and fresh water supply. It would be reasonable to expect the real value to be somewhere towards the higher end due to the presence of dense population in proximity to the site and the wealthy nature of the UK.

Glossary

The following table lists and explains key technical terms used in this report.

AONB	Area of Outstanding Natural Beauty
Appraisal Framework	The Airport Commission produced document guiding the assessment
Broad habitat	A unit for assessment based on a general habitat type
Cultural services	Nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences
Discounting	The process of determining the present value of a stream of payments to be received in the future, as time preference means that present benefits or costs are valued higher than future ones
Ecosystem Services	The suite of goods and services produced by functioning ecosystems
Ecosystem Services Approach	A method of assessment which interprets the environment as provider of ecosystem services
Environmental impact	Possible adverse effect on the environment due to development, industry, infrastructure project or pollution
Environmental goods and services	The naturally produced outputs of the environment
Environmental stock	The present stock of environmental assets
GAL	Gatwick Airport Limited
HAL	Heathrow Airport Limited
HH	Heathrow Hub Limited
Land use change	Impact on the way land is used in response to a project
LNR	Local Nature Reserve
Loss Aversion	An economic principle whereby it has been shown that people have a tendency to strongly prefer avoiding losses to acquiring gains, generally by roughly double
Marginal	Incremental change, the change output given a set change in input
MCM Handbook	Multi-Colour Manual is a manual for economic appraisal of flood and coastal risk management produced by the Department for Environment Food & Rural Affairs
Meta-analysis	A method of combining and contrasting results from different studies in order to aggregate

	information and identify common patterns
Monetised value	The application of a monetary value where a standard market based value does not exist
NCA	National Character Area is a subdivision of England based on a combination of landscape, biodiversity, geodiversity and economic activity as defined by Natural England.
Net Present Value	The net some of the present values of a time series of cash flows, both incoming and outgoing.
Provisioning services	Products obtained from ecosystems
Regulating services	Benefits obtained from the regulation of ecosystem processes
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
Stream (values)	The annual value of inflow or outflow over multiple time periods
Supporting services	Ecosystem services that are necessary for the production of all other ecosystem services
TEEB	The Economics of Ecosystems and Biodiversity is a global initiative focused on drawing attention to the economic benefits of biodiversity which produced a range of transfer values for ecosystem services based on analysis of hundreds of independent studies
Threshold (ecosystems)	The point at which a relatively small change in external conditions causes a rapid change in an ecosystem
Transfer value	Valuation data which is transferred from one site to a site of similar characteristics so that assessment may occur where no bespoke valuation has been conducted
UK NEA	The United Kingdom National Ecosystem Assessment is an analysis of the UK's natural environment in terms of the benefits it provides to society and the economy
Uplift (values)	The adjustment of values to different price years for consistency amongst different base year values
Willingness to pay	The maximum amount an individual is willing to sacrifice to procure a good or avoid something undesirable, which can also be used as a means to value non-market goods

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Appendix A TEEB APPENDIX C

Appendix C:

Estimates of Monetary Values of Ecosystem Services

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Introduction

This Annex presents the monetary values found for ecosystem services provided by the main biomes[1] identified in Chapter 1. As has been explained in earlier TEEB D0-chapters (notably Chapter 1 and 5), economic values have many shortcomings and limitations, not only in relation to ecosystem services but also to man-made goods and services. They are by definition instrumental, anthropocentric, individual based, subjective, context dependent, marginal and state dependent (Goulder and Kennedy, 1997; Baumgartner et al., 2006, Barbier et al., 2009, EPA., 2009). However, despite these fundamental issues in economic theory and practice, information about the monetary importance of ecosystem services is a powerful and essential tool to make better, more balanced decisions regarding trade-offs involved in land use options and resource use.

In this Annex, we present the results of an analysis of 11 main biomes/ecosystem-complexes (i.e. open ocean, coral reefs, coastal systems, coastal wetlands (mangroves & tidal marshes), inland wetlands, rivers & lakes, tropical forests, temperate & boreal forests, woodlands, grasslands and polar & high mountain systems) and collate their monetary values from different socio-economic contexts across the world. For each biome, all 22 ecosystem services identified in Chapter 1 were taken into account in the data collection. With help of the Contributing and Lead authors, hundreds of publications were screened[2] from which approximately 160 were selected for detailed analysis and data-entry into the "TEEB-database" which was especially designed for this study. Thus far, over 1200 original values (data points) are stored and based on a number of criteria slightly over 600 values were used for the analysis presented in this Annex (for details on the data base, the selection procedure and original values will be made available through the TEEB-website (www.teebweb.org) in June 2010.

An important purpose of the TEEB database is the possibility to use the values for scenario-analysis at different scale-levels. To allow for these kind of studies, the database presents the

[1] Throughout this Annex we use 'biome' as shorthand for the 11 main types of ecosystem-complexes for which we analysed the monetary value of the services they provide. Each biome can be split into several ecosystems, each with their own set of ecosystem services, but for the purpose of this chapter, data on monetary values was presented at the biome-level (for details see www.teebweb.org/Database).

[2] In addition to individual publications, the following ecosystem service databases were used: COPI (Ten Brink et al., (2009)), EVRI (1997), ENValue (2004), EcoValue (Wilson et al., 2004), Consvalmap (Conservation International, 2006), CaseBase (FSD, 2007), ValueBaseSwe (Sundberg and Söderqvist, 2004), ESD-ARIES (UVM, 2008) and FEEM (Ojea et al., 2009). See www.es-partnership.org for access to most of these data bases.

data in one value unit (US$) per ha per year and in a contextual explicit way. For each value, the database includes information on, among others, socio-economic variables, biome type, ecosystem type, ecosystem services and sub-services, valuation method, reference details and the location details of the case study. The web-version of the database thus makes it, in principle, possible to analyze the data in relation to the main determining factors of the values, such as influence of income level, population density, and proximity of user to the service

Figures A5.1-A5.3 give an overview of the distribution of the monetary values selected for this Annex by ecosystem (biome), region and service.

Figure A5.1 Number of monetary values used for this Annex per biome

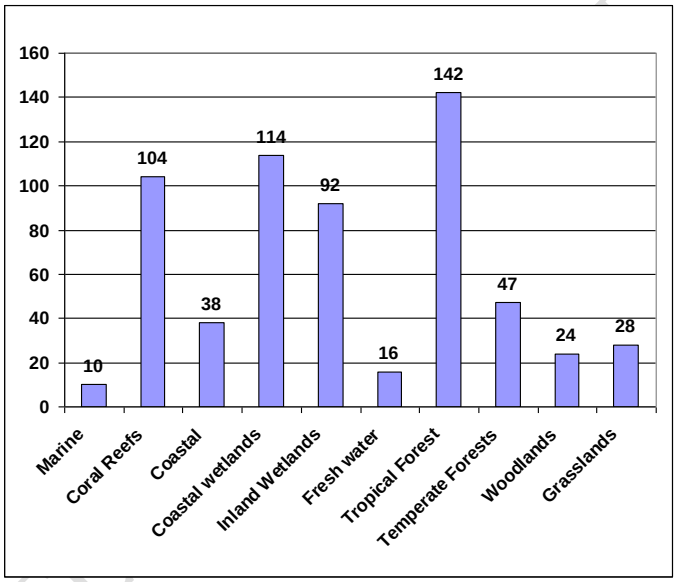


Figure A5.2 Geographic distribution of the monetary values used in this Annex

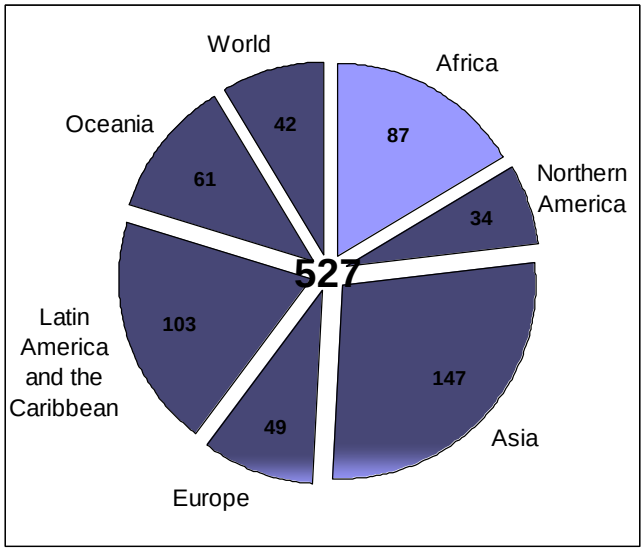
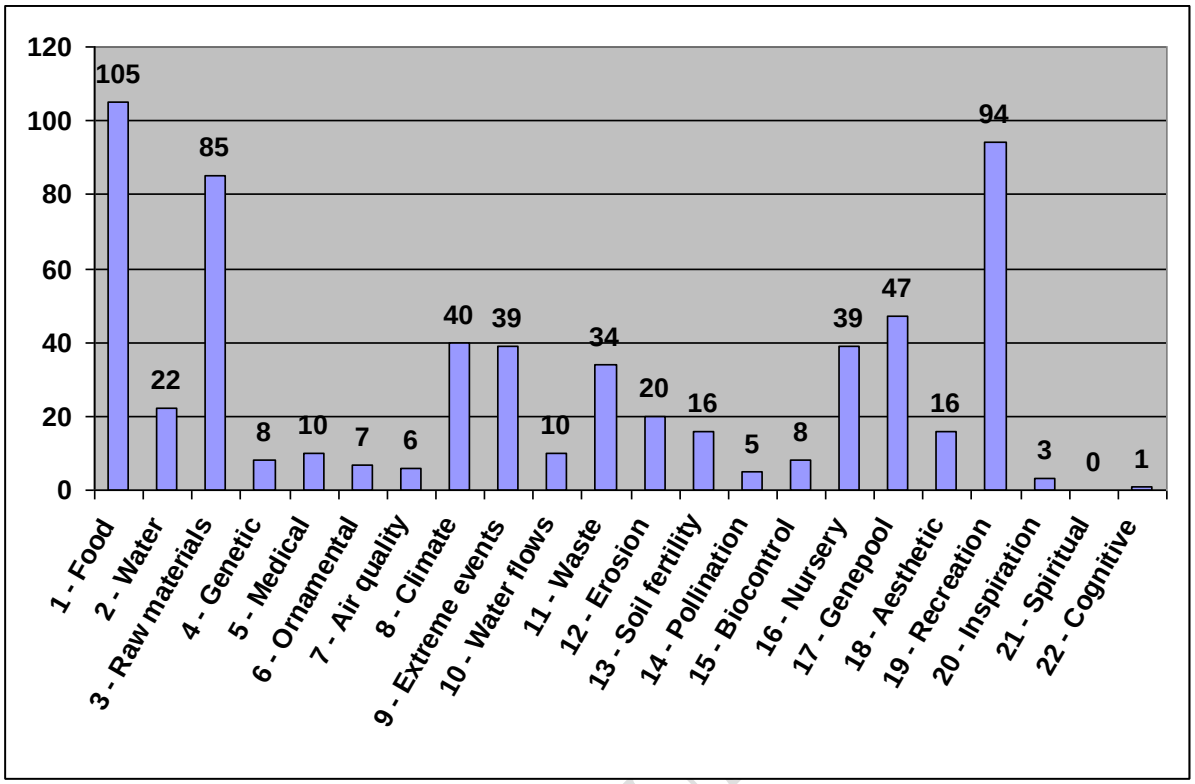


Figure A5.3 Number of monetary values used in this Annex for 22 ecosystem services



For the purpose of this Annex, all values were converted into 2007 Int. Dollar values using the GDP deflators and purchasing power parity converters from the World Bank World Development Indicators 2007 (World Bank, 2007).

To provide a preliminary overview of the range of monetary values found for each ecosystem service, per biome, only the minimum and maximum values are given in this Annex. Since all values are based on individual case studies this sometimes leads to very big value-ranges. For example, the main economically important service of coral reefs is tourism. Based on 30 studies this service shows a value-range from a little over 0 to more than 1 million US$/ha/y (with an average monetary value of almost 68.500 Int. $/ha/y)[3] This illustrates that using average values in benefit-transfer between locations must be done with great care: there will be many coral reefs that currently have a 0-value for tourism because nobody is going there (yet), or because they are less attractive than the reefs involved in the 30 case studies.

[3] Note that often the minimum and maximum values are outliers. When using the information in this Annex for benefit transfer purposes (which is not recommended since all values are highly context-specific) one should not simply take the average of these minimum and maximum values but consult the original values presented in the Database Matrix on the TEEB Website.

Other issues to be aware of are that values should be based on sustainable use levels (which we tried to verify and when in doubt we chose the lower-bound values) and that the magnitude of the value will vary depending on the socio-economic context (see also Box A5.1 for guidance how to use, or not use, the data presented in this Annex).

Box A5.1 Guidance for use of the data and link with TEEB reports D1-D4

The rationale for developing the database of value estimates was to provide an input to policy appraisal. Specifically, the database was set up so as to provide where possible not only a range of *total* values for a biome on a per hectare basis but also, where data are available, values *disaggregated on the basis of ecosystem services* [ESSs]. This set-up was applied so as to facilitate the application of the Ecosystem Approach. A further benefit of this disaggregation is that it allows policy-makers to determine which of the ESSs are pertinent to their particular policy perspective. We pre-suppose that the objective of the policy-maker using this database is to find a monetary value for the benefits of conserving a particular habitat. However the decision as to whether to choose conservation versus the extractive alternative depends on a number of factors, some of which are linked to the nature of individual ESSs. The database-user may thus decide to *filter* the values outputted.

Filtering for appropriate data points

Some of the filters that might be considered are set out below Once a biome is selected, the total number of available data points/value estimates will be presented. This is important in that filtering only really works if there are sufficient data points for the biome in question.

- *Locally-derived ESSs versus globally derived ESSs*

After the user has determined the biome to be considered, the first choice is between (i) ESSs for which benefits are in the main locally-derived benefits, (ii) ESSs that are in the main globally-derived and finally (iii) ESSs that are local and global in nature, i.e. all ESSs. The reason for allowing this first stage of filtering is that policy-makers might want to focus on ESSs that benefit local people *and local people alone*. This does not imply that these policy-makers do not care about global benefits, only that they might look to global donor agencies to fund the positive global externality.

- *Tourism*

There is enormous variability in the value estimates per hectare and one of the reasons for this is that some sites are valued based in part on tourism revenues. Thus the end-user might decide whether to include values that either (i) include leisure and tourism as an ESS or (ii) exclude it are a better match for the choice the policy-maker is seeking valuation estimates for. It would be appropriate to pick (i) if there is the *potential* for tourism activity.

- *Protected Area designation*

Many of the data points in the valuation database pertain to protected areas (PAs). Although values derived outside PAs might be useful for analysis within PAs, the end-user might choose to select only these PA data points. Again, it would be appropriate to pick PA if a policy-maker is considering the establishment of a PA.

- *High income/low income*

There is evidence from meta-analyses carried out in the environmental economics literature that studies carried out in higher income countries realise a higher value estimate on average.

Appropriate use of the findings

The database of environmental values for biomes and ESSs within these biomes is one of the most extensive (if not *the* most extensive) database of its kind. All values within the database have been screened with respect to the methodological integrity applied in the primary literature

sources. Notwithstanding this, caution must be applied in using the values revealed in searches owing to the inherent limitations of benefits transfer. The results are intended to provide an *indicative* value, not *the* value. Even a primary valuation study cannot offer a precise value for a non-traded ESS, and benefits transfer adds an additional layer of abstraction.

Where the outputs may be particularly useful in the policy debate is in considering the relative value of different ESSs. So even if (say) we do not have a reliable, precise value for 'water purification' we can assess broadly how valuable it is as an ESS relative to others.

Below, the main results are briefly presented for the 11 main biomes/ecosystems, we distnguished The Desert and Tundra biomes are not included because there was too little data found on their services and values in this stage of the TEEB study.

Each biome-section starts with a very brief description of the main ecosystem-types included in that biome followed by a table showing the minimum and maximum values found for the services of that biome, follwed by a column with "single values" meaning that for that service only one value was found and thus no minimum or maximum could be given). Services that are not applicable to a given biome were left out of the table. A question-mark means that that service is applicable to that biome but no (reliable) values were found yet.

For each biome the table is followed by an example of a good case study that has applied the Total Economic Value framework, or similar approach, to monetize the total bundle of services provided by that biome/ecosystem, including information on the policy context (purpose) and influence of determining factors (eg. the socio-economic context).

A5.1 Monetary value of ecosystem services provided by Open Oceans

The open ocean is the largest area of the marine ecosystem, including deep sea (water and sea floor below 200 m). Excluded from this biome-section are shelf sea, coral reefs, ocean islands and atolls which are included in other sections (A5.2 – A5.4). As Table A5.1 shows, based on 6 data points, the total monetary value of the potential sustainable use of all services of open ocean combined varies between 13 and 84 Int.$/ha/year. This excludes four services for which only one value was found (which would add 9 Int$/ha/year to the total value).

Table A5.1 Monetary value of services provided by Open oceans (Int. $/ha/year-2007)

	Marine	**No. of used Estimates**	**Minimum values (Int$/ha/y)**	**Maximum values (Int.$/ha/y)**	***No. of Single estimates***	***Single values (Int$/ha/y)***
	TOTAL:	**6**	**13**	**84**	***4***	***9***
	PROVISIONING SERVICES	**2**	**8**	**22**	***1***	***0***
1	Food	2	8	22		
3	Raw materials				*1*	*0*
4	Genetic resources	?				
5	Medicinal resources	?				
	REGULATING SERVICES	**4**	**5**	**62**	***1***	***7***
7	Influence on air quality	?				
8	Climate regulation	2	4	55		
11	Waste treatment / water purification	?				
13	Nutrient cycling				*1*	*7*
15	Biological control	2	1	7		
	HABITAT SERVICES	**1**	**0**	**0**	***1***	***2***
16	Lifecycle maintenance (esp. nursery service)					
17	Gene pool protection (conservation)				*1*	*2*
	CULTURAL SERVICES	**1**	**0**	**0**	***1***	***1***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism				*1*	*1*
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.2 ***Example of TEV case study*****: benefit-cost assessment of Marine Conservation Zones (MCZs) in UK**

Hussain et al. (2010) analysed the benefits and costs of the UK Marine and Coastal Access Bill (2009)[4] and specifically the establishment of a network of marine protected areas, termed Marine Conservation Zones (MCZs) in UK legislation. The benefit assessment was commissioned in order to provide an evidence base for this legislation and to meet Impact Assessment guidance. Two sets of management regimes (with varying degrees of exclusion/reduced anthropogenic impact) were assessed in the context of three network scenarios describing the proposed location of MCZ sites. The main methodological challenges were (i) the lack of appropriate primary valuation studies for BT and (ii) the way that estimates were framed in these studies, viz. in aggregate terms. Aggregate values for different ESSs pertaining to UK temperate marine ecosystems are presented in Beaumont et al. (2008) which forms a basis for the values used in Hussain et al. (2010).

The methodology developed had to account for the following constraints: (i) the impact of MCZ designation would vary across the different ecosystem services (ESSs); and (ii) within any single ESS, the impacts would vary across different landscape types. The methodology thus scored the impact of designation for each individual ESS/each landscape. This scoring was relative to the benchmark, i.e. how much provisioning of the particular ESS/landscape combination would occur without MCZ designation?

Since the only estimates (where available) were for 2007-equivalent provisioning, this had to be used as the benchmark. Two elements were scored: (i) the extent to which MCZs would impact on provisioning, measured as a percentage change relative to 2007 provisioning; and (ii) when this change in provisioning would likely occur – the impact trajectory. The latter meets the requirement for a consistent discount rate to be applied (in this case 3.5%, a HM treasury requirement) for both costs and benefits in Impact Assessment. As well as assigning this score for each ESS/landscape, the methodology had to account for how important one hectare of a particular landscape is relative to other landscapes for that ESS. Marine ecologists determined four categories based on combinations of (i) spatial extent, (ii) proximity to coastline, (iii) average per hectare provisioning

Once this methodology had been applied, the aggregate benefit estimates for each of the three propose MCZ networks/two management regimes were calculated. The present value (using the 3.5% discount rate over the 20 year study period) ranged from around £11.0-£23.5 billion. Applying sensitivity analysis reduced this range from around £6.4 to £15.1 billion. 'Gas and climate regulation' accounted for the bulk of this expected benefit (around 70%) with 'nutrient cycling' and 'leisure and recreation' around 10% each.

The assessment of the costs of the MCZ networks was assessed by ABPMer (2007). Secondary data and literature were assessed and interviews carried out with affected industries (fisheries, telecommunications, oil and gas extraction etc.); the cost estimate ranged from £0.4-£1.2 billion, implying a worst-case benefit-cost ratio of five.

The implications of this research are significant: (i) it is possible to apply (to a limited extent) an Ecosystem Approach to the marine biome; (ii) values were found for only seven of the 11 ESSs and yet even these alone derived a significant benefit-cost ratio. The lobbies linked to the exploitation of marine ecosystems are highly organised and well resourced; this kind of research and evidence-based justification for conservation is thus important

[4] This Bill is now an Act, see http://www.defra.gov.uk/environment/marine/legislation/mcaa/index.htm

A5.2 Monetary value of ecosystem services provided by coral reefs

The term "coral reef" generally refers to a marine ecosystem which the main organisms are corals that house algal symbionts within their tissues. These ecosystems require fully marine waters warm temperatures and ample sunlight. They are therefore restricted to shallow waters of tropical and sub=tropical regions. Corals that do not have algal symbionts can also form significant reef communities in deeper, darker, and colder waters, but these communities are distinguished as cold-water coral bioherms. Corals are often included in the "coastal systems-biome" but are dealt with here separately because of their unique and important ecosystem services

As Table A5.2 shows, based on 101 data points, the total monetary value of the potential sustainable use of all services of coral reefs combined varies between 14 and 1,195,478 Int.$/ha/year. This excludes three services for which only one value was found (which would add over 200.000 Int$/ha/year to the total value, mainly from erosion-prevention).

Table A5.2 Monetary value of services provided by Coral reefs
(in Int.$/ha/year-2007 values)

	Coral reefs	No. of used Estimates	Minimum Values (Int$/ha/y)	Maximum Values (Int$/ha/y)	*No. of Single estimates*	*Single values Int$/ha/y)*
	TOTAL:	**101**	**14**	**1,195,478**	***3***	***206,873***
	PROVISIONING SERVICES	**33**	**6**	**20,892**	***1***	***20,078***
1	Food	22	0	3,752		
3	Raw materials	6	0	16,792		
4	Genetic resources				*1*	*20,078*
5	Medicinal resources	?				
6	Ornamental resources	5	6	348		
	REGULATING SERVICES	**17**	**8**	**33,640**	***2***	***186,795***
7	Influence on air quality	?				
8	Climate regulation				*1*	*627*
9	Moderation of extreme events	13	2	33,556		
11	Waste treatment / water purification	2	5	77		
12	Erosion prevention				*1*	*186,168*
13	Nutrient cycling	?				
15	Biological control	2	1	7		
	HABITAT SERVICES	**8**	**0**	**56,137**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	8	0	56,137		
	CULTURAL SERVICES	**43**	**0**	**1,084,809**	***0***	***0***
18	Aesthetic information	12	0	27,317		
19	Opportunities for recreation and tourism	31	0	1,057,492		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.3 Example of TEV case study: The total economic value of the coral reefs on Hawaii

Hawaii's coral reef ecosystems provide many goods and services to coastal populations, such as fisheries and tourism. Besides, they form a unique natural ecosystem, with an important biodiversity value as well as scientific and educational value. Also, coral reefs form a natural protection against wave erosion. Without even attempting to measure their intrinsic value, this paper shows that coral reefs, if properly managed, contribute enormously to the welfare of Hawaii through a variety of quantifiable benefits. Net benefits of the State's 166,000 hectares of reef area of the Main Hawaiian Islands are estimated at US$360 million a year for Hawaii's economy (Cesar and van Beukering 2004).

Table 1: Annual benefits of the Hawaiian coral reefs

Types of value	units	Value
Recreational value	Million$/year	304
Amenity (real estate) value	Million$/year	40
Research value	Million$/year	17
Fishery value	Million$/year	2.5
Total annual benefits	Million$/year	363.5

Source: Cesar and van Beukering 2004, p.240.

To assess the spatial variation of economic values of the Hawaiian reefs, the overall values are also expressed on a 'per area' basis (Cesar et al., 2002). Three case study sites were considered in particular. The most valuable site in Hawaii, and perhaps even in the world, is Hanauma Bay (Oahu) which was an extremely high intensity of recreational use. Reefs at Hanauma are ecologically average for Hawaiian standards, yet are more than 125 times more valuable (US$92 per m^2) than the more ecologically diverse reefs at the Kona Coast (US$0.73 per m^2). This demonstrates that economic values can differ dramatically from ecological values or researchers' preferences.

A5.3 Monetary value of ecosystem services provided by coastal systems

The coastal biome includes several distinct ecosystems such as sea-grass fields, shallow seas of continental shelves, rocky shores and beaches, which are found in the terrestrial near-shore as well as the intertidal zones – i.e. until the 200m bathymetric line with open oceans. Usually, coral reefs and coastal wetlands (mangroves and tidal marshes) are also included in the "coastal systems-biome" but are dealt with here separately (in A5.2 and A5.4 respectively) because of their unique and important ecosystem services.

As Table A5.3 shows, based on 32 data points, the total monetary value of the potential sustainable use of all services of coastal systems combined varies between 248 and 79,580 Int.$/ha/year. This excludes six services for which only one value was found (which would add over almost 78,000 Int$/ha/year to the total value, mainly from moderation of extreme events).

Table A5.3 Monetary value of services provided by Coastal Systems
(in Int.$/ha/year-2007 values)

	Coastal systems	No. of used Estimates	Minimum Value (int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**32**	**248**	**79,580**	***6***	***77,907***
	PROVISIONING SERVICES	**19**	**1**	**7,549**	***1***	***1,453***
1	Food	14	1	7,517		
2	(Fresh) water supply				*1*	*1,453*
3	Raw materials	5	0	32		
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**4**	**170**	**30,451**	***2***	***76,144***
7	Influence on air quality	?				
8	Climate regulation	?				
9	Moderation of extreme events				*1*	*76,088*
10	Regulation of water flows	?				
11	Waste treatment / water purification	?				
12	Erosion prevention	?				
13	Nutrient cycling / maintenance of soil fertility	4	170	30,451		
14	Pollination	?				
15	Biological control				*1*	*56*
	HABITAT SERVICES	**2**	**77**	**164**	***1***	***164***
16	Lifecycle maintenance (esp. nursery service)	2	77	164		
17	Gene pool protection (conservation)				*1*	*164*
	CULTURAL SERVICES	**7**	**0**	**41,416**	***2***	***146***
18	Aesthetic information				*1*	*110*
19	Opportunities for recreation and tourism	7	0	41,416		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)				*1*	*37*

Box A5.4 Example of TEV case study: Valuing the services provided by the Peconic Estuary System, USA (Johnston et al., 2002)

This study looks at the wide range of ecosystem services provided by the Peconic estuary system, NY, USA, with twofold objectives. On the one hand, it aims at informing local coastal policies by assessing the economic impacts of ecological management strategies for the reservation or restoration of the estuary. On the other hand, it discusses various non-market valuation methodologies to identify the most appropriate approaches for different types of services, and the highlights the issues arising in the integration of the findings of different methods in a total economic value.

The coastal region valued is at the East End of Long Island and comprises a system of bays, islands, watershed lands, and coastal communities. It includes a wide range of coastal resources, including fisheries, beaches, parks, open space, and wildlife habitat, which are under threat from localized water pollution and loss of coastal habitats due to land conversion by development activities.

The study integrates the results of four economic studies:

A hedonic pricing study examines the value of environmental amenities such as *open space and attractive views* on the market price of property in the coastal town of Southold. In the 374 investigated parcels of land, the preservation of nearby open space is found to increase property values on average by 12.8%, while dense development and proximity to highways and agricultural land have negative impacts ranging from 13.3 to 16.7%.

A travel-cost study investigates the value of recreational activities such as *swimming, boating, fishing, and bird and wildlife viewing* taking place in the estuary. Based on 1,354 completed surveys, the study estimated the consumer surplus that recreationists received, i.e., the value above the cost of their recreational trip. Aggregating individual consumer surplus estimates over the whole population or recreationists reveals values equal to 12.1 M$/year for swimming, 18.0 M$/year for boating, 23.7 M$/year for recreational fishing, and 27.3 M$/year for bird and wildlife watching.

A productivity function study assesses the value of eelgrass, sand/mud bottoms, and inter-tidal salt marshes as a *nursery habitat for fish, shellfish and birds*. The study simulates the biological functions of the ecosystems to assess the marginal per acre value of productivity in terms of gains in commercial value for fish and shellfish, bird-watching, and waterfowl hunting. Estimated yearly values per acre are $67 for inter-tidal mud flats, $338 for saltmarsh, and $1,065 for eelgrass.

Finally, a contingent choice study investigates the willingness-to-pay of local residents for the preservation and restoration of key ecosystems in the Peconic estuary. Although the value estimates elicited partly overlap with the results of the other three methods, this study adds the additional dimension of *non-use and existence values* to the picture of the total economic value of the estuary. The highest values are found for the preservation of farmland ($6,398-9,979 acre/year), eelgrasses ($6,003-8,186 acre/year), and wetlands ($4,863-6,560 acre/year). Lower values are for undeveloped land ($1,203-2,080 acre/year) and shellfish areas ($2,724-4,555 acre/year).

Some useful general lessons for the valuation of the total economic value of coastal ecosystems can be drawn. First, a single valuation method can hardly capture the complexity of the interactions between different types of land uses and services in coastal areas. Consider the case of farmland in the discussed study. Although hedonic pricing indicates negative *use values* of farmland, the contingent choice experiment shows that the willingness-to-pay of residents for farmland is high, suggesting that *non-use values* may play an important role in determining the

total value of such land use.

Second, even when budget and time limitations allow for the implementation of different valuation methodologies, one must consider that integration of their findings is not straightforward. In the present study, simply summing up the values determined with hedonic pricing and the travel cost methods would lead to double-counting benefits, since property values will likely also reflect the opportunities for recreation available in the neighborhood. Similarly, the values elicited by the production function will partly reflect the opportunities for bird-watching and waterfowl hunting that high productivity entails.

A5.4 Monetary value of ecosystem services provided by Coastal Wetlands

The coastal wetlands biome includes two main types of ecosystem, tidal marshes and mangroves (for other coastal systems, see A5.3). The coverage of this section is weighted towards mangrove ecosystems although the available valuation literature on tidal marshes is also presented.

As Table A5.4 shows, based on 112 data points, the total monetary value of the potential sustainable use of all services of coastal wetlands combined varies between 1.995 and 215.349 Int.$/ha/year. This excludes two services for which only one value was found (which would add 960 Int$/ha/year to the total value).

Table A5.4 Monetary value of services provided by Coastal wetlands
(in Int S$/ha/year-2007 values)

	Coastal wetlands	No. of used Estimates	Minimum value (Int$/ha/y)	Maximum value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**112**	**1,995**	**215,349**	***2***	***960***
	PROVISIONING SERVICES	**35**	**44**	**8,289**	***0***	***0***
1	Food	12	0	2,600		
2	(Fresh) water supply	3	41	4,240		
3	Raw materials	18	1	1,414		
4	Genetic resources	?				
5	Medicinal resources	2	2	35		
6	Ornamental resources	?				
	REGULATING SERVICES	**26**	**1,914**	**135,361**	***2***	***960***
7	Influence on air quality				*1*	*492*
8	Climate regulation	6	2	4,677		
9	Moderation of extreme events	13	4	9,729		
10	Regulation of water flows	?				
11	Waste treatment / water purification	4	1,811	120,200		
12	Erosion prevention	3	97	755		
13	Nutrient cycling and maintenance of soil fertility				*1*	*468*
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**38**	**27**	**68,795**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	33	2	59,645		
17	Gene pool protection (conservation)	5	25	9,150		
	CULTURAL SERVICES	**13**	**10**	**2,904**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	13	10	2,904		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.5 Example of TEV case study: The Total Economic Value of the Muthurajawela Wetland, Sri Lanka (*Emerton and Kekulandala, 2003)*

The Muthurajawela Marsh covers an area of 3,068 hectares, and is located near Colombo, the capital of Sri Lanka. It forms a coastal wetland together with the Negombo Lagoon. It is rich in biodiversity and in 1996 part of the wetland was declared a Wetland Sanctuary.

The pressures facing the Muthurajawela wetland are growing. Major threats are urban, residential, recreational, agricultural and industrial developments; over-harvesting of wetland species; and pollution from industrial and domestic wastes. As a result, the wetland has been seriously degraded.

The economic values of ecosystem services and total economic value of the Muthurajawela wetland are presented in Table 3. This study used direct market prices to estimate direct use values such as fishing, firewood, agricultural production, recreation and also the support service to downstream fisheries. The replacement cost method was used to value indirect use values including wastewater treatment, freshwater supplies and flood attenuation.

Table 3: Economic Value of the Muthurajawela Wetland, Sri Lanka

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Flood attenuation	5,033,800
Industrial wastewater treatment	1,682,841
Agricultural production	314,049
Support to downstream fisheries	207,361
Firewood	82,530
Fishing	64,904
Leisure and recreation	54,743
Domestic sewage treatment	44,790
Freshwater supplies for local populations	39,191
Carbon sequestration	8,087
TOTAL ECONOMIC VALUE	7,532,297

A5.5 Monetary value of ecosystem services provided by Inland Wetlands

This biome-type includes (freshwater) floodplains, swamps/marshes and peat lands. It explicitly does not include coastal wetlands and rivers & lakes, which are addressed in sections A5.4 and A5.6 respectively.

As Table A5.5 shows, based on 86 data points, the total monetary value of the potential sustainable use of all services of inland wetlands combined varies between 981 and 44.597 Int.$/ha/year. This excludes six services for which only one value was found (which would add 282 Int$/ha/year to the total value).

Table A5.5 Monetary value of services provided by Inland wetlands
(in Int $/ha/year-2007 values)

	Inland wetlands	No. of used Estimates	Minimum value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**86**	**981**	**44,597**	***6***	***282***
	PROVISIONING SERVICES	**34**	**2**	**9,709**	***3***	***167***
1	Food	16	0	2,090		
2	(Fresh) water supply	6	1	5,189		
3	Raw materials	12	1	2,430		
4	Genetic resources				*1*	*11*
5	Medicinal resources				*1*	*88*
6	Ornamental resources				*1*	*68*
	REGULATING SERVICES	**30**	**321**	**23,018**	***3***	***115***
7	Influence on air quality	?				
8	Climate regulation	5	4	351		
9	Moderation of extreme events	7	237	4,430		
10	Regulation of water flows	4	14	9,369		
11	Waste treatment / water purification	9	40	4,280		
12	Erosion prevention				*1*	*84*
13	Nutrient cycling and maintenance of soil fertility	5	26	4,588		
14	Pollination				*1*	*16*
15	Biological control				*1*	*15*
	HABITAT SERVICES	**9**	**10**	**3,471**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	2	10	917		
17	Gene pool protection (conservation)	7	0	2,554		
	CULTURAL SERVICES	**13**	**648**	**8,399**	***0***	***0***
18	Aesthetic information	2	83	3,906		
19	Opportunities for recreation and tourism	9	1	3,700		
20	Inspiration for culture, art and design	2	564	793		
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.6 Two examples of TEV case studies on island wetlands

a) Economic value of Whangamarino wetland, North Island, New Zealand (Kirkland, 1988)
Whangamarino wetland is the second largest peat bog and swamp complex on North Island, New Zealand. It is the most important breeding area in New Zealand for Botaurus poiciloptilus and a habitat for wintering birds and a diverse invertebrate fauna. The wetland covers and area of 10,320 hectares and supports a commercial fishery, cattle grazing, recreational activities. Estimated use and non-use values for Whangamarino are presented in Table X. These value estimates are estimated using the contingent valuation method.

Table X Economic Value of Whangamarino wetland, New Zealand

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Non-use preservation	7,247,117
Recreation	2,022,720
Commercial fishing	10,518
Flood control	601,037
TOTAL	**9,881,392**

b) Economic value of the Charles River Basin wetlands, Massachusetts, US (Thibodeau and Ostro, 1981)
The Charles River Basin wetlands in Massachusetts consist of 3,455 hectares of freshwater marsh and wooded swamp. This is 75% of all the wetlands in Boston's major watershed. The benefits derived from these wetlands include flood control, amenity values, pollution reduction, water supply and recreational opportunities. Estimates of economic values derived from these wetlands are presented in Table X. Value estimates are obtained using a variety of valuation methods including hedonic pricing, replacement costs, and market prices.

Table X Economic Value of Charles River Basin wetlands, Massachusetts, US

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Flood damage prevention	39,986,788
Amenity value of living close to the wetland	216,463
Pollution reduction	24,634,150
Recreational value: Small game hunting, waterfowl hunting	23,771,954
Recreational value: Trout fishing, Warm water fishing	6,877,696
TOTAL	**95,487,051**

A5.6 Monetary value of ecosystem services provided by lakes and rivers

This biome-type includes freshwater rivers and lakes. Saline lakes, and wetlands and floodplains are not included in this biome (see coastal and inland wetlands).

As Table A5.6 shows, based on 12 data points, the total monetary value of the potential sustainable use of all services of rivers and lakes combined varies between 1.779 and 13.488 Int.$/ha/year. This excludes four services for which only one value was found (which would add 812 Int$/ha/year to the total value).

Table A5.6 Monetary value of services provided by Rivers & Lakes
(in Int. $/ha/year-2007 values)

	Rivers and Lakes	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**12**	**1,779**	**13,488**	***4***	***812***
	PROVISIONING SERVICES	**5**	**1,169**	**5,776**	***1***	***3***
1	Food	3	27	196		
2	(Fresh) water supply	2	1,141	5,580		
3	Raw materials				*1*	*3*
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**2**	**305**	**4,978**	***2***	***129***
7	Influence on air quality	?				
8	Climate regulation				*1*	*126*
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	2	305	4,978		
13	Nutrient cycling and maintenance of soil fertility				*1*	*3*
15	Biological control	?				
	HABITAT SERVICES	**0**	**0**	**0**	***1***	***681***
16	Lifecycle maintenance (esp. nursery service)					
17	Gene pool protection (conservation)				*1*	*681*
	CULTURAL SERVICES	**5**	**305**	**2,733**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	5	305	2,733		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.7 Example of TEV case study: TEV of the River Murray, Australia

The 2,700 km River Murray is Australia's longest freshwater river system and has been heavily modified and developed. Water from the River Murray is used for human consumption, and industrial and agricultural production. The River Murray channel and interconnected wetlands are important habitat for a large diversity of species and many locations along the river are recognised as internationally significant under the Ramsar Convention. The major ecosystem services provided by the river include freshwater for human consumption, recreation and tourism, aesthetics, agricultural production, and fishing. Over development and extraction of water for consumption and production purposes, exacerbated by recent drought, has compromised the ecological health or the river system. In 2007-08, the lack of inflows resulted in near-zero allocations to many irrigators who extract water from the River Murray and its upstream tributaries.

The annual economic values of major ecosystem services provided by the River Murray is listed in Table X. Values are drawn from several sources. Food produced from irrigation water diverted from the River Murray and the tourism and recreation services along the river account for the bulk of economic value. Other smaller but important values are the avoided damages provided by a freshwater system with low salt content, and the maintenance of sufficient environmental flows to maintain riverine species habitat.

Total economic value of ecosystem services provided by the River Murray, Australia
(2007 $AUD/Year)

Ecosystem Service	Valuation Method	Source	Total Value ($m)
Recreation and tourism	Market Prices	Howard, 2008	2,970
Food production	Market Prices	Australian Bureau of Statistics, 2008	1,600*
Water Quantity (environmental flows)	Contingent Valuation	Bennett, 2008	80
Water Quality (no salinity)	Avoided Cost	Connor, 2008	18
Total Economic Value			**4,668**

**An estimate for the River Murray water only. Total value of irrigated agriculture in Murray-Darling River Basin is $4,600m. Water drawn from the River Murray for irrigation is approximately a third of the total water drawn from the Basin, suggesting the river's water accounts for a third of irrigated agriculture value.*

For other examples of good TEV-studies, see Thomas et al., (1991)

A5.7 Monetary value of ecosystem services provided by Tropical Forests

The Tropical Forests biome includes various types of forests, eg. moist- or rainforests, deciduous/semi-deciduous broadleaf forest and tropical mountain forests.

As Table A5.7 shows, based on 140 data points, the total monetary value of the potential sustainable use of all services of tropical forests combined varies between 91 and 23.222 Int.$/ha/year. This excludes two services for which only one value was found (which would add 29 Int$/ha/year to the total value).

Table A5.7 Monetary value of services provided by Tropical Forests
(in Int. $/ha/year-2007 values)

	Tropical Forests	No. of used Estimates	Minimum Value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**140**	**91**	**23,222**	***2***	***29***
	PROVISIONING SERVICES	**63**	**26**	**9,384**	***0***	***0***
1	Food	24	0	1,204		
2	(Fresh) water supply	3	8	875		
3	Raw materials	27	2	3,723		
4	Genetic resources	4	14	1,799		
5	Medicinal resources	5	1	1,782		
6	Ornamental resources	?				
	REGULATING SERVICES	**43**	**57**	**7,135**	***1***	***12***
7	Influence on air quality	2	13	957		
8	Climate regulation	10	13	761		
9	Moderation of extreme events	4	8	340		
10	Regulation of water flows	4	2	36		
11	Waste treatment / water purification	6	0	665		
12	Erosion prevention	11	11	3,211		
13	Nutrient cycling and maintenance of soil fertility	3	2	1,067		
14	Pollination	3	7	99		
15	Biological control				*1*	*12*
	HABITAT SERVICES	**13**	**6**	**5,277**	***1***	***17***
16	Lifecycle maintenance (esp. nursery service)				*1*	*17*
17	Gene pool protection (conservation)	13	6	5,277		
	CULTURAL SERVICES	**21**	**2**	**1,426**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	21	2	1,426		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.7 Example of TEV case study: Economic valuation of the Leuser National Park on Sumatra, Indonesia.

One of the best examples of an evaluation of the total economic value of tropical forests is the research undertaken by Van Beukering et al. (2003) which aimed to evaluate the TEV of the ecosystem services associated with the 25,000 km^2 Leuser rainforest and buffer zone, and evaluate the consequences of deforestation on the delivery of these services.

Despite its protected status, about 20% of Leuser National Park has been lost or degraded due to logging, exploitation of non-timber forest products (NTFP), illegal poaching, unsustainable tourism, and conversion to crop plantations. The consequence of this is that there has been a reduction in the forest area (ultimately leading to the development of wastelands), increased soil erosion (reducing agricultural productivity), reduced water retention (leading to increased frequency and intensity of floods and droughts), and reduced pollination and pest control (reducing agricultural productivity). To address these issues, the study examines three possible future scenarios for Leuser: a *deforestation* scenario (i.e. the current trend in logging and exploitation of NTFP continues); a *conservation* scenario (i.e. logging of primary and secondary forest cease, and eco-tourism is developed); and a *selective use* scenario (i.e. logging of primary forest is substantially reduced and logged forests are replanted + some eco-tourism development).

Eleven services were identified as being important for the appraisal of the three scenarios: water supply, fishery, flood and drought prevention, agriculture and plantations, hydro-electricity, tourism, biodiversity, carbon sequestration, fire prevention, NTFP, and Timber. The economic value of the impacts were assessed using a wide range of economic techniques, including production functions, market prices and contingent valuation. The important message here is the fact that no single valuation method is capable of evaluation all the benefits streams; different valuation methods are suited to evaluate different impacts.

Following the approach described above, the authors estimate that the total economic value of Leuser National Park (for the period 2000 – 2030) is 9,538m US$ for the *Conservation* scenario, 9,100m US$ for the *Selective use* scenario and 6,958m US$ for the *Deforestation* scenario.

Finally, it is worth highlighting some key factors that made this an exemplar case study of the value of tropical forests. First, the authors utilized the knowledge and experience of local, regional and national stakeholders at all stages of the research. This is important as it helps to better define the impacts. Second, the use of the 'impact pathway' is important to help identify what they key impacts are. Finally, the research utilized a wide range of valuation methods to assess the impacts.

A5.8 Monetary value of ecosystem services provided by Temperate and Boreal Forests

This biome-type includes Temperate and Boreal forest, or taiga. Temperate forests can be sub-divided in temperate deciduous forest, temperate broadleaf and mixed forest, temperate coniferous forest, temperate rainforest.

As Table A5.8 shows, based on 40 data points, the total monetary value of the potential sustainable use of all services of temperate and boreal forests combined varies between 30 and 4,863 Int.$/ha/year. This excludes seven services for which only one value was found (which would add 1,281 Int$/ha/year to the total value).

Table A5.8 Monetary value of services provided by Temperate forests
(in Int $/ha/year-2007 values)

	Temperate Forests	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**40**	**30**	**4,863**	***7***	***1,281***
	PROVISIONING SERVICES	**15**	**25**	**1,736**	***1***	***3***
1	Food	5	0	1,204		
2	(Fresh) water supply	3	0	455		
3	Raw materials	5	2	54		
4	Genetic resources				*1*	*3*
5	Medicinal resources	2	23	23		
6	Ornamental resources	?				
	REGULATING SERVICES	**14**	**3**	**456**	***5***	***1,277***
7	Influence on air quality				*1*	*805*
8	Climate regulation	8	3	376		
9	Moderation of extreme events				*1*	*0*
10	Regulation of water flows	2	0	3		
11	Waste treatment / water purification	4	0	77		
12	Erosion prevention				*1*	*1*
13	Nutrient cycling and maintenance of soil fertility	?				
14	Pollination				*1*	*452*
15	Biological control				*1*	*20*
	HABITAT SERVICES	**7**	**0**	**2,575**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	7	0	2,575		
	CULTURAL SERVICES	**4**	**1**	**96**	***1***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	4	1	96		
20	Inspiration for culture, art and design				*1*	*0*
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

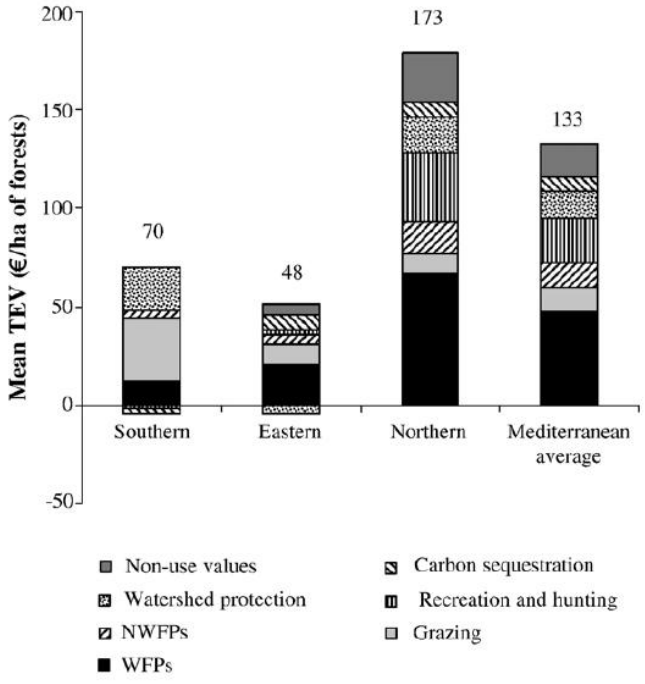
Box A5.9 Example of TEV case study: Economic valuation of Mediterranean forests (Croitoru, 2007)

Mediterranean forests provide a wide array of benefits; however, most of them are poorly recognized. This study attempted to value comprehensively all forest benefits in Mediterranean countries. Its objective is to arrive at a rough order of magnitude of total forest value in each country and in the Mediterranean region as a whole, and of the composition of this value, using available data. Forest benefits are identified based on a common framework and valued using a range of methods. The novelty of this study arises from undertaking it on a large scale, within a structured framework that allows for estimates to be aggregated within countries and compared across countries.

The study covered 18 countries, divided into: Southern countries: Morocco, Algeria, Tunisia and Egypt; Eastern countries: Palestine, Israel, Lebanon, Syria, Turkey and Cyprus; Northern countries: Greece, Albania, Croatia, Slovenia, Italy, France, Spain and Portugal.

The average TEV of Mediterranean forests is about €133/ha. The average TEV in northern countries (about €173/ha) is higher than that in the southern (about €70/ha) and eastern countries (about €48/ha). In per capita terms, forests provide annual benefits of over €50 to the Mediterranean people. Average benefits are higher in northern countries (over €70 per capita) and lower in southern (under €7 per capita) and eastern countries (under €11 per capita). The large difference between the estimates for northern and those for southern and eastern countries is due in part to the much larger extension of forest area relative to population in the north, as well as to their relatively higher quality, thanks to more favourable climatic conditions and lower levels of degradation. To some extent, it is also due to the greater degree of underestimation of benefits in southern and eastern countries.

The figure below shows the average estimates of forest benefits at Mediterranean and sub-Mediterranean levels.



The study shows that Wood Forest Products (WFPs) such as timber account for only a small portion of total forest benefits. Watershed protection benefits are often much more important. In the southern and eastern Mediterranean, grazing dominates. Recreation is already very important in the northern Mediterranean and its importance is likely to grow throughout the region. This multifunctionality needs to be explicitly recognized and incorporated into forest policy

Another good TEV-study was done on Chilean Temperate rainforests by Nahuelhual et al., 2007.

A5.9 Monetary value of ecosystem services provided by Woodlands

The "woodland-biome" includes a large range of vegetation types including savannas, shrublands, scrublands and chaparral interleaved with one another in mosaic landscape patterns distributed along the western coasts of North and South America, areas around the Mediterranean Sea, South Africa, and Australia, jointly representing about 5% of the planets surface.

As Table A5.9 shows, based on 18 data points, the total monetary value of the potential sustainable use of all services of woodlands varies between 16 and 1.950 Int.$/ha/year. This excludes six services for which only one value was found (which would add 5,066 Int$/ha/year to the total value).

Table A5.9 Monetary value of services provided by Woodlands
(in Int. $/ha/year-2007 values)

	Woodlands	No. of used Estimates	Minimum Value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**18**	**16**	**1,950**	***6***	***5,066***
	PROVISIONING SERVICES	**12**	**7**	**862**	***1***	***25***
1	Food	4	0	203		
2	(Fresh) water supply					
3	Raw materials	8	7	659		
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources				*1*	*25*
	REGULATING SERVICES	**6**	**9**	**1,088**	***2***	***130***
7	Influence on air quality				*1*	*80*
8	Climate regulation	2	9	387		
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	4	0	701		
12	Erosion prevention				*1*	*49*
13	Nutrient cycling and maintenance of soil fertility	?				
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**0**	**0**	**0**	***2***	***1,005***
16	Lifecycle maintenance (esp. nursery service)				*1*	*1,003*
17	Gene pool protection (conservation)				*1*	*1*
	CULTURAL SERVICES	**0**	**0**	**0**	***1***	***3,907***
18	Aesthetic information				*1*	*3,907*
19	Opportunities for recreation and tourism	?				
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.10 Example of TEV case study: Goods and services from Opuntia Scrublands in Ayacucho, Peru *(Rodriguez et al., 2006)*

Opuntia scrublands, one of the most important Andean socio-ecosystems in terms of the social and ecological functions that they provide. They perform a major role protecting slopes against erosion, improving the soil properties and providing a variety of products employed in the human diet, and in animal feeding, as well as cochineal insects, a highly valued source of dyes.
The ecosystem goods and services provided by Opuntia scrublands are very diverse with regard to the structures and functions involved in their supply, in their level of integration to diverse markets, and with regard to their contribution to human wellbeing**.**

Rodriguez et al. 2006 contributed to the estimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the 'cultural domain' of Opuntia in order to identify the ecosystem goods and services recognized by the Andean communities. Then, the local perception of the internal relationships among the goods and services provided by the scrubland was estimated, as well as the relationships between the Opuntia scrubland and-other environmental and socio-economic systems existent in the region. The authors presented empirical estimates of the values of the goods and services provided by the Opuntia scrubland and their contribution to household income (see Table below)

Goods and services from Opuntia Scrublands in Ayacucho, Peru)
Source: Rodriguez et al., 2006

	Average value PEN/US$/year
Provisioning services	**461**
Cochineal production	215.69
Fruit production	100.64
Fodder production	73.62
Fuel production	59.05
Ornamental production	12.41
Total Production Function	
Habitat service	**497**
Cochineal infestation for dye production	496.83
Regulating services	**5**
Erosion control	5
Information Function / cultural services	
Not quantified in monetary terms. Many lyrics of Pumpin music, a traditional genre in Ayacucho are inspired by the Opuntia. Lyrics represent advices, rules and norms for the sustainable use of the goods and services provided by Opuntia scrublands	NA

Note: see section A5.10 for examples of TEV-calculations for fynbos & thicket ecosystems in S.Africa

A5.10 Monetary value of ecosystem services provided by grasslands

Grasslands occur in a wide variety of environments. They include tropical grasslands (savannas), temperate grasslands (including the European and Central Asian steppe and North American prairie), boreal grasslands (tundra's) and mountainous grasslands (such as the Latin American Paramo highlands). The largest continuous stretch of tropical grassland is the North African Sahel, that stretches from Senegal to the Horn of Africa.

As Table A5.10 shows, based on 25 data points, the total monetary value of the potential sustainable use of all services of grasslands varies between 297 and 3.091 Int.$/ha/year. This excludes three services for which only one value was found (which would add 752 Int$/ha/year to the total value).

Table A5.10 **Monetary value of services provided by Grasslands**
(in Int. $/ha/year-2007 values)

	Grasslands	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**25**	**297**	**3,091**	***3***	***752***
	PROVISIONING SERVICES	**9**	**237**	**715**	***1***	***0***
1	Food	3	4	82		
2	(Fresh) water supply	4	219	602		
3	Raw materials	2	14	31		
4	Genetic resources				*1*	*0*
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**10**	**60**	**2,067**	***2***	***752***
7	Influence on air quality				*1*	*219*
8	Climate regulation	5	9	1,661		
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	3	13	358		
12	Erosion prevention	2	38	47		
13	Nutrient cycling and maintenance of soil fertility				*1*	*533*
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**3**	**0**	**298**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	3	0	298		
	CULTURAL SERVICES	**3**	**0**	**11**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	3	0	11		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.11 Example of TEV case study: The difference in ecosystem services supply before and after restoration in five catchments in dryland-areas in South Africa

An example of a best-practice study is an elaborate hydrological-ecological-economic study undertaken to analyse ecosystem rehabilitation options in the Maloti–Drakensberg and Tsitsikamma-Baviaanskloof mountain ranges in South Africa (Blignaut et al., 2010, Mander et al., 2010). These studies targeted a fire-prone grassland ecosystem (the Maloti-Drakensberg sites), and compared it with Fynbos and Subtropical-thicket sites (the Tsitsikamma-Baviaanskloof), which together form some of South Africa's most strategic sources of fresh water. For example, the Maloti-Drakensberg range occupies less than 5% of South Africa's surface area, yet it produces 25% of the country's runoff through rivers, major dams, and national and international inter-basin transfers.

The specific objective of the studies was to analyse the financial and economic viability of restoration of these catchments, considering the costs of restoration and the benefits of enhanced watershed regulation, carbon sequestration and sediment retention services. Restoration includes the removal of invasive alien woody plant species, the introduction and re-vegetation of areas that are denuded of any vegetation due to overgrazing with indigenous vegetation, erosion control measures and improved fire management regimes. The results are listed in the table below.

The difference in ecosystem services supply before and after restoration in five catchments in dryland-areas in South Africa* [1]

	Unit	**Upper-Thukela**	**Upper-Mzimvubu**	**Krom**	**Kouga**	**Baviaans**
		Grasslands biome	Grasslands biome	Fynbos biome	Fynbos biome	Sub-tropical thicket biome
Size of catchment	ha	187,619	397,771	101,798	242,689	160,209
Changes in watershed services						
Change in base-flow	m^3/ha/yr	68.6	9.9	196.7	65.4	35.3
Sediment reduction	m^3/ha/yr	6.7	12.4	0.9	0.5	0.3
Carbon dioxide sequestration	t//ha/yr	0.7	0.9	1.5	1.2	2.2
Financial and economic analysis of changes in watershed services following restoration						
PV of base flow	$./ha/yr	2.8[2]	1.1[2]	7.2	2.4	1.3
PV of carbon	$./ha/yr	10.5	12.6	9.5	7.4	14.0
PV of sediment reduction	$./ha/yr	4.4	8.5	0.3	0.2	0.1
PV of all other services[3]	$./ha/yr	8.7	8.7	1.7	5.5	8.6
PV of total services	$./ha/yr	26.5	31.0	18.7	15.5	24.0
PV of cost of intervention[4]	$./ha/yr	5.1	12.5	7.1	2.9	6.4
NPV of intervention[5]	$./ha/yr	21.5	18.5	11.6	12.6	17.6
Benefit-Cost Ratio	ratio	5.2	2.5	2.6	5.6	3.7
Average net return per ha: unsust. land use[6]	$/ha/y	11.3 (+/- 3)	11.3 (+/- 3)	6.7 (+/- 4)	6.7 (+/- 4)	6.7 (+/- 4)

*) sources: Blignaut et al., 2010; Mander et al., 2010

Notes:

1. Taken over 30 years at a social discount rate of 4%.
2. Taken only for the dry winter months.

3. Value of all other quantifiable services for which a market exist, such as tourism, sustainable agriculture, etc.
4. Intervention implies the cost of restoration and the ensuing annual management action(s) after restoration.
5. Difference between the benefits and the costs.
6. These are the returns before the introduction of restoration and the conversion of the land use practice to sustainable land management practices. These are therefore the current net financial returns to the landowner/user as a result of current land use practices that result in increased degradation as a result of, among others, overgrazing and the application of wrong fire management practices. These values are lower than the NPV of restoration, indicating a positive societal benefit and net benefit for the landowner/user if they can be lured into a PES scheme and change their land use practices.

The study shows that the PV of the benefits of the examined watershed services ranges from $15.5 to $31/ha/yr over the project period. The PV of the cost (both restoration and management) ranges from $3 to $12.5/ha/yr resulting in an NPV of $11.6 to $21.5/ha/yr. The study concluded that the benefits of introducing improved management practices exceeds cost in low to medium degraded areas, but not in heavily degraded ones. The economic return on the water (baseflow) produced by such a system of improved land use management, however, far exceeds that of conventional (construction-based) water development programmes and offers meaningful economic and market development opportunities in the study area.

Another interesting study was done by Fernandez-Nunez, et al. (2007) on an economic evaluation of land use alternatives between forest, grassland and silvopastoral systems.

A5.11 Monetary value of ecosystem services provided by polar & high mountain systems

The definition of polar and high mountain biomes used here deviates slightly from that used in the Millennium Ecosystem Assessment (2005). In particular, we define this biome in terms of its cryosphere (Kotlyakov, 2009). Based on this definition, Polar regions include all the Arctic seas and much of the Southern Ocean, the tundra/permafrost zone to the tree line, areas where there is long term snow cover (especially in the Arctic), and sub/marine zones in the Southern/Arctic oceans. This definition corresponds well with the WWF Arctic ecoregions (www.panda.org), the Udvardy (1975) and Clark and Dingwall (1985) biogeographical provinces for Antarctica.
Similar criteria could be applied to high mountains extrapolating from the altitudinal maps produced by Messerli and Ives at the UNU. So, for example, high mountain regions could be defined as those areas higher than the 1000masl mean line.
The MA gives the share of terrestrial space of polar and high mountains as 31% (MA, 2005 Synthesis volume p31 Table 1.1). Our revised definition would put the cryosphere proportion nearer 50% of terrestrial space (at maximum seasonal extension).

As Christie et al. (2005) note, there is currently very little quantification of the monetary value of services provided by polar and high mountain systems. The lack of monetary valuation research, however, should not be interpreted to infer the polar and high mountain areas to do deliver important services. Indeed, it is clear that these cryospheres are of paramount importance in terms of global ecosystem services.
The most important services are briefly discussed below.

1) Fishing
It is estimated that the Southern Oceans contribute around one sixth of the global fish take (Kock, 1992) and that this resource may become increasingly important as other areas are fished out. However, legal protection of these marine resources are fragile (Constable et al., 2000). For example, the Commission for the Conservation of Antarctic Marine Living Resources suggests that 80 – 90% of the take of the rare Patagonian toothfish was illegal (MA, 2005 p 487).

2) Freshwater Storage
Approximately 80% of the planet's freshwater (ID 2) is locked up in the ice caps (Pitt, 1995; Gabler, 2008). A significant proportion of the world's population depends on the meltwater of high mountain glaciers. Climate change threatens the existence of these glaciers, which in turn could have significant local and global consequences. For example, the glaciers in the Himalayas and on the Tibetan plateau sustain the major rivers of India and China which are used for irrigation of wheat and rice fields. Given that India and China are the world leading wheat are rice producers, projected melting of the glaciers presents a significant threat to local and global food security (Brown, 2009).

3) Raw Materials
Raw materials (ID 3) are very valuable too in the cryosphere (e.g. Howard, 2010; Emmerson, 2010; Orrego-Vicuña (Edited), 2009) and becoming a major area for international conflict. The Arctic is said to contain more than a quarter of the world's hydrocarbons (Mikkelsen and Langhelle (Edited), 2008) and is widely presumed to be a future flashpoint as nations compete. The Antarctic Treaty System (ATS) currently prohibits exploitation of raw materials and creates the world's largest protected and demilitarized area reserved “for peace

and science": however, the ATS expires in 2041 and its replacement is uncertain. Even now there is conflict over resources. The Australians and New Zealanders are currently taking the Japanese to court over abuses of the whaling moratorium. The British and Argentineans are involving warships as oil drilling is explored in the Falkalnds/Malvinas, whilst even old friends like Canada and the USA are at daggers drawn over the NW passage"

4) Climate Regulation

Both the Southern Ocean and the Arctic Permafrost / tundra are major greenhouse carbon sinks. However, global warming is likely to convert the Arctic permafrost/tundra into a net source of GHG (including methane) (McGuire et al., 2000). The polar regions also have a significant role in reducing climate change through the albedo effect, i.e. they reflect the sun's light back into space (MA, 2005 v1 p859). Prizborski (2010) also suggest that the recent calving of the 2,545 km^2 Mertz glacier tongue iceberg may disrupt ocean currents worldwide by blocking the flow of bottom water.

The Pew Report on Arctic melting (Goodstein et al., 2010) estimates that the loss of Arctic snow, ice and permafrost currently costs the world US$61 billion to US$371 billion annually.

5) Habitat service

The apparently dead and frozen waste of the cryosphere has been called species poor but evidence is accumulating not only of life in the extreme cold (including suspended animation), but also of vibrant hot spots e.g. in the polynyas, sea leads , extensive sub glacial lakes or on the seamounts, around the volcanic vents etc. The IPY archive will contain faunal census material though we have some estimates for some species (e.g. Shirihai (2007) for Antarctica, CAFF (2001) and Ervin (2010) in the Arctic) whilst the international circum Antarctic census of marine life will be a benchmark in the Southern Ocean (Stoddard, 2009). In biomass terms the primary productivity of the Southern Ocean is enormous: van der Zwaag (1986) estimates that it is more than fifty times that of the North Sea in terms of grams of carbon per m^2 per annum. The NPP figures in the MA Synthesis Table (op cit) are very low for the polar biome especially and may need revisiting after IPY.

6) Cultural services and Tourism

Current there is little information on the aesthetic, recreational, inspirational, spiritual, cognitive etc values (ID 18-22) of the cryosphere, and innovative methods such as those highlighted by Christie (2005) will be needed to calculate these types of values. For example, Samson and Pitt (Edited) (2000) explore the passive use values of the cryosphere including the role it plays in what has been called the noosphere: the realm of ideas which embraces all cultural activities. Pitt (2010) have explored how iconic cryosphere species score in terms of internet hits: penguins top the poll. High mountains contain the most sacred and holy sites of humanity.

The cryosphere is also an important tourism resource. Snyder and Stonehouse (Edited) (2007) project that in 2010 there will be 1.5 million visitors to the Arctic, 80, 000 Antarctic, 10 million to the Alps and many more in other high mountains.

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